DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

PROFESSIONAL PAPER 74

GEOLOGY AND ORE DEPOSITS

OF THE

BUTTE DISTRICT, MONTANA

BY

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WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

CONTENTS.

ILLUSTRATIONS.

GEOLOGY AND ORE DEPOSITS OF THE BUTTE DISTRICT, MONTANA.

By Walter Harvey Weed.

CHAPTER I.—INTRODUCTION.

INVESTIGATIONS.

The first geologic investigation of the Butte district was made in 1896 by S. F. Emmons, assisted by G. W. Tower and the writer. The results of this work were published as a geologic folio in 1897. So many new facts in regard to the geological conditions of the veins were afterward determined by the extensive exploration connected with the litigation that followed that Mr. Emmons decided to make a thorough study of the district, the results to be published as a joint monographic report by him and the writer. Work was begun in 1901, but after gathering data for several years Mr. Emmons, because of the pressure of his duties in supervising the mining investigations of the Survey and because of the severe physical labor involved, decided to transfer the entire investigation to the writer. The material that had already been prepared by him has, however, been incorporated in this report.

The underground development since 1896 shows that the geologic structure is far more complex than had been supposed. The primary veins are displaced by great faults, and these later fractures have themselves been mineralized and again displaced. The working out of the structural relations has been particularly difficult because the deposits occur in a body of homogeneous granite, which affords no clue to either the amount or the direction of displacement. Notwithstanding this, the correlation of displaced areas has been satisfactorily completed, being based on the rhyolite porphyry and aplite intrusions in the granite and on the structural and mineralogic variations of individual veins.

In the beginning of the work it was found that the complexity of the structure made detailed observations necessary. Maps of each level of every mine were therefore transferred to notebooks, and with these in hand the writer and his assistants, while underground, carefully examined the drifts and crosscuts and plotted on the maps the occurrence of each slip, vein, and fault, noting the dips, strikes, and other important features. This task involved several months of work, as the levels alone are many miles in extent. Stopes and raises were noted in the same way, and sketches were made of particular features of vein structure and ore occurrence.

The field work involved a careful examination, by the writer, of over a hundred miles of these underground workings, and, owing to the magnitude of the task and the pressure of other investigations, it was not completed until the autumn of 1905. The work of assembling, plotting, and checking the mass of detail collected has been very great, hence the completion of this report has been delayed. The chief cause of the delay, however, is the litigation that has been in progress in the district and the assurance given that the report would not be published in time to be used by either litigant.

ACKNOWLEDGMENTS.

The writer desires to acknowledge his great indebtedness to companies and individuals for courtesies extended and for information freely given throughout the period of field work To Mr. John Gillie, general manager of the Anaconda Co., Mr. C.W. Goodale, of the Boston &

Montana Consolidated, and Mr. A. H. Wethey, the writer owes especial thanks. The geologic department of the Anaconda Co. has been particularly generous. Mr. Horace V. Winchell, former chief geologist of the Anaconda mine, and his successor, Mr. Reno Sales, have most freely imparted the many important facts in regard to the mines, knowledge of which had been acquired by long and continuous underground study, and most of the theoretical conclusions stated in this report accord with those advanced by them. The valuable detailed geologic notes of all the mine workings of the Amalgamated properties have been freely placed at the disposal of the Survey and have been freely used in this report.

GEOGRAPHY.

Like other midcontinental States, Montana embraces within its borders the western part of the Great Plains region and the eastern part of the Rocky Mountain or Cordilleran region. The mountain region, comprising the western third of the State, is an assemblage of ranges whose

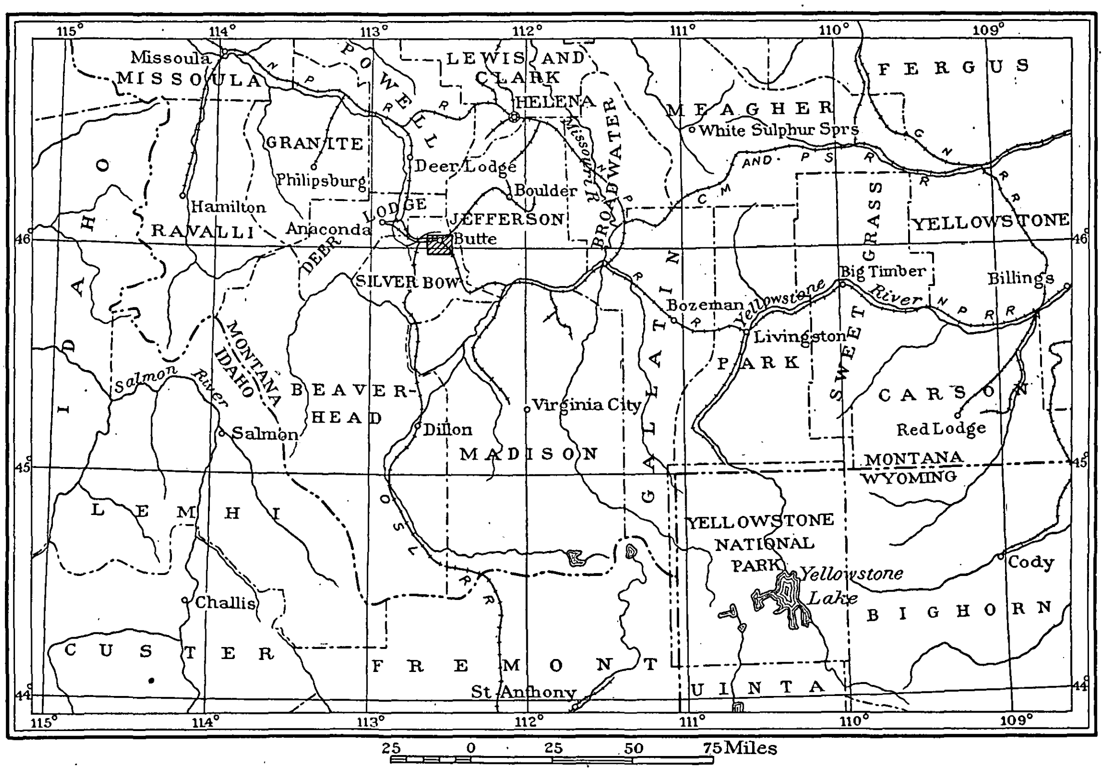


FIGURE 1.—Index map showing position of Butte district.

eastern front extends northwestward from the borders of the Yellowstone Park to the Canadian line. Its southern part is traversed by well-defined ranges, with intervening valleys whose fertile river bottoms and bench lands are well settled and extensively cultivated.

The Butte district lies in a well-defined mountainous tract in the center of this system of ranges. This tract, which lies mostly in Jefferson County, has long been famous for its mineral wealth. Helena, the capital of the State, stands on its northern flanks, and Butte, the greatest mineral producer of the country, on its southern foothills. The broad Deer Lodge Valley, to the west, separates it from the towering peaks of the Mount Powell Range. On the east it is bounded by a continuous depression, formed by several separate valleys, which cuts it off from the higher ranges beyond. The tract thus outlined is broad and relatively low, none of its summits exceeding 9,000 feet in height, but it forms the main continental watershed separating the streams tributary to Missouri River from those flowing into the Pacific Ocean. (See map, Pl. I, in pocket, and fig. 1.)

Though often called the Boulder Mountains, the tract contains no sharply outlined peaks, nor do its hills constitute a well-defined range. Its central part is covered by a forest of small pines, its lower slopes are open and grassy, and its valleys are arid; in scenery and mountain sculpture it presents a contrast to the more alpine type of the adjoining ranges. Its geology is equally distinctive, and in this, as in its geographic relations, it constitutes a unit.

The city of Butte is the largest settlement in the State. It is built about and over the copper mines which support it as well as the neighboring city, Anaconda, 20 miles distant, where the chief industry is the reduction of the Butte ores. Four transcontinental railways run to Butte, and its traffic surpasses that of all the other cities of the State combined.

To one approaching the city the general appearance is most desolate. Bare, brown slopes, burnt and forbidding, from which all vegetation was long ago driven by the fumes from the smelters, rise from an almost equally barren valley. The city lies toward the base of the slopes. Within it and dotting all the hills about rise red mine buildings, which with the great heaps of gray waste rock from the mines form the most conspicuous feature of the landscape. The waters of Silverbow Creek flow through the valley toward the west, encircling the base of the slopes. West of the city is the sharply conical hill, Big Butte (Pl. II, *A*, p. 26), from which the city takes its name. In itself, the city is not unpleasing, showing compact, well-built brick business blocks and many residences on hills which command magnificent mountain views.

The area shown on the map (Pl. X, in pocket) includes part of the nearly level floor of a broad valley, locally called the Flat, traversed by Silverbow Creek and connecting with a wide, open basin to the west. The larger part of the mapped area is hilly and forms the outer flanks of a higher region to the north. This tract, constituting the Butte mining district, is bounded by the low and almost featureless lake-bed country on the west and by the valley of Silverbow Creek on the east and south. The general slope is westward, but a number of gulches transect the area, and minor eminences give a pleasing relief. The city is built upon the slopes of Missoula Gulch, the largest of the depressions, and between it and a lesser depression to the east known as Dublin Gulch. The lesser settlements, known as Walkerville and Centerville, are built on the slopes above the city proper, and are really a part of it. The growth of the city northward is limited by the land owned by the mining companies, and the abrupt transition from compactly built blocks to the bare surfaces of many of the mining claims is very striking.

In the copper area the slopes are gridironed by railway tracks leading to the different mines, and great mine buildings, tall smokestacks, and steel hoist frames mark the course of the greater veins. Throughout most of the silver area the monotonous aspect of the slopes is relieved only by occasional shaft houses, now mostly deserted, and by the almost innumerable prospect pits and trenches, which simulate gopher holes. The most important of these openings are shown on the topographic map, but many of the shallower workings are unmarked.

Heaps of waste are everywhere prominent, attesting by their great size the extent of the underground workings. The many prospect pits and shafts permit a tracing of the veins, which otherwise would be in many places impossible. Yet even these are not abundant enough to determine the boundaries of some of the rhyolite dikes, and it was only by a careful examination of the soil and in some places by digging through the veneer of gravel-like débris covering the surface that the limits of the intrusive masses could be established.

Originally named the Summit Valley district, a name still retained in official records and significant of its situation almost on the divide where the waters of the Pacific and Atlantic separate, it is now universally known as the Butte district, the name being derived from Big Butte.

The district is, as a whole, distinguished by a lack of prominent rock outcrops or strong topographic features. The Butte alone is conspicuous. In the north part of the district a number of striking rock outcrops do occur, but throughout the mineralized area disintegration and decomposition have been active agents and good outcrops are rare.

The climate is rigorous, owing to the altitude and midmountain situation, but precipitation is not abundant, the few streams are small, and the water supply not plentiful. Silverbow Creek, the largest stream, rises in the high granite region to the north, and Missoula Gulch has a small natural supply. A few springs on the otherwise bare and arid slopes afford scanty flows. The city has, however, an abundant water supply, derived from the high peaks to the south, and ditches bring water from higher levels on the eastern side of the Continental Divide for the use of the concentrating plants and smelters. Vegetation is practically absent, but the stumps seen on Anaconda Hill attest a former forest growth and Dublin Gulch is said to have been once green with verdure and trees. Though the higher country near by is green and wooded, the Butte district was never abundantly watered nor deeply wooded, resembling in this respect the foothill tracts surrounding the valley outside the limits of the district.

DISCOVERY AND DEVELOPMENT.

EPOCH OF GOLD MINING.

The discovery of the rich placer gold deposits of Bannock, Alder Gulch, and Last Chance Gulch in 1863 caused an extraordinary influx of population to the hitherto almost unknown mountainous region of Montana. A multitude of prospectors, trained in the gold placers of California, poured into the State and searched every valley and gulch for gold-bearing gravels.

Gold was first noticed in the placer gravels of the Butte district by a passing emigrant early in the summer of 1864, at a point on the west side of what is now Main Street, but no placer mining was done in the district until late in the summer of that year. The following winter the Summit Valley district was organized and claims were staked out along Missoula, Buffalo, Town, and Parrot gulches. Placer mining was not so remunerative here as at other camps of the State, for the gold was of low grade, worth but $11 to $14 an ounce, and occurred in fine particles; moreover, the gravel had to be hauled by ox teams down to Silverbow Creek for washing. Several ditch lines were built, and in 1866–67 three of these carried water to the "diggings." One of these ditch lines is still in use. The amount of gold washed at Butte during the three years of placer mining has been estimated at $1,500,000.

The quartz veins prominent on the hillsides about the placer field were promptly located by the early miners. The first vein was located by W. L. Farlin, who staked the Asteroid claim late in 1864 on the great black-stained quartz reef west of the city. This was called the Black Chief, but when afterward relocated became the Travona. During the next two years many lode locations were made, but at that time only free milling gold ores were sought; the black manganese-stained outcrops of the silver veins were not considered especially valuable until brought to attention by the discovery of the Comstock lode. Claims along the Rainbow lode at Walkerville were located in the middle sixties; and at the Mountain Chief mine ore was taken out, shipped by wagon train to Fort Benton and by steamer down the Missouri, eventually reaching Newark, N. J. The town of Butte was laid out in the fall of 1866 and reached its greatest prosperity of this, its early stage, in 1867–68; later it was nearly deserted until 1875, when copper smelting began. After this it grew rapidly and became a city in 1879.

EPOCH OF SILVER MINING.

No excitement arose over silver ores until the rich ore shoot of the Travona mine was found in 1865. The first attempt to work silver ores was made in a small arrastre built in 1866, just south of the Finlen (formerly McDermott) Hotel. The first mill, the Continental, an old 10-stamp battery hauled in from Stirling, Mont., proved a financial failure. At this time some of the Travona ore was roasted and amalgamated and a few ounces of silver bullion produced, but no important development of the property was undertaken until 1875, when Mr. Farlin erected the Dexter 10-stamp mill and furnace near the mine and began to treat the ore by chloridizing, roasting, and amalgamation. This mill did not produce much bullion until 1876, when it was completed by W. A. Clark, and the first successful treatment of the silver ores of the district was commenced. The price charged for treatment—$25 to $30 a ton—though not excessive for those times, led to active mill building. In 1868 a mill for treating ores by the free-milling process was built in a gulch at the corner of Arizona Street and Broadway. It was later purchased by the Lexington Mining Co., a corporation formed in France, which built a 50-stamp mill, with roasting furnaces, near the mine in 1881.

In 1875 McEnery & Packard located a claim called the Acquisition, from which they shipped some rich silver ore to Walker Bros. in Salt Lake City. The high value of this ore led Walker Bros. to send Marcus Daly to the district to look over the mining prospects. He arrived in 1876 and took a bond on the Alice mine for $5,000. Robert Walker and Prof. John E. Clayton then came to Butte, and selected the site of the present main shaft of the Alice mine as a suitable place for sinking. Prof. Clayton named the great lode on which the Alice, Magna Charta, Valdemere, and Moulton claims are located the Rainbow lode, from the broadly sweeping curve of its outcrop.

Work was started in the late summer of 1876. In 1877, the Alice shaft having reached a depth of 200 feet, an old 20-stamp mill was brought in from Ophir Canyon, Utah, and was erected on the property. It was a dry-crushing plant (water in sufficient quantities for wet crushing not being available) and was designed to treat oxidized or free-milling ores. This mill started in the fall of 1877. In 1878 and 1879 a White-Howell roaster was added, thus providing for the chloridizing roasting of sulphide ores, and the Washoe process was introduced. The 60-stamp mill of the Alice Co. was built in 1880 and was equipped with two White-Howell roasters and revolving drier. The Moulton mill, completed about the same time as the Alice, was equipped with 40 stamps and White-Howell roasters.

The Silverbow Mining & Milling Co.'s mill was built in the early eighties for the treatment of ore from the La Plata and other mines owned by the company. In 1884 the Bluebird mine was purchased by a London company, and in 1886 a 90-stamp mill built for the property was completed.

The climax of what may be called the silver period of Butte's history was reached in 1887, when the Alice mill was dropping 80 stamps, the Moulton 40, the Lexington 50, the Bluebird 90, and the Silverbow 30, a total of 290 stamps. The amount of ore worked in these mills aggregated nearly 400 tons a day, to which should be added the silver ores shipped to the smelters, aggregating probably at least 100 tons a day. All this ore carried considerable gold. The average yield was probably about $25 a ton in gold and silver.

The period of active silver mining continued until 1892, when, in common with other silver producers, the Butte mines were almost prostrated by the decline in the price of silver. A few mines, notably the Nettie and Lexington, continued to work up to 1896–97, and others have worked at intervals since then, but none has been an active producer since 1896 save the Lexington, in which veins carrying copper are mined.

In the history of Butte the metallurgical advance in the treatment of the silver ores has been very steady, the free-milling process giving place to chlorination and roasting, and these in turn to more improved methods, so that ores lower and lower in grade could be treated. With the great decline in silver in 1892–93 and the closing down of all the large silver plants in 1896, the mining of silver ores became of relatively slight importance and has since been carried on chiefly by lessees. The present importance of Butte as a producer of silver and gold is due to the fact that each pound of copper produced contains 0.0375 ounce of silver and $0.0025 in gold, or approximately $0.02½ in precious metals. According to this ratio the Butte copper mines yielded 8,550,000 ounces of silver in 1891.

DEVELOPMENT OF COPPER MINING.

As most of the copper ledges were destitute of vegetation and the Parrot ledge, just north of the city, was strewn with copper carbonates, the copper veins were early noticed. The claims along the Parrot lode, embracing the Park, Parrot, Original, and Gagnon mines, were among the first located, the papers being filed October 14, 1864. In 1865 the Park had a 40-foot shaft, which disclosed a vein of copper ore 6 or 7 feet wide. In 1866 an unsuccessful attempt was made to smelt copper ores from the Parrot mine. About a year later a second smelter, built of rock and provided with a bellows blast, was put in the gulch of the Washoe claim; this also proved a failure. In this period no ore was known to exist in Anaconda Hill; the Anaconda-Neversweat claim was not located until 1875 and the patent not applied for until February 18, 1878.

In 1872 W. A. Clark turned his attention to the copper veins of the district and in 1873 and 1874 began to develop the Original, Colusa, Mountain Chief, and Gambetta claims. The ore from these claims was hauled 400 miles in wagons to Corinne, whence it was shipped by rail to various buyers of copper ore. Among the latter was the Boston & Colorado Smelting Co., at Black Hawk, Colo., and in 1878 Mr. Clark suggested to the management of this company the construction of a custom smelter in Butte. Henry Williams was sent to examine and report on the outlook. His report being favorable, the Colorado & Montana Smelting Co. was formed in 1879, the present site of the Colorado smelter was purchased and reduction works were erected, so that a local market for the copper as well as for the silver ore of the district was established. The importance of this smelter can be judged from the fact that one shipment of 35 per cent copper ore from the Green Mountain claim to the works at Baltimore, Md., in 1877, gave no profit to the shipper after mining, freight, and reduction costs were paid, although the ore carried about $130 a ton in copper (then worth 18⅝ cents per pound), and not less than $50 a ton in silver and gold. The smelters charged a high price for treatment, owing to the presence of arsenic, which in those days was a troublesome element in smelting.

The Colorado Smelting Co. leased the Fredonia, Nettie, and Selfrising mines and, using their manganiferous silver ores as flux, made a copper matte, or regulus, which was shipped to the Argo works in Colorado for further treatment. In 1883 the company was reorganized and consolidated with the Gagnon mine, which has since furnished the main supply of ore for this smelter. This company was afterward called the Trenton.

In 1881 Marcus Daly, representing the newly organized Anaconda Silver Mining Co., leased the Dexter mill and treated about 8,000 tons of oxidized silver ore from the Anaconda ledge, obtaining about 30 ounces of silver to the ton. The ore contained just enough copper to make it unnecessary to add bluestone in raw amalgamation but yielded a very base bullion, some of which ran only 400 fine. A seam of copper glance a few inches wide encountered at a depth of 100 feet, however, led to further extensive development. George Hearst, on visiting the district, recommended deep development and selected the site of the present Anaconda shaft as the most suitable place for sinking. A crosscut run from this shaft at a depth of 300 feet encountered 5 feet of copper glance, which was extracted and shipped to Swansea. Soon after this the smelters of the Parrot, Montana Copper, Clark's Colusa, and Bell companies began operations, the matte produced being shipped to eastern markets for refining. The formation of the Butte Reduction, Boston & Montana, Butte & Boston, and Montana Ore Purchasing companies, in the years 1884 to 1896, greatly added to the production of copper of the district.

The advent of the railroads marked the beginning of Butte's prosperity. The Utah Northern, which was finished to Butte December 21, 1881, gave access to Ogden, Salt Lake City, and the markets of the world over the Union Pacific lines. On July 12, 1888, the Montana Central Railway, which for some months had been racing with the Northern Pacific to get to Butte, was completed and thrown open for traffic. The branch line of the Northern Pacific from Helena was never completed to Butte, but a few years later that company built a line from Three Forks direct to Butte. The Montana Union Road from Butte through the Deer Lodge Valley to Garrison, on the Northern Pacific, built by the Union Pacific interests, was finished on September 8, 1893. An interest in this road was purchased a few years later by the Northern Pacific, and it was operated jointly by both companies; it is now owned and operated by the Northern Pacific system.

In the year 1883 the Anaconda Co. commenced the erection near Anaconda on Warm Spring Creek, a branch of Deer Lodge River about 27 miles west of Butte, of what soon became one of the largest copper-smelting plants of the world. The works were partly destroyed by fire in 1889, but were immediately rebuilt. However, they soon proved too small and too far out of date to handle the increasing output of the mines, and in 1900 a new plant called the Washoe, with a daily capacity of 8,000 (now 12,500) tons of ore, was built.

In 1886 the Butte Reduction Works were built on Silverbow Creek, just south of the city, and, after changing hands several times, became the property of W. A. Clark & Bro., who still operated them in 1906. The Great Falls Copper Smelter, completed by the Boston & Montana

Silver & Copper Co. in 1892, has been gradually enlarged until it now handles 4,500 tons of ore a day.

The organization of the Amalgamated Copper Co. on April 27, 1899, was one of the most important events in the history of Butte. As a holding corporation this company soon acquired control of the larger copper properties of the district, owning the entire capital stock of the Washoe Copper Co. and the Colorado Mining & Smelting Co. (now the Trenton) and controlling the Parrot and Anaconda companies. In 1901 the capitalization was increased from $75,000,000 to $155,000,000, and the Butte & Boston and the Boston & Montana Consolidated Copper & Silver companies were purchased. The Amalgamated therefore owns the greatest mines of the district and, by its affiliation with the Butte Coalition and North Butte Copper companies, controls all the large mines except the two owned by W. A. Clark.[1]

About 1893 the Montana Ore Purchasing Co. was organized by F. A. Heinze and associates and soon became an important factor in the mining industry of the district. Owning the Rarus, Cora, and Rock Island claims, with chief ownership in the Parnell, L. E. R., and Nipper mines, and with interests in the Snohomish and Tramway claims this company soon entered into an active legal campaign to capture the great ore bodies of the mines worked by the Boston & Montana and Anaconda companies. In the subsequent litigation the Heinze interests won in the lower courts, many mines were shut down by injunctions, and veins worked for years by the opposing companies were, by decree of the courts, turned over to the Montana Ore Purchasing Co. The result was a great diminution in the output of the district. Most of this litigation was based on the so-called "law of the apex," which gives to the owner of a mining claim the right to follow his vein downward in depth underneath the surface owned by other people. Owing to the complicated faulting and the closely spaced vein systems the experts who testified in the various lawsuits gave conflicting testimony, for many of those who were not specially trained in mining geology did not understand the prevailing conditions. In the first great suit, known as the Rarus case, the continuity of a number of veins through and across the Rarus fault was alleged. In the second great case, known as the Colusa-Parrot, brought by W. A. Clark, at that time an ally of the Heinze interests, against the Anaconda Co. for possession of the Anaconda vein in depth, a junction of veins downward and consequent ownership by reason of prior location was claimed. This claim was opposed by the Anaconda Co., which offered proof of the existence of a cross fault called the Blue Vein, cutting off and displacing the Anaconda ledge. The Anaconda Co.'s claim was sustained by Judge Knowles of the United States district court.

The acquisition of the Minnie Healy mine by the Heinze interests was followed by the starting of several suits involving the ownership of the extremely rich ore bodies mined in the Leonard and other claims of the Boston & Montana Co., and of other suits involving the ownership of the rich veins in the Pennsylvania mine and the ore bodies of the Nipper mine.

A protracted period of litigation was ended in 1906 by the sale of the Heinze interests to Mr. F. A. Cole, who organized the Butte Coalition Co., a holding corporation, and the Red Metal Co., a mining corporation, formed to work the properties in contest. A satisfactory agreement between the various companies was thus reached and litigation was ended.

In 1902 the United Copper Co., a securities-holding corporation similar to the Amalgamated was organized and acquired control of the Montana Ore Purchasing Co. and of other companies organized by Mr. Heinze in his legal campaign against the Amalgamated. As already stated, this company has been succeeded by the Butte Coalition Co.

In 1904 the newly organized North Butte Copper Co. acquired control of the Speculator mine for $5,000,000, and subsequently purchased a number of claims lying in its immediate vicinity. Large and extremely rich ore bodies were soon uncovered in these properties and the company became an important copper producer. Its success led to the organization in 1905 of the East Butte Copper Co., which owns a number of claims in the southern part of the copper area.

[1] These were purchased in 1910.

The Pittsburg & Montana Co., organized in 1902 to develop a large tract lying between the copper area and East Ridge, explored the ground by several shafts 1,000 or more feet in depth and by extensive underground workings, and proved the existence of copper ores beneath the flat. In the years 1905, 1906, and 1907 many exploration companies were organized to develop outlying portions of the district, in which up to that time no copper ores had been found. The future of the district depends largely on the success of these companies.

PRODUCTION.

The enormous value of its metallic product makes the Butte district the most important mining center in the United States and the second greatest in the world. Its annual production is exceeded in value only by that of the Rand, in South Africa, which was $101,000,000 in 1905 against about $65,000,000 for Butte. Up to the close of 1906 the total product of the Butte district may be roughly estimated at $650,000,000, which is considerably in excess of that of Leadville and probably about that of the Comstock lode.

It is not possible to obtain strictly accurate data concerning the early production of the district, for in the pioneer days no records were made and in later years some of the larger companies, for business reasons, have not been willing to disclose their exact output. The statistics presented in various publications, however, show that up to January 1, 1906, 971,000 ounces of gold, 194,000,000 ounces of silver, and 3,961,000,000 pounds of copper were mined in the district. The placer gold production of the district has been comparatively unimportant, being not only small in amount but also low in bullion value, on account of the large alloy of silver. At present gold forms about 3 per cent of the total value.

Silver in the district is now mainly a by-product of copper mining, the copper ores containing about one-fourth ounce of silver to 20 pounds of copper, or, in value, about 14 per cent of silver to 86 per cent of copper.

The annual copper product in 1906 was about 283,000,000 pounds, constituting the predominant value in the yield of the district. Its increase, both absolute and relative, in the last decade has been great.

In 1888 nearly 41 per cent of the total copper product of the world came from North America and over 92 per cent of this was furnished by the United States. In 1895 the North American proportion of the world's product was 56½ per cent and in 1905 it had increased to 69 per cent.

Previous to 1880 the Lake Superior region produced, on the average, more than 80 per cent of the total copper product of the United States. In 1883 Lake Superior's proportion of this total product was 51.6 per cent, Butte's was 21.4 per cent, and Arizona's was 20 per cent. In 1887 Butte passed Lake Superior, and in 1905 the relative percentages were: Montana (Butte), 31.2 per cent; Arizona, 28.9 per cent; Lake Superior, 25.3 per cent. In 1906 Butte was furnishing about 20.6 per cent of the copper product of the world, more than three-fourths of which was from mines controlled by the Amalgamated Copper Co. In 1907 Montana produced 25.81 per cent of the total copper output of the United States, or 13.8 per cent of that of the world.

In early years the statistics of the Butte copper production were not carefully kept. The first definite statement is by the Director of the Mint in his report for 1880, in which he credits the district with a production of 9,452,800 pounds of copper. In succeeding years the production increased rapidly. The total output from 1880 to the end of 1905 is estimated at 38,000,000 tons of ore, which yielded 3,960,964,935 pounds of copper. At the average price prevailing during the year of its production, this copper was worth $498,493,035. If to this sum be added the value of the gold and silver produced from the copper ores mined in the district the total value will approximate $600,000,000.

The following table was prepared by Mr. Emmons from many sources, including company records, reports on the mineral resources west of the Rocky Mountains, records of the division of mineral resources of the United States Geological Survey, and reports on the production of precious metals by the Director of the Mint:

Production of the Butte district, by years, from 1882 to 1910.[a]

Year.	Gold.[b]	Silver.[b]	Copper.[c]	Year.	Gold.[b]	Silver.[b]	Copper.[c]
	Ounces.	*Ounces.*	*Pounds.*		*Ounces.*	*Ounces.*	*Pounds.*
1882	12,094	2,699,296	9,058,284	1898	55,344	8,996,555	206,173,157
1883	14,561	3,480,547	24,664,346	1899	62,038	9,855,831	225,126,855
1884	21,776	4,481,180	43,093,054	1900	54,552	9,454,279	270,738,489
1885	13,838	5,180,331	67,797,864	1901	45,850	10,136,892	229,870,415
1886	31,223	5,924,315	57,611,621	1902	46,051	10,106,884	288,903,820
1887	48,175	6,958,981	78,699,677	1903	48,800	9,811,544	272,555,854
1888	44,320	8,275,956	97,897,968	1904	46,974	10,530,582	290,032,979
1889	31,652	6,560,038	98,222,444	1905	61,251	11,191,016	304,307,893
1890	25,705	7,500,000	112,980,896	1906	60,495	10,715,721	289,780,050
1891	29,395	7,985,090	112,063,320	1907	34,368	7,516,659	218,836,627
1892	36,223	8,311,130	163,206,128	1908	32 005	8,500,729	250,150,712
1893	33,808	6,668,730	155,209,133	1909	39,443	10,609,328	311,323,650
1894	36,768	7,561,124	183,072,756	1910	37,014	10,400,840	284,264,862
1895	41,433	10,051,760	190,172,150				
1896	59,816	11,120,732	221,918,179	Total	1,159,170	241,296,885	5,288,021,324
1897	54,198	10,710,815	230,288,141				

[a] The statistics for Butte being confidential, the production for the county is given; for gold and silver this corresponds closely to that of the precious metals recovered from copper ores for the whole State.
[b] Figures from reports of Director of the Mint and from Mineral Resources; U. S. Geol. Survey.
[c] Figures from Mineral Resources, U. S. Geol. Survey.

The table shows the total production of gold and silver from the Butte district for the years given, but does not give the silver produced from the silver-bearing veins as distinguished from the copper-bearing veins. The silver mines proper yielded much gold and silver from 1888 to 1893, and have continued to yield lesser amounts up to the present time, but there is no way of differentiating this product.

In the following table the Butte production from 1881 to 1897 is separated according to companies, and their relative importance is readily seen.

Production of copper in the Butte district, by mining and smelting companies, from 1881 to 1897.

[In pounds.]

Year.	Anaconda.	Boston & Montana.	Butte & Boston (now part of B. & M.).	Butte Reduction Works (W. A. Clark).	Colorado Mining & Smelting Co. (Trenton Copper Co.).	Parrot.	Montana Ore-Purchasing Co. (Butte Coalition).
1881							
1882	[a] 33,300,000						
1883							
1884	3,886,000						
1885	40,462,000	7,500,000		2,500,000	1,200,000	9,809,000	
1886	32,858,000	2,000,000		1,935,846	2,000,000	10,000,000	
1887	59,242,000	1,500,000		1,649,308	1,411,000	10,000,000	
1888	67,106,000	18,278,667		3,549,165	1,440,600	10,750,000	
1889	61,810,000	26,425,228	1,103,125	2,499,648	1,774,400	9,500,000	
1890	67,676,000	26,942,298	5,485,434	3,332,934	2,252,200	9,000,000	
1891	48,098,000	26,567,929	18,392,054	2,912,274	3,365,200	14,108,382	
1892	93,918,000	30,386,595	10,641,269	2,850,227	4,076,800	12,438,782	
1893	81,446,000	31,800,000	20,457,928	3,078,337	6,809,000	7,791,167	8,400,000
1894	98,680,000	57,937,633		2,281,993	4,210,198	7,469,908	12,293,686
1895	103,442,000	60,746,000		3,393,920	8,004,848	7,257,000	14,861,000
1896	119,700,000	60,250,000	4,500,000	4,237,660	9,267,496	8,045,648	14,230,000
1897	128,391,100	59,600,000		8,645,782	8,911,578	14,997,000	13,047,048

[a] Ore sold.

The Anaconda, the largest of the copper-producing companies, produced from June 30, 1884, to June 30, 1898, a period of fourteen years, 9,575,793 tons of ore, which yielded 1,068,922,000 pounds of copper. This is equivalent to 5½ per cent copper, 4½ ounces silver, and 35 cents gold per ton of ore. This output covers the period during which the bonanza ore bodies of the Anaconda were mined, and very large amounts of extremely high grade ore were extracted.

Production of Butte mines in May and June, 1907.

Companies.	Daily production.			Production for May.		Production for June.	
	Ore.	Copper per ton.	Total.	Ore.	Copper.	Ore.	Copper.
	Tons.	*Pounds.*	*Pounds.*	*Tons.*	*Pounds.*	*Tons.*	*Pounds.*
Boston & Montana	3,500	67	234,500	108,500	7,269,500	100,500	6,834,000
Anaconda	4,250	61	259,250	131,750	8,036,750	123,000	7,380,000
Butte & Boston	600	60	36,000	18,600	1,116,000	19,500	1,209,000
Washoe	400	59	23,600	12,400	731,600	10,650	628,350
Parrot	350	58	20,300	10,850	629,300	11,250	630,000
Trenton	380	60	22,800	11,780	706,800	12,000	708,000
North Butte	1,300	92	119,600	40,300	3,707,600	37,500	3,003,500
Coalition	1,550	65	100,750	48,050	3,123,250	45,000	2,970,000
Original	950	62	58,900	29,450	1,825,900	24,000	1,488,000
East Butte	200	80	16,000	6,200	496,000	6,750	526,500
Pittsburg & Montana	225	70	15,750	6,975	488,250	7,500	525,000
La France	200	68	13,600	6,200	421,600	3,000	225,000
Miscellaneous	200	75	15,000	6,200	465,000		
Total	14,105	66	936,050	437,255	29,017,550	400,650	26,161,350

The above table, compiled from figures furnished by the Mining and Scientific Press, shows the relative importance of the different mines as producers and indicates plainly the low-grade character of the ore now being treated. The best ore is mined by the North Butte Co., which is extracting extremely high-grade glance and enargite ores from the Jessie and Edith May veins. The output of this company, 1,300 tons a day, averaging nearly 5 per cent in copper, approaches that of the Anaconda mine during its bonanza days. The lowest-grade ore, carrying only 3 per cent copper, comes from the Trenton Co.'s Gagnon mine, but the Anaconda ore contains only 1 pound more of copper per ton and carries lower silver values.

COSTS.

The cost of producing a pound of copper is made up of the costs of mining, reduction, freight, and selling. In 1906 the cost of Butte copper ranged from 9½ cents to 11 cents a pound at the mines. As the cost per pound depends largely on the character and richness of the ore, as well as on the cost of mining and production, no general or comprehensive statement in regard to it can be made. Mining cost alone, including that of ore development work, ranges from $2.75 to $3.50 per ton. The system of working with square sets, necessitating great quantities of timber and the presence of soft ground, making it necessary to drive laterals parallel to the vein from which crosscuts are made, increases the cost per ton to a figure that is high compared with that of other districts. The pumping expenses have been minimized by a system of drain tunnels which concentrate the water from the entire Amalgamated properties at the High Ore shaft. Moreover, there has been a decided saving in the amount of copper recovered from the mine waters, it being generally stated that the copper so recovered pays the entire expense of pumping.

The cost of mining and reducing silver ore at the Lexington mine was given at $18.58 in 1902. (See p. 240.)

FUTURE OF THE DISTRICT.

As it is the duty of the geologist to formulate, if possible, such deductions concerning the future of the district as the facts appear to warrant, it seems proper to state that the evidence accumulated in this study indicates that the quartz-pyrite veins are becoming exhausted with depth, that the amount of glance is decreasing, but the limit of workable ore has not yet been reached. In all the big veins of this class the amount of glance is notably less at the bottom levels. On the Syndicate ledge the main vein is lean on the 2,200-foot level except at a few places where fracturing is most severe. On the 2,400-foot level the Anaconda lode proper is lean, but the Middle ledge, which is a fault vein, contains a large ore body of high-grade glance ore.

On the other hand, the fault fissures, which are now generally recognized throughout the district, hold little if any ore in the upper levels, but contain large and rich ore bodies at depths of 1,000 to 2,000 feet; at the High Ore mine one of these levels is said to show a large high-grade ore body as deep as 2,800 feet. As is stated elsewhere (p. 77), the proportion of enargite coming in at the deeper levels gives hope that this mineral may extend downward for several hundred feet. At any rate it is believed that the fault veins will make up for the deficiency in the older ores and that the future of the district is assured for many years. The mining, in 1906–7, of ores carrying 2 per cent or less was a result of the high price of copper and was due to the desire of the mine managers to take advantage of the opportunity to prolong the life of the mine by extracting the low-grade ores which would not pay for mining when copper was at a lower price. The tables of production show that a maximum has been reached, and a knowledge of the mining conditions indicates that the output of the district will remain constant for some years to come and will then gradually and slowly decline. It is believed that some modification of the flotation process or newer and cheaper methods of milling, which may lead to the recovery of metal now lost in slimes, will make pay ore of what is now called waste. The zinc ores of the district also promise to be of great value and to add both to the wealth of the district and to the length of its productive period.

CHAPTER II.—GEOLOGY OF THE REGION.

RELATIONS AND BROADER FEATURES.

The rocks in the Butte district are of igneous origin, are of few types, and are closely related in mineral and chemical composition, though very different in appearance. To enable the reader to understand the origin and relation of these rocks and their bearing on the economic geology of the district it is necessary to present a brief sketch of the geologic features and history of the larger region of which the Butte area is a part.

The map (Pl. I, in pocket) shows the areal distribution of the rocks in the region about Butte. Its area includes the gold district near Helena, the Elkhorn silver-lead district, and a large number of other silver-mining districts, of which those of Wickes, Lump Gulch, Red Mountain or Rimini, Lowland Creek, and Whitehall are the most important. Many of these are on the borders of the granite area, but others are well within it.

IGNEOUS ROCKS.

The quartz monzonite of the Butte area is part of a mass of granular rock, clearly of igneous origin, which has broken its way through and has altered earlier sedimentary and igneous rocks and has itself been partly covered by later volcanic outbursts and cut by massive rocks. The areal extent of this granitic batholith is shown on the map (Pl. I), on which the general features of the geology are delineated. The area covered by this map, 60.4 miles from north to south and 38 miles east and west, is 2,295 square miles; it embraces parts of four of the quadrangles of the United States Geological Survey. It includes not only the Butte district but several others of the best-known mining districts of Montana as well.

Geographically this tract is in the center of the mountainous part of the State. The map, however, shows only part of the delimiting valleys east and west, the area mapped having been selected primarily to show the extent and outline of the granitic mass, often briefly referred to as granite.

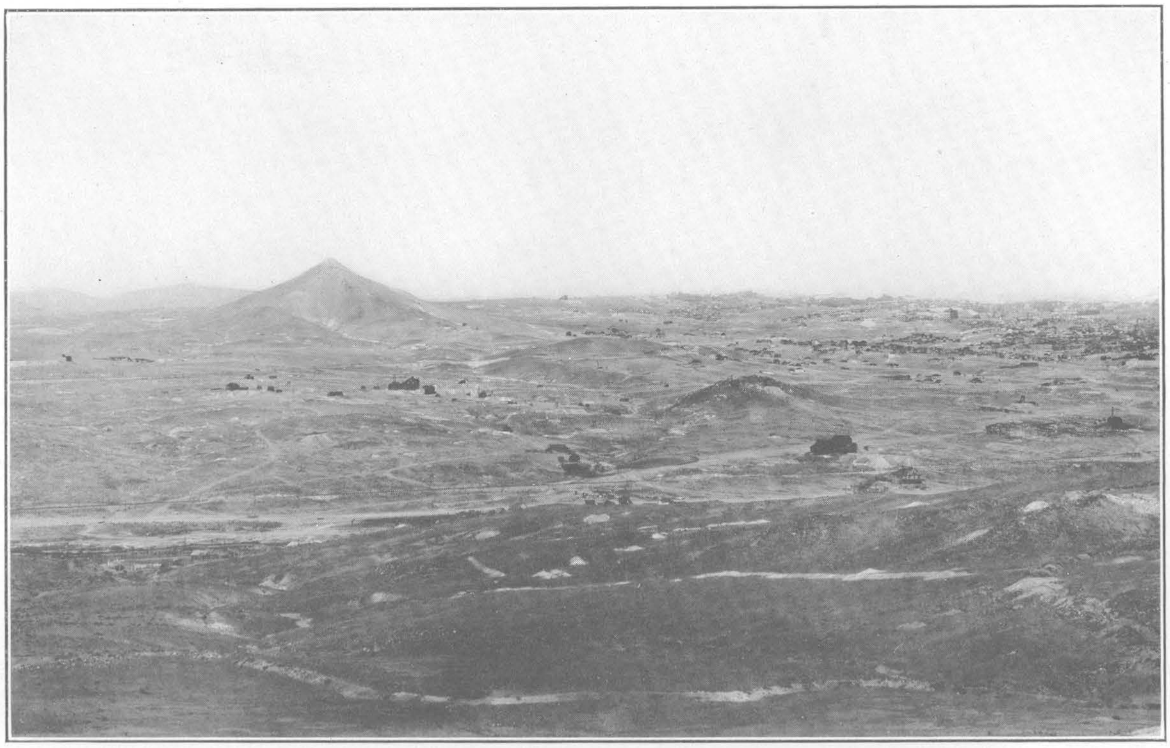
A tract 40 miles wide and 70 miles long from north to south, extending from the peaks of Red and Table (Highland) mountains on the south nearly to Helena on the north, and from the Deer Lodge Valley on the west to the Elkhorn Mountains and Bull Mountain on the east, is underlain by granite concealed in part by other igneous rocks but constituting one connected mass. This granite is traversed by different well-defined systems of joint planes, is extensively decomposed in some localities, and weathers into rugged crags, monoliths, and great bowlder masses, which form the picturesque scenery so frequently typical of granitic areas (Pl. II, *B*). The larger topographic features lack the ruggedness of the sedimentary ranges, for the coarsely granular rock weathers down into broad summits and smooth-surfaced valleys.

SEDIMENTARY ROCKS.

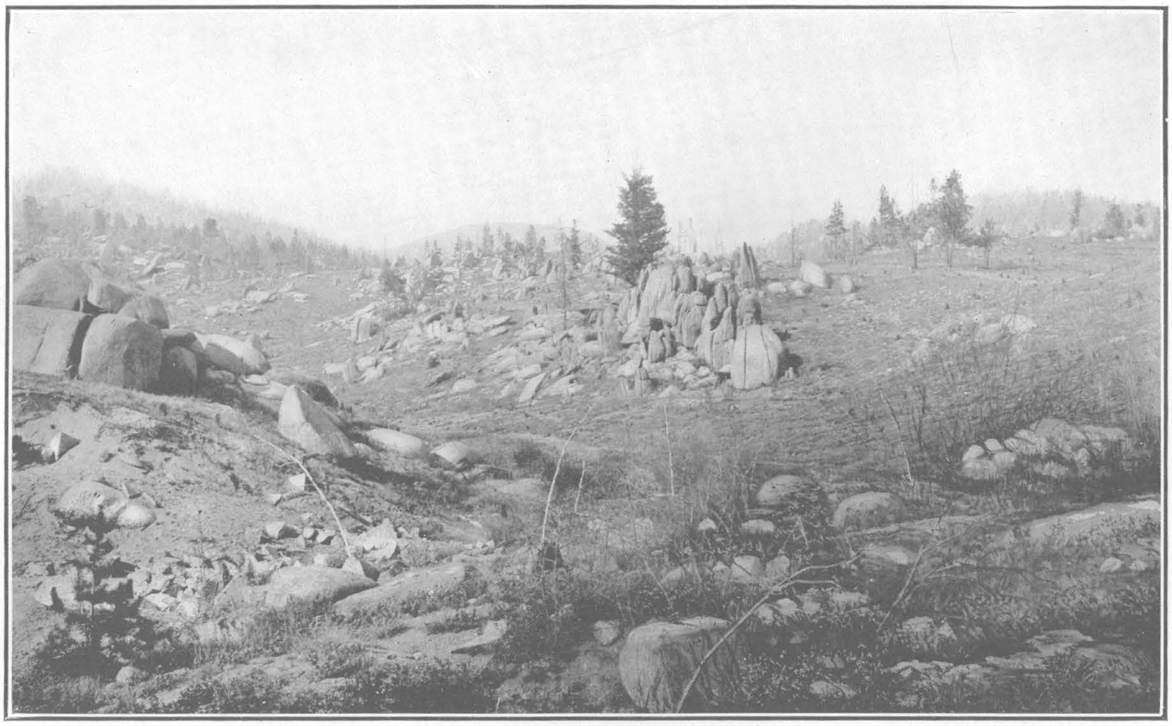
Broken and folded sedimentary rocks many thousands of feet in thickness form higher peaks and ranges that surround the granite and afford evidence as to its age and igneous nature. These sedimentary rocks are shown on the map (Pl. I) at six principal localities, the exposures not being visibly connected, as later detrital deposits cover much of the lower country. The granite contact is irregular, and could not be shown completely without greatly enlarging the map.

The sedimentary rocks consist of sandstone, limestone, shale, and slate. Many beds contain fossils, the series including strata ranging in age from oldest Algonkian to late Cretaceous.

The stratigraphic section is practically that common to central Montana, and the formations are similar in lithological character to those found in the Little Belt and Front ranges of the State. The lowest strata are phyllites and slates with interbedded sandstones and belong to the Belt series, of Algonkian age. At the southern border of the area they rest unconformably



A. GENERAL VIEW OF WESTERN PART OF BUTTE DISTRICT, INCLUDING THE BUTTE.
See page 17.



B. SHEETED GRANITE OF BOULDER BATHOLITH NEAR HOMESTAKE TUNNEL.
See page 28.

upon crystalline schists, supposedly Archean. The next succeeding terrane contains Middle Cambrian fossils, the Lower and Upper Cambrian faunas being absent. The rocks embrace a basal quartzite, with shales, limestones, and limestone conglomerates readily distinguished from those of the underlying Belt series, and an overlying black limestone, the Jefferson limestone of Devonian age. A thin belt of shaly impure limestones—the Threeforks shale, also of Devonian age—intervenes between the black limestone and the massive white limestone (Madison limestone) of the Carboniferous, the most conspicuous rock of the sedimentary series. The white Madison limestone is succeeded by white and pale-pink quartzite, also of Carboniferous age, known as the Quadrant quartzite. The Triassic (?) red beds, so conspicuous in Wyoming and Colorado scenery, are not present. Jurassic fossils occur in abundance in impure marly shales and limestones, which are succeeded above by rocks carrying Cretaceous fossils. The youngest sedimentary rocks (except only the Neocene lake beds) are the post-"Laramie" rocks, exposures of which occur in the extreme southeast corner of the area shown on the map (Pl. I, in pocket).

These stratified rocks are unaltered except near the granite borders and are conformable with those lying farther east.

The structural relations of the sedimentary rocks differ at each of the localities shown on the map. Near Helena the strata all dip southward and form the southern flank of a broad-domed uplift whose center, now eroded away, forms the basin known as Prickly Pear Valley. At Elkhorn, at the eastern limit of the area mapped, the beds are conformable to those folded in the Crow Creek Hills. Near Whitehall and south of Jefferson River the strata are parts of the general folds formed during the mountain-making uplifts of the region. At none of these places do the igneous rocks markedly disturb the attitude of the beds.

ANDESITE.

The igneous rocks that rest upon and flank the granite mass are of two distinct kinds and represent two distinct periods of volcanic activity. The older rocks are andesites and diorites. The andesites differ in appearance from place to place but are generally dark colored and have a compact and dense groundmass, commonly dotted with porphyritic crystals of feldspar, augite, and other minerals. They are readily distinguished from the granites, from which they differ in color, texture, and character of outcrop. Though usually massive and dense, porous varieties and varieties containing agate amygdules also occur. Owing to their superior hardness, fragments of andesitic rock are numerous and conspicuous in the gravels of all the streams draining localities where bodies of andesites occur.

The andesites are of volcanic origin and are older than the granite. In part they are intrusive, breaking through the sediments, and in part extrusive, forming accumulations of breccia, underlain by granite. They probably once covered a large part, if not all, of the granite tract, but are not now found near Butte, though they form the high mountain summits east of the granite region extending from the valley of the Jefferson northward to Missouri River. They also occur in numerous isolated areas throughout the central part of the mountain mass between Butte and Helena. Mineral deposits occur in the andesites as well as in the acidic granites, productive veins in them having been worked at the Zosel district, a few miles east of Deer Lodge, at Wickes, Alta Mountain, and elsewhere.

The andesitic rocks are largely fragmental, in places rudely bedded, and contain lava flows, dikes, and sills. They evidently represent the remains of old volcanic piles. The distribution of these rocks and their relations to the granite show that they once covered a large part or all of the region. These rocks form the Elkhorn Mountains. At Thunderbolt Mountain, 20 miles north of Butte, unaltered bedded andesitic tuffs show fragmental leaf remains and fossil wood, and greatly resemble the middle Tertiary beds of the fossil forests of Yellowstone Park. In general, however, the andesites show induration and pronounced metamorphism near the granitic contact, having evidently been baked and altered by the granite. Moreover, the granite near Pipestone Springs includes fragments of andesite. The granite is therefore the younger rock, intruded both along the contact and from beneath upward into the mass of andesite.

This is not the view formerly held, which was based on the occurrence of andesitic caps on many granite ridges, the other evidence being then unknown.[1]

The thickness of the andesitic rocks which once covered the granite can not be conjectured, as the only remnants now remaining are north and west of the town of Boulder.

GRANITE.

The granite area is the exposed part of a great mass, a batholith, which, intruded from below, has taken the place of the sedimentary and pregranitic rocks which undoubtedly once covered this district. Similar batholiths of granite occur elsewhere in the Montana ranges and are all probably connected with a deep-seated parent mass that underlies the entire region between the Front Range and the Idaho plains. Thus the granite and the older andesite and the rhyolite make up a mountainous region, which, though it contains no commanding peaks and summits, forms the continental water parting that separates the Atlantic from the Pacific drainage. The granite is called the Boulder batholith, because the greater part of the area over which it is exposed is drained by Boulder River and its branches, and because the county seat, Boulder, lies at about its center.

The rock of the batholith (Pl. II, *B*) is a quartz monzonite of very uniform composition through the entire area except at its contact with sedimentary rocks, especially limestones, where it shows basic facies, and in the Butte district proper and its vicinity, where it shows an unusual and significant amount of aplite. The rock prevailing about the copper mines has in previous publications been called Butte granite. Although it is technically a quartz monzonite and is called in this report the Butte quartz monzonite it will for convenience be frequently referred to as granite. It contains all the ore deposits of Butte.

The evidence of the igneous and intrusive character of the granite mass is abundant, varied, and conclusive. The granite is seen in actual contact with the sedimentary series at Helena, at Elkhorn, and in the Highland Mountains. It cuts the stratified rocks abruptly, the contact crossing the ends of the folds so that the granite is seen truncating strata of different ages. The actual contact is even more irregular and indented than is shown upon the map, and it is clear that the granite intrusion has broken across the beds and has not been influenced by the preexisting structure. Near Helena the granite extends underneath the sediments, which can be seen capping it as a thin cover, the plane of contact dipping northward at a low angle. As the beds preserve their normal sequence and conform in attitude to those farther north, it is evident that the granite has broken off and removed the continuation of the fold. The irregularity of the contact and the projecting tongues and dike like masses show the true nature of the intrusion.

West of the Highland Mountains, at the extreme southwest corner of the area shown on the general map (Pl. I), several great blocks of white limestone are included in and entirely surrounded by the granite. Near Elkhorn are similar blocks torn off from the sedimentary rocks.

The alteration of the sedimentary rocks at the contact with the granite is intense and shows unmistakably the intrusive nature of the latter. The alteration is greatest at the contact and becomes less and less away from it. The width of this zone of alteration differs at different places and with different rocks; it is commonly half a mile across, but in many places is more, though conspicuous for only a small part of this distance. So far as observed the bedded rocks are nowhere metamorphosed to schist. At the contact, rocks formed of garnet, epidote, calcite, etc., represent the recrystallized condition of the impure limestones. Where the alteration was less intense coarsely crystalline marbles were formed from limestone and dense hornstone from shale. All the varied products of thermal metamorphism may be observed. These facts indicate that the granite broke up through sedimentary beds while in a molten condition.

The granite also shows internal evidence of its intrusive nature. The mass as a whole is an undoubted unit and its coarseness and evenness of grain show that its magma cooled slowly and under cover. The rock varies but slightly in nature throughout the greater part of the area,

[1] See Butte special folio (No. 38), Geol. Atlas U. S., U. S. Geol. Survey, 1897, p. 1.

the differences in appearance being due to jointing and weathering or to chemical alteration. Near the borders of the mass, however, the rock changes from a light-colored typical granite to a dark variety approaching quartz diorite or even gabbro in composition. In many places near the contact with the sedimentary rocks these changes are abrupt and pronounced in character. The highest parts of the granite mass do not, as a rule, show the irregularities of grain and composition observable at the borders of the intrusion, but in a few places, where the andesite cover remains, similar variations may be seen.

That this great granite mass is not Archean, but is a more recent intrusion of igneous rock, is conclusively proved by the exposures at several localities along the contact with the sedimentary rocks. Of the rocks actually cut and altered the youngest whose age is definitely recognizable are Cretaceous. Furthermore, folded coal-bearing rocks of "Laramie" (Cretaceous) age occur near Anaconda, and the general mountain folding of the adjacent sedimentary formations is known to have occurred after the "Laramie" epoch. The granites are therefore younger than the Cretaceous rocks and not older than the post-"Laramie."

That the granite is younger than the andesitic rocks is proved by the presence in it of blocks of andesite near Pipestone Springs and north of Whitehall, and by the pronounced baking of the andesite at the contacts. The facts observed elsewhere indicate an Eocene age for the andesite, which would make the granite Miocene in age.

LAKE BEDS.

A large part of the granite tract is now covered by volcanic rocks which have been cut through by the canyons of the region. Between the time of the granite intrusion and the later rhyolitic volcanic outbursts a prolonged period of erosion must have intervened, during which the rocks above the granite were largely removed and the mountain masses and intervening valleys of the present day carved out by the streams, the Butte district being thus developed into a roughly hilly surface before the succeeding periods of volcanic activity began.

The Jefferson and Missouri valleys on the east and the Deer Lodge Valley on the west were at that time deeper than and as broad as they are to-day. A long period of undisturbed equilibrium was succeeded by a tilting of the region which reversed the drainage of the greater valleys, whose water accumulated in lakes, a phenomenon general throughout the region. The lake beds formed at this time may be seen about the borders of the granite tract, and in the Silverbow Valley they were deposited upon the granite itself.

RHYOLITE AND DACITE.

Rhyolite and dacite are prominent over a large part of the region surrounding the Butte district. These rocks are light colored, present a wide variety of types, and occur both as dikes cutting granites and andesites and as extrusive lavas and fragmental rocks. They form the hills west of Butte and the summits of the continental divide north of the district. The fragmental rocks and lava flows rest upon granites and andesites whose surfaces were uneven as is that of the present day. The rocks are of volcanic origin and came from a number of vents. They represent the product of the third and latest period of igneous activity, which accompanied or followed the great disturbance that formed the Miocene lakes of the region. The effects of this period of volcanic activity were general over this part of the Rocky Mountain region but are most marked in the Yellowstone Park. The age of the eruptions is of interest since the rocks are more recent than the ore deposits of Butte. The lake beds of the valley are formed largely of rhyolitic dust which fell into the waters of the rivers and lakes and of fine volcanic ash and débris washed from the surrounding slopes. In these beds vertebrate remains of late Miocene age have been found, furnishing definite evidence of the date of the rhyolitic eruptions. The hot springs which occur at a number of localities in the Boulder and Butte regions are believed to be due to the lingering heat of this period of volcanic activity and to furnish evidence of its comparative recency.

Extensive areas of rhyolitic rocks lie northwest of Butte and cover considerable territory in the district proper.

SUMMARY OF GEOLOGIC FEATURES.

A central mass of granitic rock now exposed for about 64 miles in length and 12 to 16 miles in width is surrounded by upturned and folded sedimentary rocks whose edges are abruptly cut off by the granite. Remnants of a former capping of dark-colored and baked andesites occur as patches over the northern part of the granite region, and extensive areas of these same rocks form mountain masses flanking the granite on the east, north, and west, concealing the sedimentary contact in these areas. These andesitic rocks are partly intrusive but are mainly extrusive lavas or volcanic débris. The granite itself contains numerous patches and dikes of white aplite, in places tourmaline-bearing, that are regarded as a later siliceous phase of the granite itself. All these earlier rocks, including the sedimentary limestones, etc., are cut by rhyolitic dikes and capped by extensive accumulations of fragmental rhyolitic rocks and lava flows. Mineral vein formation preceded this later volcanic period and is still in progress in some parts of the district. Over the northeastern part of the granite region quartz veins, usually barren, are extremely common and of unusual size, forming the crests of long high ridges and dominating the local topography. The deeper older valleys of the district are filled by alluvial and lake beds largely composed of rhyolitic volcano dust and material washed down the slopes when the rhyolitic eruptions occurred.

From studies elsewhere it is known that over a large part of the State igneous activity began on a grand scale at the close of the Cretaceous period. The region between Helena and Butte yields no positive evidence of the age at which the andesitic rocks were formed further than that it was post-Cretaceous and earlier than the deposition of the Neocene lake beds.

Since the close of the volcanic epoch represented by the rhyolite no great changes have occurred in the geologic features of the district. The Miocene lakes have been drained by streams flowing northward. During later glacial time the higher summits were covered by local ice sheets, which formed the moraines now conspicuous in the mountains east of Elk Park and at other localities, though not near Butte. The grander features of topography are the same to-day as at the close of Miocene time, having been modified only by canyon cutting and valley filling, which changed only the scenic details.

CHAPTER III.—DESCRIPTIVE GEOLOGY OF THE BUTTE DISTRICT.

OCCURRENCE AND CHARACTER OF THE ROCKS.

The hilly tract containing the mines of the Butte district is made up entirely of igneous rocks. Those of earlier age than the ore deposits are mainly coarse-textured granitic rocks; those of later age are of volcanic origin. These later rocks are largely fragmental, resulting from the hardening of tuffs and breccias thrown out from a volcanic vent. Big Butte, from which the city takes its name, is formed of rocks typically volcanic; it is the site of a small volcano, the only one yet revealed by erosion in this part of the State. Massive volcanic rocks also occur, partly as dikes radiating from this vent and cutting both granite and mineral veins, and partly as the remains of irregular intrusions or lava flows that were partly destroyed by later outbursts. In the mineralized areas the rocks of the district are more or less profoundly altered, but unweathered material is easily obtainable from underground workings and surface quarries.

Two general subdivisions of the rocks of the district can be made. The first and older embraces the granitic rocks, these rocks being older than the mineral veins. The second group includes the porphyritic rocks, which, with the exception of the rhyolite porphyry of Anaconda Hill, are later than the ore deposits. The rocks erupted from the Butte volcano or from some neighboring center of activity, those intrusive in the granite, and those that accumulated in the Tertiary lake basin, all belong to this second group. In the eastern part of the district a large area which covers the old valley floor is mapped as alluvium.

GRANITIC ROCKS.

TYPES.

The oldest rocks of the district are of recognizable granitic habit, having an even and coarse grain and the usual appearance of a granite. They consist of two strongly contrasted types. One is a dark-grayish coarse-grained rock, which differs somewhat in appearance and mineral composition from the rock commonly prevailing throughout the surrounding region; as it is nearly constant in character and chemical composition and is characteristic of the district, it has been given the distinctive name of Butte quartz monzonite. In previous reports it has been called Butte granite.[1]

A second type is a white or cream-colored aplite or alaskite of variable but coarse grain and granitic habit, which occurs in the district in great abundance. In previous reports it has sometimes been alluded to as "Bluebird granite," but as it is the only aplite of the region and is easily distinguished from the Butte quartz monzonite it will be called simply aplite in this report. The two rocks are not only unlike in color and appearance but are readily distinguished in outcrop, the aplite forming rocky exposures standing above the surface of the more readily disintegrated Butte quartz monzonite.

BUTTE QUARTZ MONZONITE.

PETROGRAPHIC CHARACTER.

The Butte quartz monzonite, the common and characteristic rock of the district, covers the eastern half, where the great producing mines occur, and underlies the city. Throughout the district it is very uniform in color and texture and in the kind, amount, and distribution of its component minerals. To the unaided eye it is a dark-colored rock, of coarsely and evenly granular appearance (Pl. III), but so dark and basic looking as to resemble a coarse diorite. Black hornblende occurs in abundant, irregular grains. Black biotite mica is but little less

[1] Notes on the geology of Butte, Mont.: Trans. Am. Inst. Min. Eng., vol. 16, 1887, pp. 49–62.

common, occurring rarely in grains with crystalline form. The light-colored constituents, forming about four-fifths of the bulk of the rock, consist of pink orthoclase and little less abundant gray and faintly greenish plagioclase, together with clear but not conspicuous quartz. Scattered black grains of magnetite, brown zircon, and apatite are recognizable, and pyrite is locally visible, even in the freshest rocks. Isolated, rudely square or rectangular masses of pink feldspar, some of which are an inch across and show partly crystalline forms, are a common feature and as they weather in relief give the rock a somewhat porphyritic appearance.

Thin sections of the rock studied under the microscope show that the orthoclase and plagioclase feldspars are present in nearly equal amounts, so that the rock, according to precise petrographic nomenclature, should be called a quartz monzonite. The biotite is quite black to the eye but is dark brown in color under the microscope and shows very marked pleochroism. The hornblende is black, but is pleochroic in dark-green tints with large extinction angle when seen under the microscope. Augite is usually present in very small amount. The plagioclase is a sodic labradorite of the composition Ab_1An_1, and the orthoclase is also soda-bearing. The dark-colored constituents form a little over one-fifth of the rock. (See Pl. III.) Examination of numerous sections shows a slight variation in the relative amounts of plagioclase (oligoclase-albite). The extreme variations are from a typical hornblende granite to a diorite-granite. The most basic form was found at the Poulin mine, the sodic labradorite feldspar of this rock slightly exceeding the orthoclase in amount. In the rock quarried east of the Bell mine the plagioclase feldspar equals the orthoclase in amount. No order of arrangement of such variations was found, and chemical analyses of material showing the extreme variations (p. 33) are nearly identical and show a remarkably uniform composition of the rock throughout the district.

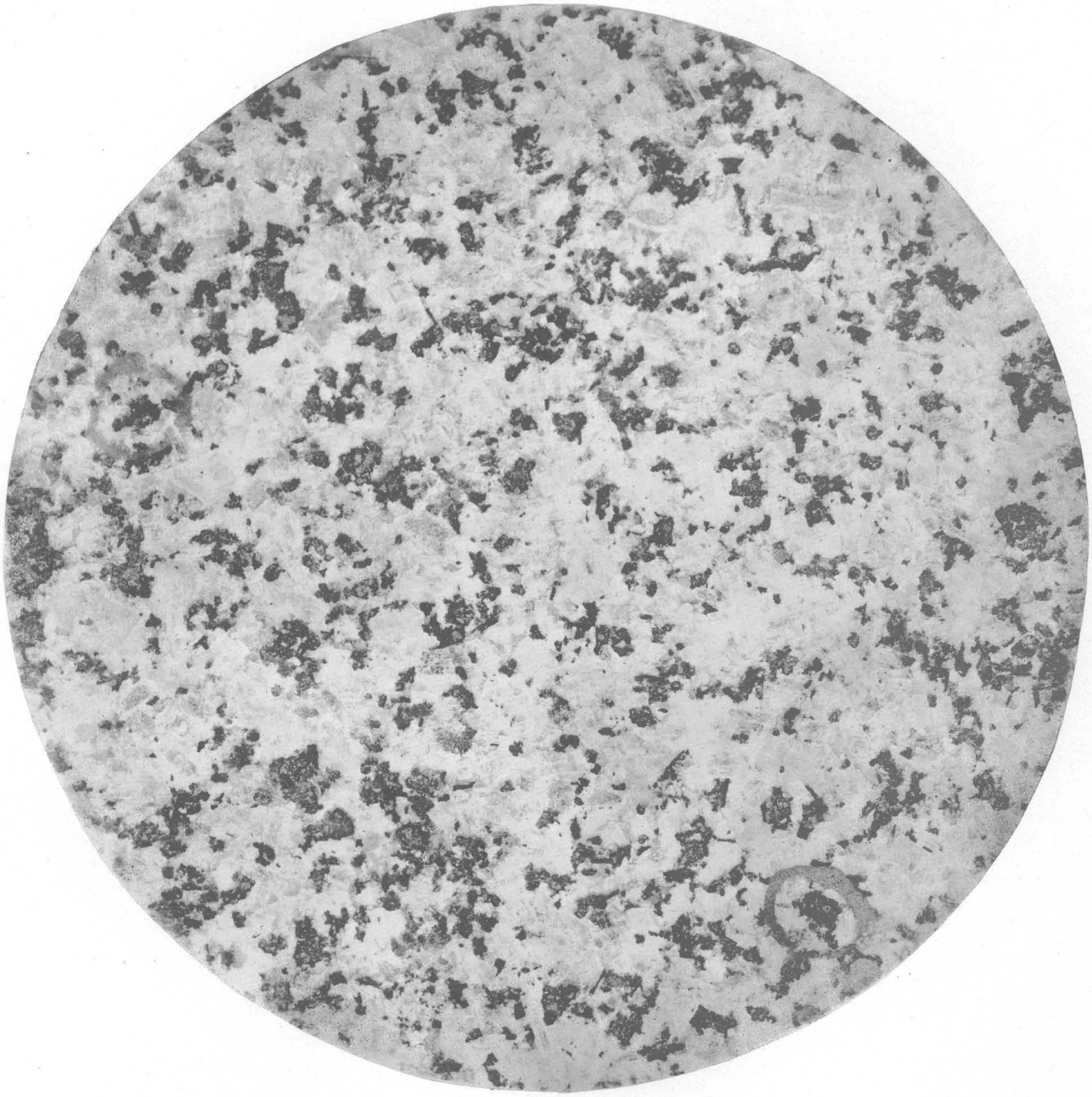
Included fragments of a fine-grained and much darker colored rock occur in the granite in a few localities. These inclusions weather less rapidly than the rock containing them and project sharply above the weathered surfaces. Such fragments carry a much larger proportion of the dark-colored minerals and are finer grained than the granite. They resemble the basic contact forms of the great granitic mass and may represent portions of a partly hardened dioritic contact crust of the Butte quartz monzonite torn from deeper-seated parts of the rock mass and brought up while the monzonite was still molten.

DISTRIBUTION.

The Butte quartz monzonite occurs in all parts of the district, but is in part concealed by later rocks. It may be traced northward and northeastward beyond the area shown on the map into the general granite mass of the region, but elsewhere its surface is obscured by fragmental material, so that continuous exposures are not presented and its transition into the general mass of the batholith is not apparent.

The copper-bearing area at Butte shows comparatively few natural exposures, being in this respect in marked contrast to areas of the same rock in the surrounding region. In the vicinity of the important mines the rock is not only traversed by a multitude of large and small veins, but it disintegrates readily under atmospheric agencies into a coarse sand which obscures the underlying decomposed and sandy rock. The transition from the surface sands to the firm and solid rock may be observed in many open cuts throughout the district. In a very few places rounded bowlder masses and smooth rock surfaces may be seen.

The comparatively few rock outcrops which form a prominent feature of the ore-bearing area are generally due to either vein quartz or to a silicification of the altered granite. Numerous railroad cuts show good exposures of the upper disintegrated layer of the granite. In excavations throughout the city the outer zone of soft disintegrated rock yields readily to the pick and shovel to a depth of 6 to 10 feet. In a majority of these exposures the granite is seamed with a coarse network of iron-stained seams and quartz veins of varying thickness. (See Pl. IV, *A*.)



BUTTE QUARTZ MONZONITE, SHOWING TEXTURE AND OCCURRENCE OF PRIMARY SULPHIDES.

White areas, quartz and feldspar; dark areas, hornblende (augite) mica, magnetite, and very little pyrite. Enlarged one-half.

A. MINERALIZED JOINTS IN GRANITE IN AN EXCAVATION FOR THE FOUNDATION OF A CHURCH AT BUTTE.

B. PART OF MODOC DIKE.

Shows rhyolite porphyry intrusion surrounding bowlders of Butte quartz monzonite and filling horizontal joints in that rock. Railway cut near East Colusa mine. See page 42.

Much of the surface extension of the large mineralized veins consists of leached and altered rusty granite or more rarely of soft clayey material. The granite is, moreover, netted with a system of close and small fractures, many of which seem to be merely shear or joint planes, along which permeating waters have concentrated the iron either as a film along the plane itself or as a staining of the walls of the seam, giving it a rusty ocher color. Other veinlets are actual seams of quartz.

CHEMICAL AND MINERALOGICAL CHARACTER.

The coarse-grained granitic rocks of the Butte district are parts of a large mass of great extent called the Boulder batholith, and in order to determine, if possible, why ore deposits occur near Butte it is necessary to ascertain in what respect, if any, the rock there differs from that of other parts of the mass.

ROCKS OF THE BOULDER BATHOLITH.

A study of the field relations shows that the rocks of the batholith must be regarded not only as facies of the same magma but even as parts of one mass. Yet they present a wide variation in mineral and chemical composition. All the very basic rocks occur at the margins, but clearly recognizable types, which yet can not be discriminated in mapping, occur within the main body. This same difficulty has been experienced by geologists working in the Sierra Nevada, where, as stated by Turner,[1] a considerable variety of rock types have been mapped as granodiorite, "although as a rule gabbro, even when genetically related to granodiorite proper, has been separated."

Where detailed mapping on a large scale is not possible, this difficulty of separating parts of a single intrusive body in which the rock types grade into one another can be met only by arbitrarily applying the name of the prevailing rock type to the entire mass, as has commonly been done heretofore, or by using a generic term like granolite [2] to embrace all coarsely granular rocks.

In the following table are given the results of the analyses so far made of the rocks of the Boulder batholith. Specimen 518 represents the prevailing type of the batholith.

Analyses of rocks from the post-Cretaceous granitic batholith of the Boulder Mountains, Mont.

[H. N. Stokes, analyst.]

	526	525	130	311	625	6	989	98	518	640	951
SiO_2	49.22	56.41	61.64	63.87	63.88	64.05	64.34	64.17	67.12	76.87	77.05
TiO_2	.95	.68	.71	.65	.65	.60	.53	.67	.48	.11	.12
Al_2O_3	12.02	17.62	15.63	15.39	15.84	15.38	15.72	15.25	15.00	12.52	12.84
Fe_2O_3	2.77	1.24	3.39	1.93	2.11	2.20	1.62	2.16	1.62	.67	.56
FeO	8.80	3.55	2.69	3.08	2.59	2.74	2.94	2.98	2.23	None.	.14
MnO	Trace.	.08	.04	.11	.07	.11	.12	.04	.06	...	None.
CaO	10.56	8.66	4.90	4.30	3.97	4.30	4.24	4.24	3.43	.49	.57
MgO	9.29	3.97	2.82	2.23	2.13	2.08	2.17	2.60	1.74	.09	Trace.
K_2O	1.70	2.61	3.72	4.18	4.23	4.00	4.04	4.34	4.52	5.78	5.52
Na_2O	1.90	3.35	2.64	2.76	2.81	2.74	2.76	2.62	2.76	2.47	2.81
H_2O below 110°	.27	.14	.28	.19	.22	.27	.25	.16	.09	.25	.22
H_2O above 110°	1.63	.76	.91	.69	.66	.83	.76	.65	.58	.52	.48
BaO	.03	.09	.08	.07	.09	.08	.06	.07	.07	...	None.
SrO	.03	.08	.04	.02	.04	.03	Trace.	Trace.	.03	...	None.
P_2O_5	.43	.49	.21	.17	.21	.21	.14	.16	.15	.05	None.
Cl	.08	.07	...	...	...	...	...	Trace.	...	...	...
S	.05	...	...	.07	...	.07	.03	...	...	...	None.
SO_3	.04	...	None.	...	...	...	...	.07	Trace.	...	...
CO_2	...	...	None.	.15	...	.35	.03	None.	None.	...	None.
ZrO_2	...	...	...	...	...	...	...	...	...	...	...
Total	99.77	99.70	99.70	99.91	99.72	100.055	99.80	100.18	99.88	99.82	100.31

526., 525. Contact facies of granite mass, Red Mountain.
130. Diorite, Red Rock Creek. Intrusive in batholith.
311., 625., 6., 989. Butte quartz monzonite, Butte district.
98. Head of Clancey Creek, northern part of batholith.
518. Prevailing type of granite of Boulder batholith.
640., 951. Aplite of Butte district.

[1] Turner, H. W., Granitic rocks of Sierra Nevada: Jour. Geology, vol. 9, 1899, p. 146.

[2] Idem, p. 141.

The prevailing rock of the batholith is a normal hornblende granite, which is very generally sheeted, forming picturesque crags and bowlder groupings. It disintegrates readily into platy masses that shell off from the bowlders and in time crumble to a coarse sand. Over large tracts this disintegration has reduced the rocks to a smoothly rolling surface, on which scattered bowlders rise above the general level. Perfectly fresh material can therefore be obtained only where the rock has been quarried or exposed by mining operations. It is a medium to coarse grained rock, the average size of the grains being 3 to 5 mm. The grayish quartz and white feldspar grains are of about equal size. Black mica and dark-green hornblende are present in considerable quantity. Under the microscope it shows the normal characters of a granite but contains an unusual amount of plagioclase.

In the following table only the essential elements of this rock are given, the complete analysis being shown in the preceding table. Partial analyses of quartz monzonite from the Sierra Nevada and of Brögger's adamellite are given for comparison.

The first column gives the approximate composition of the hornblende granite of the Boulder batholith, the second and third columns the composition of quartz monzonite from California, and the fourth column that of adamellite. It is evident from the analyses that the Boulder rock nearly corresponds to Brögger's adamellite.

Principal constituents of Boulder granitic batholith and allied rocks.

	Hornblende granite of Boulder batholith.	Quartz monzonite of Sierra Nevada.	Quartz monzonite of Pyramid Peak, Cal.	Landsberg b. Barr, Vogesen. Rosenbusch.
Silica	67.12	66.83	67.45	68.97
Alumina	15.00	15.24	15.51	14.80
Lime	3.43	3.59	3.60	3.82
Magnesia	1.74	1.63	1.10	1.15
Potash	4.52	4.46	3.66	4.53
Soda	2.76	3.10	3.47	2.40

QUARTZ MONZONITE OF BUTTE DISTRICT.

The exact relations of the Butte quartz monzonite to the granite of the general area were not satisfactorily determined, though it appears certain from the exposures that it is an integral part of the batholith and not a separate intrusion. At several localities a sharp gradation was observed, with narrow transition bands between the lighter-colored granite, with its white feldspars, and the darker Butte type. It will, however, be seen from the analyses that the quartz monzonite is only a somewhat more basic phase of the granite of the region and that it closely resembles granodiorite; the plagioclase is more basic, being sodic labradorite.

The quartz monzonite mass is remarkably uniform in character, not only megascopically and microscopically in texture and mineral composition, but also chemically. The analyses confirm this statement, which has also been noted by Washington.[1] Eutaxic and schlieric masses occur rarely and were avoided in taking samples for analysis.

The following table gives partial analyses of the Butte quartz monzonite and of related rocks from other localities:

Partial analyses of Butte quartz monzonite and related rocks.

	Butte quartz monzonite.	Grano-diorite.	Boise rock.	Banatite average.	Granite of Boulder batholith.
Silica	64.03	65.48	65.23	64.39	67.12
Alumina	15.58	16.05	16.94	15.90	15.00
Fe_2O_3	1.96	1.47	1.60	5.63	1.62
FeO	2.83	3.02	1.91	......	2.23
Lime	4.20	4.88	3.85	4.15	3.43
Magnesia	2.15	2.13	1.31	1.93	1.74
Potash	4.11 } 6.87	2.43	3.02	3.57 } 7.05	4.52
Soda	2.76	3.49	3.57	3.48	2.76

[1] Washington, H. S., Prof. Paper U. S. Geol. Survey No. 14, 1903, p. 17.

The first column gives the mean of the four analyses. The second column shows the mean of five analyses of granodiorite as given by Turner.[1] The Boise rock is described by Lindgren.[2] The banatite is a mean of five analyses quoted by Brögger.[3] From the analyses it will be seen that the rock closely resembles a banatite in composition, the lime and sum total of the alkalies being the same, though in the Butte quartz monzonite the potash exceeds the soda in amount. It also resembles the granodiorites, but the alkalies are present in an inverse ratio.

In order to furnish a basis for calculating the mineral composition of the Butte quartz monzonite, fresh material was crushed, and the hornblende and biotite were segregated in the Survey laboratory by Dr. H. N. Stokes by the use of Thoulet solutions, and these two minerals were separated from each other by sliding on paper. The resulting material was examined under the microscope and found to be very pure.

To the naked eye the biotite appears quite black, but under the microscope it is dark brown, showing very marked pleochroism. It is characteristic not only of the Butte quartz monzonite, but of the hornblende granite of the Boulder batholith as well. In many sections examined it appears the same in color and pleochroism, not only for the Butte quartz monzonite but for the normal granite of the batholith, and it may be assumed to be the same for both. The microscopic examination of the biotite material showed a little apatite, a very little chlorite, and very little hornblende, but these impurities form a very minute part of the whole.

The amphibole is also characteristic of both the Butte quartz monzonite and the normal hornblende granite of the region. It is black or very dark green when seen with a hand lens, but pleochroic in dark-green tints with large extinction angle when seen under the microscope. The material analyzed was very pure.

The following table shows the result of the analyses of these minerals. Dr. Stokes was unable to obtain a higher summation in the analyses made of each, as the amount of material available was exhausted. The analyses published by Turner of the biotite and amphibole from the quartz monzonite of the Sierra Nevada are given for comparison. The close resemblance of the analyses of both rocks and minerals to those of the Butte quartz monzonite is noteworthy.

Chemical composition of biotite and hornblende in the granitic rocks of Butte, Mont., and of the Sierra Nevada; and the composition of the Butte quartz monzonite.

	Biotite.		Hornblende.		Butte quartz monzonite.[a]	
	Butte.[a]	Sierra Nevada.[b]	Butte.[a]	Sierra Nevada.[b]	Per cent.	Ratio.
SiO_2	35.79	36.75	45.93	47.49	64.03	1.0671
TiO_2	3.51	3.16	1.43	1.21	.60	....
P_2O_5	.10	.03	.28	.06	.18	.00126
F	.76	....	.17	....	....	....
Cl	.20	....	....	....	....	....
Al_2O_3	13.70	14.70	6.77	7.07	15.58	.1527
Fe_2O_3	5.22	4.65	4.94	4.88	1.96	.0123
FeO	13.72	14.08	10.39	10.69	2.83	.0393
MnO	.19	.45	.54	.51	.11	.00015
BaO	.13	....	None.	....	.07	.0005
SrO	None.	.12	None.	....	.04	.0004
CaO	.05	.17	11.25	11.92	4.20	.0750
MgO	12.13	12.37	12.32	13.06	2.15	.0537
K_2O	9.09	9.19	1.22	.49	4.11	.0436
Na_2O	.15	.32	.77	.75	2.76	.0445
Li_2O	Trace.	Trace.	Trace.	Trace.	....	....
H_2O below 110°	1.21	1.03	.49	....	.20	....
H_2O above 110°	3.64	3.64	2.29	1.86	.73	.00405
Total	99.59	100.0	98.77	100.03	99.87	....
Less O for F+Cl	.37	....	.12	....	....	....
	99.22	....	98.65	....	....	....

[a] Analysis by Stokes.

[b] Analysis by Hillebrand.

[1] Turner, H. W., Rocks of the Sierra Nevada: Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, pp. 478, 482.

[2] 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. 81.

[3] Die Eruptionfolge der Triadischen Eruptivgesteine bei Predazzo, p. 62.

The Butte analyses are incomplete, as the amount of material was too small for further work. The analyses of the biotite and hornblende of the Sierra Nevada rocks are those given by Turner.[1]

To calculate the mineral composition of the Butte quartz monzonite, one must assume that the phosphoric pentoxide (P_2O_5) in the biotite and hornblende and in the rock itself is present as apatite and must deduct it, with an appropriate amount of lime, from the analyses. The water below 110° C. is assumed to be accidental and is also deducted. The analyses are then reduced to 100 and the molecular ratios calculated.

All the soda is calculated as albite. As the microscope shows the plagioclase to be andesine of about the composition of Ab_1An_1 (or sodic labradorite) and as albite is not seen in the section the orthoclase must contain the albite molecule. The hornblende is therefore estimated and an equivalent amount of lime deducted; the remainder of the lime is then calculated with the albite molecule to form plagioclase. The result shown in column 1 of the table gives the mineralogical composition of the rock.

Mineralogical composition of the Butte quartz monzonite.

	1	2	3	4
Quartz	23.70	22.55	20.34	19.61
Orthoclase	19.88	17.57	19.82	23.69
Albite	22.98	42.47	41.48	25.23
Anorthite	11.48			19.43
Hornblende	13.15	4.44	5.67	[a] 1.36
Biotite	4.22	9.77	8.94	[b] 6.94
Pyroxene	2.11	2.37	2.50	[c] .19
Apatite	.33			[d] 1.92
Magnetite	1.18	.76	1.02	[e] .91
Titanite	.97			.07
Pyrite	.06	.07	.04	.01
	100.06	100.00	99.81	99.36

[a] Diopside. [b] Hypersthene. [c] Fluorite. [d] Magnetite. [e] Ilmenite.

1. Calculated composition of average rock. (Weed.)
2. Measured composition of sample from Parrot mine. (Iddings and Cross.)
3. Measured composition of sample from Walkerville. (Iddings and Cross.)
4. Theoretical composition or norm. Under 4 several of the minerals present in the first three rocks are missing, and other new ones are present, as shown by the footnotes.

Analysis 1 gives 1.51 molecular weight against 1.50 for the bulk analysis of the rock, showing a very close agreement. Analyses 2 and 3 give the percentages measured in thin sections by Cross, Iddings, et al.,[2] for the same rock, analysis 2 representing material from near the Parrot mine, and analysis 3 rock from the quarry near Walkerville. The percentage of plagioclase is greater and that of hornblende much less than in the earlier calculation made by the writer (analysis 1). Analysis 4 represents the normal or standard composition of the rock as calculated from the analysis.

The uniformity of the rock is an expression of like conditions prevailing throughout the mass at the time of solidification, since it is well known that a "magma may crystallize with quite different mineral combinations, according to the influence of attendant conditions upon the union of the various chemical constituents."[3]

APLITE.

PETROGRAPHIC CHARACTER.

The second variety of granite found at Butte is an alaskite or aplite granite. In previous reports it has sometimes been alluded to as "Bluebird granite." It is a granular, or finely granular, siliceous granite, consisting of alkali feldspar and quartz. At Butte it contains very little plagioclase feldspar and some small scattered grains of biotite and is white or cream-colored, medium grained, of sugary texture, and bears a superficial resemblance to sandstone. Transi-

[1] Some rock-forming biotites and amphiboles: Am. Jour. Sci., 4th ser., vol. 7, 1899, p. 294.
[2] A quantitative classification of igneous rocks, Univ. of Chicago Press, 1903, p. 226.
[3] Idem, p. 100.

tion also occurs into the darker Butte quartz monzonite. Under the microscope it is seen to consist of a mosaic of orthoclase and quartz grains, locally rounded, with a sprinkling of small biotite mica plates. When slightly decomposed the biotite is altered to chlorite, staining the rock pale green; further alteration changes this to iron oxide, giving the rock a rusty tinge.

The rock varies greatly in granularity. In narrow dikes it is commonly quite fine grained. In the larger masses coarser grained often alternates with finer grained rock in bands or irregular patches. The rock grades into micropegmatite, and at times into true pegmatite, in which the constituent minerals are easily recognizable by the eye. In one instance such pegmatites showed tourmaline.

The contact between the aplite and the granite is very sharp in the small intrusions, but shows gradation about the larger masses. No evidence of contact chilling is ever shown by a denser band of material at such contacts. In places joint planes in the rock show finer-grained surfaces that may represent shrinkage cracks.

VARIATIONS IN CHARACTER.

The aplite varies greatly in texture. In the Bluebird area it is fairly constant, except at the edges of the intrusion. In the smaller intrusions, however, it tends to become a pegmatite, and in places grades into such. More generally, however, the pegmatite forms veinlike masses in the main body of the aplite. The pegmatite may be fine-grained graphic granite or a coarse, open-spaced aggregate of quartz and feldspar crystals, showing very little hornblende.

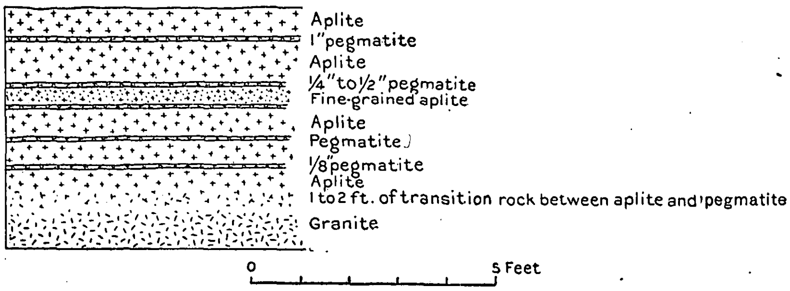


FIGURE 2.—Variation in texture of aplite exposed near Boulder, Mont.

At the margins of the larger intrusive masses the rock grades into a transition form that resembles both granite and aplite, and yet can scarcely be classed as either. It is too light colored and acidic to be a part of the Butte quartz monzonite, and it has too pronounced a granitic hypidiomorphic structure and contains too large an amount of dark-colored silicates to be a good aplite. It shows coarsely crystalline aggregates, filled in with aplitic material, and is decidedly pegmatitic in appearance. (See fig. 2.)

The aplite of the Butte district varies but little in mineral composition. Samples from the Nettie mine, a silver property west of Big Butte, analyzed in the Survey laboratory, show the following composition:

Analyses of aplite from Nettie mine, Butte, Mont.

Constituents.	1	2	Constituents.	1	2
Silica	76.87	77.05	Water above 110° C	.52	.48
Titanic acid	.11	.12	Baryta		None.
Alumina	12.52	12.84	Strontia		None.
Ferric oxide	.67	.56	Phosphoric acid	.05	None.
Ferrous oxide	None.	.14	Chlorine		
Manganese		None.	Sulphur		None.
Lime	.49	.57	SO_3		
Magnesia	.09	Trace.	Carbon dioxide		None.
Potash	5.78	5.52			
Soda	2.47	2.81		99.82	100.31
Water below 110° C	.25	.22			

1. Analysis by Hillebrand. 2. Analysis by Stokes.

The mineral composition of the aplite represented in analysis 1 has been calculated. A little biotite, found in the fresh aplite, is similar to that in the granite and is supposed to have the same composition; to it all the magnesia is ascribed. This leaves an excess of 0.09 per cent of titanic oxide, which is calculated as titanite.

Mineral composition of aplites from the Butte district and from the Sierra Nevada.

Constituents.	1	2	Constituents.	1	2
Quartz	37.70	39.45	Magnetite, etc	1.20	0.40
Potash feldspar	33.90	29.43	Apatite	....	.05
Soda feldspar	23.81	23.03	Titanite	.22	.18
Lime feldspar	2.45	6.56			
Biotite	.72	.90		100.00	100.00

1. Aplite from Nettie mine, Butte, Mont.
2. Granodiorite mass of the Sierra Nevada (Turner, The granitic rocks of the Sierra Nevada: Jour. Geology, vol. 7, 1899, p. 160).

INCLUSIONS.

A few inclusions of Butte quartz monzonite are found in the aplite. Some of these show fracturing, the related pieces lying near together, showing that the granite was solid and not viscous when the aplite was injected. Small aplite intrusions in the Butte quartz monzonite show, however, that the granite was not cold at the time of intrusion, as no change whatever of grain is visible up to the actual contact. This is clearly shown in specimens from the Hyde Park claim. In the south wall of the Butte, Anaconda & Pacific Railroad cut, below the road from the Nettie, the aplite intrusions follow two well-defined fissure systems and are slightly coarser grained and of more open texture on both contacts than in the center. Near the Bluebird mill an exposed wall shows rounded detached masses of aplite and irregular stringy injections that look like inclusions torn off and carried up while both rocks were still viscous. In the railroad cutting below the Philadelphia the aplite is brecciated and altered, showing pale-lâvender, cream, pink, and green tints. Some of the fragments are well rounded and are up to 6 or 8 inches in greatest dimension; they are held in a paste of aplite, sand, and clay. This seems to be a fault breccia.

WEATHERING.

In the larger intrusions the aplite weathers to rounded surfaces and gentle slopes resembling, at first sight, those of the adjacent granite areas. The smaller intrusions resist weathering better than the granite and form conspicuous exposures. Whatever may be the amount of disintegration or alteration to which the two rocks have been subjected, the aplite is always readily distinguishable from the coarser and darker granite by its light color and characteristic grain.

The slopes about Burlington and the Bluebird mine show that the aplite weathers into slabs which either scale off or rest upon and cover the surface. This weathered crust, though appearing perfectly fresh, is loosely granular and friable and is easily reduced to coarse sand. It is, however, quite unlike the loose-textured material of the disintegrated granite, for it forms smooth rock surfaces checked by a rudely hexagonal network of cracks. Even where the slopes are steepest no conspicuous outcrops occur when the rock is all aplite. It is only where it is contrasted with the granite that this difference of weathering emphasizes the aplite in the topography. The rock does not weather into bowlders or rounded monoliths, such as characterize certain parts of the granite area.

Quarries show that the aplite possesses a rudely platy parting and breaks into square-edged cubical blocks, which greatly facilitates quarrying. Where it has suffered decomposition, especially by the waters of mineral veins, the feldspars are reduced to a clayey material, through which the quartz grains are scattered. This is, however, seldom observable on surface outcroppings.

The aplite has suffered from the same forces which have sheeted and fissured the Butte quartz monzonite, but the result is not so apparent in surface exposures.

DISTRIBUTION.

The aplite occurs intrusively in the Butte quartz monzonite in a great variety of forms. It is most commonly seen in dikes and in irregular sheets of widely varying size and form. Where possible both dikes and sheets are shown on the geologic map, but many intrusions in the vicinity of the copper mines are too small to represent. Many dikes spread out into sheets, the form of the intrusion depending on the position of the fracture plane of the granite. Some of the intrusions are remarkable for their size; the largest extends 1¼ miles from the west base of Big Butte to the broad open valley at the western limit of the district, and has an equal breadth. Branches of this intrusion penetrate the borders of the quartz monzonite, and its mass contains included fragments of granite; it is, however, relatively shallow, being underlain by granite at a depth of only a few hundred feet.

Besides the large masses the aplite occurs in dikes ranging from a few inches to a few feet in width. As the rock composing these is fine grained it closely resembles vein quartz where it occurs on weathered surfaces or in railway cuttings. These small dikes are not very numerous and are not shown on the geologic map (Pl. X). No definite relation between them and the fissuring of the granite was established. Some of them connect with horizontal expansions of the same material. Where good natural exposures of the Butte quartz monzonite occur these aplite dikelets are seen weathered in relief.

The contact between the aplite and the quartz monzonite is commonly a sharp one in the dikes and smaller intrusions, but is indefinite about the borders of the larger masses. In the dikes the welding of the two rocks is perfect; the rock fractures as one mass, but the dividing line is very sharp.

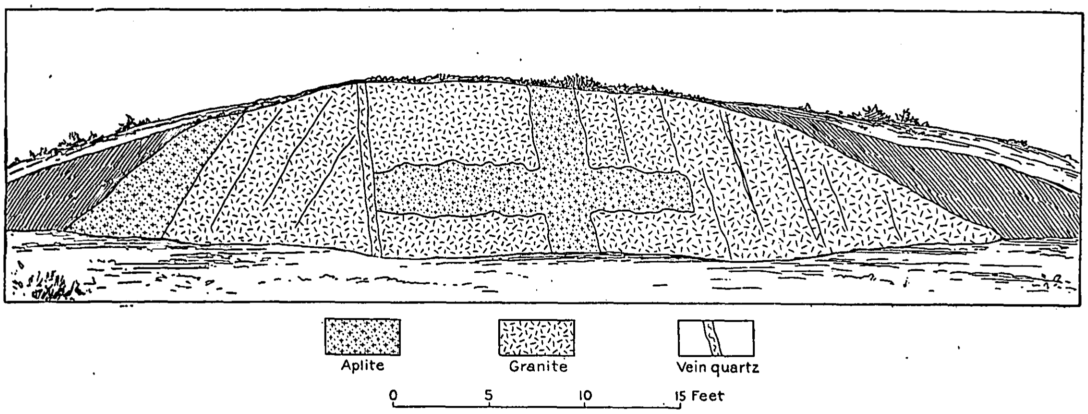


FIGURE 3.—Small aplite intrusions along fissure lines in Butte quartz monzonite.

Special occurrences worthy of note are seen near the Mountain Boy mine, where inclined dikelike masses of the aplite have been exposed in quarrying. Flat lenticular masses are also seen on the hills to the east. Commonly the aplite intrusions are rather thin sheets of small extent, soon passed through in mining (fig. 3); their prominence in surface exposures is due to their not crumbling to sand as readily as the surrounding quartz monzonite.

ORIGIN OF THE APLITE.

The commonly accepted theory of the origin of aplite is that it represents the acidic remainder in a granite or quartz diorite magma after the more basic elements have crystallized. The aplite is forced up from below and fills previously formed cracks, which are perhaps the result of cooling, in the main mass of the granitoid rock. On this hypothesis aplite is genetically related to the more basic granites with which, in the Sierra Nevada, it is most directly associated.[1]

So far as known to the writer, the aplite of the Butte district is the most extensive body of that rock yet discovered. In other occurrences observed by the writer and in those commonly described, aplite occurs in dikes generally narrow, though in many places of considerable length. A study of the aplites of the Butte district shows that though dikes of this material may be explainable by the generally accepted theory, yet some of the irregular lenslike or miniscoid-shaped masses are local bodies unconnected with any feeder. The inference derived from a careful examination of many exposures is that the material is due to some process of segregation such as that suggested by Turner—a squeezing out from the crystallizing granite and a

[1] Turner, H. W., Geology of Sierra Nevada, 1894, p. 722.

collection into shrinkage cracks. In the description of the remarkable differentiation zone of Square Butte [1] the basic outer part of the intrusions, itself a product of differentiation, contains a thin band of white syenite due to further separation or differentiation of the feldspathic constituents in the crystallizing mass.

This hypothesis, belief in which has been strengthened by further observations of other laccoliths in the same region, seems to explain the manner of occurrence of the aplite in the Butte quartz monzonite. It is believed (see p. 47) that the Butte district lies on the downthrown side of a fault, and that its granitic rocks represent the upper part of the batholithic intrusion. In this uppermost part of the intrusion partial differentiation is believed to have taken place, the normal granite splitting up into the basic phase represented by the Butte quartz monzonite and the acidic phase represented by the aplite. As the monzonite is but slightly more basic than the prevailing form, this hypothesis demands that the proportion of aplite should be small. The field observations show a quantitative relation which, as far as it can be estimated, confirms the view.

The hypothesis implies a gathering of the iron, magnesia, and lime molecules out of the general magma and their concentration in the Butte quartz monzonite, followed by a segregation of the aplitic material, richer in alumina, alkalies, and silica, not as an inner kernel (as in laccolithic differentiations), but as local masses in the basic granite. This hypothesis has been advanced by Cross in the discussion of evidence of differentiation at Rosita, Colo.[2]

If the Butte quartz monzonite is a border or upper-contact facies of the batholith, this segregation may have been induced by contact cooling. Observations of many of the smaller intrusive stocks of the Montana mountains and of the contacts of the larger batholiths show more or less mixing of basic and siliceous materials, as if they had been stirred together while pasty. The rocks grade into one another and show no sharp contacts.

In the large aplite intrusions no transition zone exists. The grain is the same in both rocks, but at a certain line a change takes place in the relative proportions of the minerals. In the smaller bodies and little dikelets the grain of the aplite is finer, though it shows no contact band nor evidence of chilling. In the Butte area this is common. True, the contact between quartz monzonite and aplite is sharp, but the latter shows transition forms and even masses of quartz monzonite that are clearly not included fragments but are integral parts of the mass. Yet the separation of the two rocks is commonly definite and it is certain that no mixing of the two materials due to convection or movement before consolidation has taken place.

In most aplite bodies the grain varies considerably from place to place; in some the rock becomes a micropegmatite, rarely a coarse pegmatite, and in some shows banding of fine and coarse grained material.

PORPHYRITIC ROCKS.

RHYOLITE PORPHYRY.

PETROGRAPHIC CHARACTER.

The rhyolite porphyry, which in other publications has been called the Modoc porphyry and is locally known by that name, occurs in dikes and wedge-shaped masses intruded in the quartz monzonite forming Anaconda Hill. It is extensively altered at the surface, and fairly fresh material is obtainable only from railroad cuttings and underground mine workings. The least-altered material has a pale-green or gray-green color and is thickly dotted with small white or cream-tinted crystals of opaque feldspar, larger but less abundant grains of quartz, and much larger pale-pink or white phenocrysts of orthoclase. Biotite grains and foils are scattered sparingly through the very dense green groundmass and in a few of the big orthoclase crystals. The large orthoclase crystals vary from half an inch to an inch in length, are mostly tabular in habit, and are more or less altered, some of them showing a vitreous center surrounded

[1] Weed, W. H., and Pirsson, L. V., Highwood Mountains of Montana: Bull. Geol. Soc. America, vol. 6, 1895, p. 406.
[2] Geology of Silver Cliff and Rosita Hills, Colo.: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, p. 329.

by a shell of opaque and altered material. More commonly they are dull and show a well-marked poikilitic structure. The smaller white phenocrysts are of feldspar and are commonly dull, opaque, and altered. Quartz is very prominent and on weathered surfaces is the only recognizable mineral. It is gray, transparent, with greasy luster, no cleavage, and splintery fracture, due to a crackled condition of the grains. The grains are mostly corroded, some of them to irregular or rounded forms, though they commonly preserve the doubly terminated pyramidal crystalline shape. All the biotite is much altered and is recognizable only in the freshest material. Epidote and pyrite are common in the material from underground workings. The groundmass is very dense and felsitic looking. In the material from the railway cuttings rectangular masses an inch or two across consist of a granular mixture of feldspar, quartz, and biotite. They apparently represent poikilitic intergrowths of quartz and feldspar, with biotite leaves, the whole resembling aplite and having the crystal form of orthoclase.

Under the microscope the rock is seen to be a rhyolite porphyry; by some it might be classed as a granite porphyry, as the groundmass is microcrystalline. It is of very uniform character in all its occurrences and is everywhere decomposed. The smaller feldspar phenocrysts are seen to be plagioclase and orthoclase, the former predominating. The groundmass consists of alkali feldspar and quartz; both feldspar and groundmass are altered, the former showing patches of sericite, especially along cleavages, and the biotite being largely altered to chlorite and iron ore. The plagioclase appears to have suffered less alteration than the orthoclase, a condition contrary to that observed in the granite. A specimen of the freshest rock obtained was analyzed by Dr. H. N. Stokes in the Survey laboratory, with the following result:

Analysis of rhyolite porphyry from Butte district.

Silica (SiO_2)	69.95	Moisture at 110° (H_2O)	0.40
Titanic acid (TiO_2)	.24	Moisture above 110° (H_2O)	.91
Alumina (Al_2O_3)	15.14	Baryta (BaO)	.13
Zirconium (ZrO_2)	.02	Strontia (SrO)	.02
Iron sesquioxide (Fe_2O_3)	.38	Phosphoric acid (P_2O_5)	.10
Iron monoxide (FeO)	.83	Sulphide of iron (FeS_2)	.39
Manganese oxide (MnO)	.08	Carbon dioxide (CO_2)	.37
Lime (CaO)	1.45	Copper (Cu)	.03
Magnesia (MgO)	.56		
Potash (K_2O)	6.36		100.06
Soda (Na_2O)	2.70		

The analysis confirms the microscopic examination and shows the rock to be a rhyolite porphyry, somewhat low in silica. Compared with the other rocks of the district the percentage of potash is rather large, being the same as that of the aplites; the percentage of soda is that common to most of the rocks of the district.

WEATHERING.

The rhyolite porphyry is well jointed and has a prevailingly smooth fracture, breaking into angular fragments, which in many places cover the ground and obscure the outcrop. Good surface exposures are, therefore, uncommon. The exposed surface is frequently brightly stained by iron oxides or is a rich umber brown. The resemblance to altered silicified granite is very great, but close inspection always shows the crystals of quartz which protrude above the weathered surface. The rock on long exposed surfaces is pitted by small rectangular centers, due to the complete removal of the smaller feldspar crystals and the biotite. In railway cuttings the rock is seen in solid masses, whose hardness is in marked contrast to the loose sandy texture of the disintegrated granite that forms the walls.

DIKES.

Rhyolite porphyry is found only in the copper area, where it forms dikes cutting the quartz monzonite of Anaconda Hill. These dikes are irregular, parallel or nearly so, have a general west-northwest direction, in many places coincident in course with the veins.

Three large intrusions of the rock are known—the Modoc, Rarus-Anaconda, and Pennsylvania dikes. The largest, the Modoc dike, is well exposed on the surface. The Rarus-Anaconda dike has not cut through to the surface in the regular way, but is recognizable in detached outcrops along a definite line a mile in length extending from the M. O. P. smelter to about west of the Anaconda shaft house. The Pennsylvania dike is recognizable on the surface by scattered débris only. All three dikes are well exposed in underground workings.

The Modoc dike is exposed both on the surface and in several railway cuttings. It is traceable from the foot slopes back of Meaderville westward to the railway line above the Modoc shaft, a distance of 3,200 feet with a vertical rise of 430 feet. The dike shows a maximum width of 210 feet in the railway cut below the Modoc mine and is 117 feet wide on the 1,000-foot level of the Modoc. The outcrop thins out westward and is about 27 feet across in the lowest exposure. Figure 4 shows a vertical section of the Modoc dike.

In the west wall of the rock cut along the main track of the Great Northern Railway the dike shows as a single intrusion 45 feet across, but in the east wall it is split into two forks, 5 and 8 feet wide, respectively, separated by 10½ feet of altered granite. This cut shows clearly that the intrusion took place in the solid granite after it had been fractured by a system of joints corresponding to those seen to-day—a system probably emphasized by later earth movements. An exposure on the East Colusa railroad cut (Pl. IV, *B*, p. 32) shows clearly

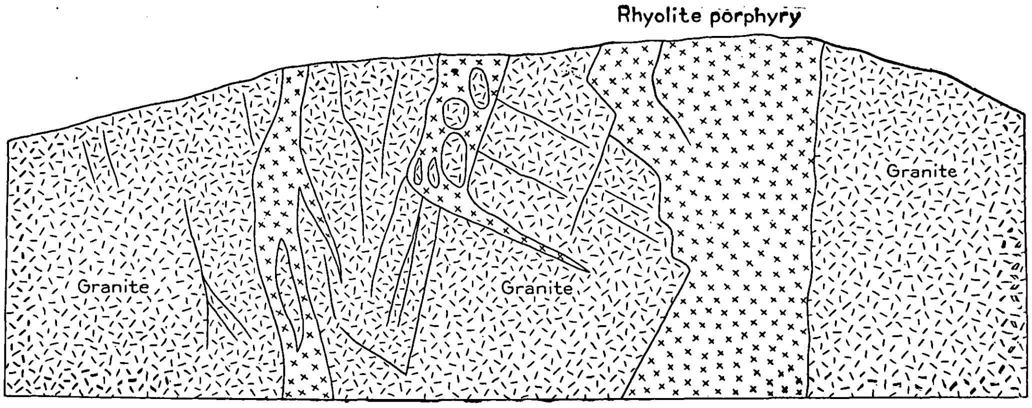


FIGURE 4.—Vertical cross section of rhyolite porphyry dike.

that the porphyry followed preexisting cracks. In a general way the contacts follow the joint fissures, but tend to widen upward, as if resistance had been less. The main body of the dike followed nearly vertical fissures, but injected stringers along planes and cross fractures. That the dike is older than the copper veins and is cut by them can be seen in the lowest railway cuttings, where a 6-inch seam of quartz, with a 3-foot decomposed zone on either side, cuts the dike, and the dike has been sheeted by the same forces that intensified the earliest fissures and was the direct cause of the vein-fracture system. (See also pp. 58–62.)

The porphyry breccia on the 1,200-foot level of the West Colusa mine on the south side line of the Modoc Extension is cut by a fault vein near the center of the Balaklava claim. This porphyry occurs not in a solid mass, but in bowlder-like and angular fragments in solid granite, which would seem to indicate that it was solid when the granite was injected.

The Modoc is the only dike having a well-defined, conspicuous outcrop. Its superior hardness causes it to weather in relief above the softer disintegrated granite, and to form the crest of a lateral spur of the Anaconda Hill on which the Modoc shaft is built.

RHYOLITE.

DISTRIBUTION AND CHARACTER.

About one-fifth of the surface of the Butte district is covered by rhyolitic rock. It is the most variable rock of the district, occurring in many colors and forms, representing the different phases which were produced from one molten rock magma under different conditions of consolidation. Two distinct varieties, distinguished by their manner of occurrence, have been mapped: (1) Intrusive rhyolite, forming the dikes and filling volcanic necks or conduits, and (2) rhyolite-dacite, an extrusive or surface type, forming lava flows and surface breccias and other products of explosive volcanic action. The boundaries are indefinite and are not always recognizable where the fragmental rocks overlap the intrusive form. Both forms are of economic interest, since the dikes intercept and cut off the ore deposits, and the surface rocks cover and conceal them.

The rhyolitic rocks are porphyritic, showing phenocrysts in a dense groundmass. The porphyritic crystals vary in abundance; in some rocks they are small and few, but commonly they are many and in places are so closely crowded as to give the rock a granular aspect. White feldspar is universally present, and biotite peppers the groundmass or appears in minute flakes, characteristic of the rocks. Quartz grains and sanidine are found in nearly all of the rocks.

Studied under the microscope the rocks are chiefly rhyolitic, but some dacites and transition forms between dacite and rhyolite are found. Though presenting strongly marked regional similarity, the rocks possess considerable diversity in groundmass, varying from microcrystalline to glassy textures, this being due to differences of origin and occurrence. Over a large part of the district they are extrusive, in part lava flows, in part the finer products of violently explosive volcanic outbursts. In other places they are intrusive dikes, resulting from injections of viscous magmas along fissures. At Big Butte both types occur in a complex of rocks filling the volcanic channel or neck of the small vent or piled up about it.

RHYOLITE-DACITE.

CHARACTER.

Extrusive rocks, consisting of rhyolitic breccias and flows, cover the northwestern part of the district, where they form the border of the great rhyolite area extending for many miles north and west of Butte. Within the Butte area they are not so varied as farther north, but are rocks of rather uniform type and appearance. They vary from massive to clearly fragmental forms of gray, pink, or yellowish color. Many of the massive forms include fragments whose differing tint and texture make them prominent on weathered surfaces. The rocks vary from dense to lithoidal forms, from those of small and scattered phenocrysts to those in which the porphyritical crystals are closely packed. The most common type shows an abundance of glassy, crackled, gray quartz grains, uniformly about 2 millimeters in diameter, together with sanidine and andesine phenocrysts, a few chloritic spots, and a dusting of biotite flakes. The phenocrysts are cracked and arranged in line showing flowage of viscous magma. The phenocrysts and crystal fragments are held in a groundmass of brown glass. In part at least the massive rocks represent lava flows in which the congealed surface portions, cracked by continued flow of the lava and mixed or kneaded in the pasty mass, make a flow breccia. The tuffaceous forms show fragments held in a well-indurated, very dense cement of similar but smaller fragments. In many places ready weathering of the fragments gives a pitted appearance to exposed surfaces of the rock.

OCCURRENCE.

The rhyolite-dacites cover large areas, but vary in thickness. Near the Nettie and other mines of the western part of the district they are locally but a few feet thick—a mere veneer upon the granite surface. In the Oro Fino Hills they are several hundred feet thick, but they rest upon a very uneven, hilly surface of granite and vary in thickness accordingly. Prominent outcrops are scarce, as the rock breaks into irregularly platy or angular fragments, few of which are a foot across, and generally forms well-rounded slopes tufted with grass. Exposures near the Nettie mine are typical; the rocks are a light rusty red and form low, rough masses not unlike débris piles. A few buttresses outcrop on the slopes north of Oro Fino Gulch.

The breccia shows a general increase in the size of the component particles toward the northwest, showing that the material was derived not from the Butte but from some unknown vent northwest of Butte.

RHYOLITIC DIKES.

CHARACTER.

The massive rock of rhyolite dikes is in few places well exposed on the surface, but the denser contact forms form many low inconspicuous reefs traceable as outcrops or débris over the smooth slopes. The main body of the dikes is similar in all the intrusions. It is white, pale cream, or pink, has a minutely rough fracture, and shows numerous phenocrysts of sanidine and plagioclase feldspar, quartz grains, and a liberal peppering of black biotite leaves. The sanidine is the most abundant, appearing as the customary square cross sections of tabular crystals; commonly these measure not over one-sixteenth inch across, though a few individuals up to one-eighth inch across, showing included biotite, occur. The gray or pale amethystine quartz occurs in rounded, corroded grains, usually slightly smaller than the sanidine. In thin section the plagioclase feldspar is seen to be andesine and the rock a typical rhyolite porphyry.

The contact forms vary in color and texture. The groundmass is most dense at the contact and less and less so away from it. Platy parting is prominent, and the biotite leaves are arranged parallel to the planes of fissility. Locally the rock is banded, dense forms, showing marked flow structure, alternating with more lithoidal varieties. Miarolitic cavities studded with sanidine, biotite, and quartz crystals appear in the rock from the south end of the east branch of the Travona dike. In general the groundmass contains fewer and smaller porphyritic crystals than the main rock of the dike. In some instances quartz appears to be entirely wanting in the contact forms, and the andesine feldspar and sanidine are present in nearly equal amount.

The following analysis of the massive rock from the Hyde Park dike was made by Dr. H. N. Stokes, of the Survey laboratory:

Analysis of rhyolite from Hyde Park dike, south of Silverbow Creek, Butte, Mont.

Silica	74.34	Soda	2.49
Titanic acid	.18	Water at 110° C.	1.11
Alumina	12.97	Barium	.07
Ferric oxide	.75	Strontium	Trace.
Ferrous oxide	.54	Phosphoric acid	.07
Manganese	Trace.	Zirconium	.05
Lime	.85		
Magnesia	.86		100.03
Potash	4.72		

This analysis shows the rock to be a normal rhyolite.

OCCURRENCE.

The dike rock breaks readily into small, generally platy débris, and it is only the denser contact form of the dike walls that offers enough resistance to weathering agencies to appear in outcrops above the general surface of the ground.

In general all the rhyolite dikes exposed have an approximately north-south trend. A few of them are directly traceable to Big Butte as a center of eruptive activity, and all of them are believed to be offshoots from this vent.

The longest dike is seen near the Nettie mine and is encountered in the mine workings. Its outcrop is obscure, but is traceable by the fine débris or in a few places by the platy contact band. The surface exposures range in width from 20 to 100 feet and extend from the rhyolite area on the north to the detrital sands and clays south of the railway track near the mine.

The Germania dike trends nearly north and south just west of the Germania mine. At the south end it is about 25 to 30 feet wide; near the north end it splits and one of its branches extends nearly to the mine shaft. It is traceable by a few obscure outcrops and by débris for nearly 4,000 feet until lost in the detrital sands of the valley.

The Soudan dike, which cuts off the vein of the Soudan mine, is the widest of the intrusions.

Dikes of rhyolite, mostly decomposed to white clay, are exposed by the placer workings west of Missoula Gulch. The Travona dike, near the Travona mine, on the east side of Missoula Gulch, has an average width of 100 feet and a general north-south direction. Southward it extends to the alluvial deposits of Silverbow Creek, and northward it terminates before reaching the Ancient vein. It is said to be cut in the Travona workings, where it has a width of 140 feet. In good exposures in the railway cuts and in prospect pits near by it has vertical walls and varies in width from 25 to 85 feet.

The Brewery dike is an irregular intrusion, with four finger-like branches running south from the main mass exposed near the Butte brewery. In the railway cut the two easternmost branches are 30 feet in width, and the granite between them is altered to clay. These branches terminate abruptly, for although 30 feet wide in one wall of the cut they do not appear on the opposite side. West of the westernmost of the two a fissure vein of brecciated material consists mainly of aplite fragments cemented together by rhyolite. The viscous rhyolite magma appears to have brought up the fragments broken from the walls. Their presence indicates that the original upper part of the dike still remains, and has been little eroded since its formation.

COMPLEX AT BIG BUTTE.

Big Butte is composed of a complex of rhyolite rocks showing a great variety of colors and textures. On the southern flank, where erosion has revealed what is very plainly a volcanic vent, the rocks are of many kinds. Pumiceous, glassy, and massive rhyolite fragments occur in a firmly indurated matrix of fine particles of the same material. Much granitic débris is also present, the fragments varying from small grains to bowlders several feet in diameter. Big Butte is formed of massive rhyolite and ejected material. Both the fragmental rocks and the massive rhyolite forming the platform to the south and underlying the butte are prevailingly dacitic in habit. To the eye they show numerous feldspar phenocrysts, abundant biotite mica, and some quartz. Thin sections show the feldspar to be mainly andesine, with a little sanidine. A little hornblende of the ordinary gray variety is accessory. The phenocrysts are cracked or broken into chips and lie crowded together in lines of flowage. The rock grades from rhyolite through rhyolite-dacite to dacite, and varies from brown and gray banded glasses and black pitchstone porphyries to lithoidal forms. The breccias containing granite and aplite fragments are the products of explosive showers; those with a glassy matrix are flow breccias. The black pitchstone is supposed to be typical of the magma, as it holds no inclusions. The following analysis of a carefully selected sample of the rock was made by Dr. H. N. Stokes in the Survey laboratory:

Analysis of porphyritic dacitic pitchstone (lassenose) from Big Butte.

Silica	67.55	Moisture below 110° C	0.38
Titanic acid	.34	Moisture above 110° C	2.76
Alumina	15.68	Zirconia	....
Ferric oxide	.98	Carbon dioxide	....
Ferrous oxide	1.02	Baryta	.11
Manganese oxide	Trace.	Strontia	.03
Lime	2.51	Phosphoric oxide	.12
Magnesia	1.11	Chlorine	.05
Potash	2.86		
Soda	4.15		99.65

Under the microscope the rock is seen to be a colorless glass thickly crowded with broken phenocrysts and smaller chips of quartz, andesine, sanidine, and biotite, with a little accessory hornblende. The andesine exceeds the sanidine in amount, thus agreeing with the analysis. In some specimens the sanidine shows indications of alkali variations by zonal structure, and the quartz phenocrysts are surrounded by coronæ of oriented quartz in the groundmass.

LAKE BEDS.

Deposits of sediment which accumulated on lake bottoms are found only in the extreme western part of the district. They consist of compact but generally unconsolidated sands, gravels, tuffs, and stony clays. The beds are horizontal, but show local cross-bedding and vary from place to place both in general character and in the nature of the material composing them. The gravel is composed of granite and aplite. The stony clays show no bedding or only such as is too rude to be recognizable in prospect shafts. The tuff beds are formed of fine rhyolitic ash, which enters also into the composition of some of the sand beds. Under the microscope this ash is seen to be a volcanic dust, the product of a volcanic explosion. It is composed of minute angular particles and threads of glass filled with tiny microlites of quartz, biotite, and feldspar, the latter arranged in keranoids. A partial chemical analysis shows 1.06 per cent lime, 14.84 per cent potash, 1.52 per cent soda, and 67.33 per cent of SiO_2; the rock is therefore rhyolitic in nature.

Lake-bed deposits form the level benches and almost flat slopes west of the district, only a small part of them occurring within its limits. Topographically the area differs markedly from the rest of the district, being the typical valley bench land so common in the State, devoid of timber, but covered by sagebrush, and from a distance looking like a burnt stubble field. Natural outcrops are poor and are seen only in the cut banks of dry channels. The material weathers down and often is recognizable only by the bare light-colored spots seen on the slopes. Near the hills the deposits form benches resting on the steep slopes. Prospect shafts sunk in these benches to depths of over 60 feet show only stony clays. The slopes of the benches show horizontally stratified gravels and sands. The gravels are generally rounded, not flat like beach shingle. The pebbles show a slightly altered surface, and some of them are lime incrusted. Locally the beds have been cemented by percolating waters carrying iron, lime, or silica in solution.

These deposits represent the material washed into a lake which covered the Silverbow Valley west of Rocker, extending south across what is now the Continental Divide. Only the extreme eastern margin and shore of this lake were within the district described, but the deposits were continuous westward and southward to places where vertebrate bones have been found. These fossils were of upper Miocene types. The evidence is of importance, as the lake beds were contemporaneous with the rhyolite eruptions, and these latter took place after the period of ore deposition, so that the age of the ores must be pre-Miocene.

ALLUVIUM.

The areas shown on the map (Pl. X, in pocket) as covered by alluvium include those parts of the district where the rock bed is concealed by a mantle of recent detritus. This includes, therefore, the alluvium of stream bottoms, the sands which cover the valley flat, whether wind blown or water laid, and the unassorted angular débris from the mountain slopes often significantly called "wash." Areas covered by tailings and other débris from the smelters are also included. These deposits are wholly detrital, are unconsolidated, and conceal the nature of the underlying rock. They vary greatly in thickness, but in general simply fill the valley bottom, as is indicated in the cross sections. In the valley east of Meaderville alluvium fills an old drainage channel to a depth of 400 feet—about 350 feet below the present channel of Silverbow Creek. The placer grounds of Missoula Gulch and South Butte have not been mapped as alluvium because the gravels are nowhere more than a few feet deep, and the workings afford numerous exposures of the underlying rocks.

VEIN OUTCROPPINGS.

Large quartz veins form a number of abrupt ridges and narrow crests rising above the general slope, and smaller veins form broken-down walls or reefs. The outcrops are composed in part of true vein quartz and in part of an altered granite indurated by secondary silica in minute veinlets and disseminated through the substance of the rocks. They are generally black with manganese oxides or rusty with iron. Such veins, though long and of great width, have not been great mineral producers. The Ancient and Czarina are the best-known and largest, forming steep ridges rising 60 to 100 feet above the general surface. (See Pl. XLI, *B*, p. 240.)

CHAPTER IV.—STRUCTURE OF BUTTE DISTRICT.

FAULTING.

MAPPING.

The faults shown on the geologic map (Pl. X) embrace only those whose existence is determinable from surface outcropping or from underground workings of the veins, since, owing to their occurrence in a single rock type, their presence can only be detected by such means. The vein fissures and sheeting planes of the rocks are in fact true fault planes, though the throw is small, often so minute as to be measured in fractions of an inch, and is determinable only when dikes of the dense white aplite afford means of measurement. The faults mapped are, however, those having a throw of many feet. They displace both copper and silver veins have a general north and south direction. Their occurrence is described later (pp. 58–64).

CONTINENTAL FAULT.

PHYSIOGRAPHIC CHANGES.

The chief mineral-producing area, embracing the hills and slopes of the Butte district proper, is bounded on the east by a depression 1 to 3 miles wide—an arm of the open and nearly level basin lying south of Butte known as the Flat. Beyond rises the precipitous granite wall of East Ridge (Rampart Mountain), sharply delimiting the Butte area from the general mountain tract of which it is geologically but not topographically a part. Mountain wall and depression are equally noteworthy, for both are believed to have originated from the great Continental fault and other fractures, which not only determined the dominant features of the present topography but perhaps had also a profound influence on the economy of the ore deposits.

It is believed that the drainage of Elk Park, which lies east of East Ridge, was formerly westward into the present course of Silverbow Creek, the present Flat being a valley in which several tributary streams gathered, the combined drainage flowing through a canyon to the Silverbow Valley. This simple system of drainage, with the appropriate topography developed by it, was completely changed by post-Tertiary faulting which developed along a line that now marks the base of East Ridge, producing parallel and closely spaced fractures. This faulting uplifted and tilted the area on the east, and depressed that on the west to a thousand or more feet below its former level, leaving the scarp of the mountain wall to mark the line of fracture. The drainage of Elk Park and vicinity was reversed so as to flow north and east to Boulder River; and the Flat, deprived of the Elk Park drainage and so depressed that its streams had little carrying power, was filled up and leveled off with the waste from the surrounding slopes and from East Ridge.

EVIDENCE OF THE FAULT.

The evidence supporting this hypothesis is triple, being derived (1) from the Elk Park drainage; (2) from the condition of the Flat; and (3) from the mountain.

EVIDENCE FROM ELK PARK DRAINAGE.

Elk Park is a mountain valley filled with waste. It shows by the arrangement of its tributary streams and their gorges, as well as by its own slope, that its drainage has been reversed and now drains to the north instead of to the south. The general map (Pl. I) shows this very clearly.

EVIDENCE FROM THE FLAT.

The Flat, south of Butte, can not have originated from any normal drainage development. Its present drainage is not only insignificant, but its watershed is too small to account for the erosion of its basin even were the rainfall augmented a hundredfold, and its slope is too gentle to afford a run-off or to give carrying power to the streams. The general arrangement of the drainage courses (Pl. I) shows that Silverbow Creek is a trunk stream beheaded of its branches, like a tree whose bushy top has been broken off, leaving only the trunk and a few lower branches. The natural exposures on the Flat and the conditions revealed in well sinking show that the valley is filled to an unknown depth with gravelly waste from the surrounding granite areas. This material is not of lacustrine origin, and there is no evidence of a permanent body of water having been retained in the basin; it is of the nature of "wash" and was evidently derived from the waste of adjacent slopes, a process still actively going on to-day. That the absence of rock in place is actual was proved by a careful examination of every place on the Flat where stream cutting or low valley bluffs showed exposures. In each case the material seen was not of rock disintegrated in place, but sand (of granitic disintegration) partly brought and arranged by stream action but being mostly flood or rain wash. The slopes immediately above the valley show rock in places beneath a few inches of sandy débris. With every rain the small gulches from the ridges bring down large quantities of this sandy material and spread it out along the base of the slopes in great flat cones, which ultimately coalesce and make a uniform valley sheet.

The unusual and abnormal depth of wash immediately west of the supposed fault line is itself valid evidence of the faulting movement.

The extension of the Flat northward, west of East Ridge, has been extensively prospected by tunnels, cuts, and shafts. Between the rocky slopes of East Ridge and the granite gorge of Silverbow Creek above Meaderville a depression filled with "wash" or waste has been found, which may be either a filled valley or a brecciated mass making a part of the fault zone.

EVIDENCE FROM EAST RIDGE.

The condition of the East Ridge wall itself shows that it owes its origin to faulting and that such movement has been repeated at relatively recent times. As the rocks are granitic, and as the supposed faulting involves a displacement of 1,000 feet or more, the observed facts will be given in considerable detail.

The long bold wall of the Continental Divide, which forms the eastern boundary of the Flat, is scored by sharply incised gulches that lie between and define numerous sharp buttress ridges or lateral spurs. These gulches, though scarcely large enough to be shown on the map, necessitate many high trestles along the Northern Pacific track. The steep lateral spurs between them are all notched in profile, markedly so between Park and Horse canyons. The notching, which abruptly cuts gentle depressions into steeply westward facing ridges, can not be accounted for hydrographically. The streams which cut back into the mountain are small and relatively insignificant, and in any event stream cutting alone could not form these features.

The most prominent notch, known as the White Notch, is about 6 miles from Butte. It is a broad white gash or scar that is very prominent upon the darker wooded mountain side. It is certainly not due to normal erosion and is not a wind gap, for no drainage could form this notch and the knob seen in front of it. The adjacent gulch is no wider than the others spanned by the trestles of the Northern Pacific track, but it is filled by a large stream of clear cold water that dashes through a rocky channel, among angular blocks of rock that all but conceal it. The bases of the slopes show disintegrated granite, the hollows being sand filled. Above a milk ranch that is situated conveniently near the stream is a small ridge covered with great bowlders, the largest 8 feet in diameter, of light-gray granite in place. This is the normal granite of the region. The rock blasted out in building the trestle is, in contrast to this, a light-gray rock, decidedly more acidic in character, resembling the semiaplitic forms of Butte. Above the trestle this rock, which extends as far as the summit of White Notch, shows gray streaks and smears. It contains a large amount, about 33 per cent, of white aplite grading into pegmatite.

Up the gulch the rocks are marked by pronounced parallel sheeting of the granite. The fissures are not close enough together to make the rock platy and are sufficiently far apart to form great blocks, which where overturned make immense monoliths. The direction of the fissure planes appears to be nearly parallel to the ridge. The crushed rock in the fissures here is the source of the water that issues in copious springs from the lower part of the notch.

White Notch itself lies transverse to the gulch and to the normal drainage. Its lower slope is steplike and consists entirely of débris, not rock altered in place, for it is most unlike the great plates of granite that rise in walls on the west and almost as abruptly on the east. Its upper slope is gentle, showing much sand and a crumbly disintegrated gray granite near the top. At the top the depression in the ridge is less prominent when examined closely than it is from a distance, and its surface can not be more than 100 feet below the top of the knob to the west. A second parallel fault slope appears higher up the mountain.

The most pertinent feature observed from this notch is the persistent, similar, though somewhat less striking, notching of each of the large buttresses between it and Horse Canyon.

If, as is believed, this notching is due to faults, it is apparent that the mountain wall is not formed by one fault, for the lines traceable by the notches are many, parallel, and overlapping, but is the result of a steplike succession of short parallel faults, to which the sheeting of the granite conforms.

The flat-topped ridge north of Columbia Garden shows a dike of rhyolite porphyry, cut by numerous faults whose displacement can be measured and whose attitude makes apparent the step-fault character of the displacement which separates the copper area of Butte from the vein area of East Ridge. The dike, which is traceable for about 3,000 feet, trends N. 45° E. on the west side of the ridge and N. 80° E. on the east side. It is faulted at least seven times, four times to the north and three times to the south. The displacement varies from 20 to 400 feet and the distance between faults from 500 to 600 feet.

Another large dike of the rhyolite porphyry, 75 to 120 feet wide, outcrops in East Ridge about 700 feet west of the portal of the Great Northern tunnel. It runs N. 75° E. to the summit of the mountain, corresponding to the dike seen in the railroad cut on the Continental Divide (Pl. I); but the latter is faulted and the two dikes do not line up. The dike in the railroad cut is 60 feet wide and trends N. 80° E.; its displacement is due to the great north-south fault which runs along the west side of Elk Park.

The fault, which is recognizable in the White Notch and which forms the saddles back of the foothill knobs, has a general north-south course and is the cause of the abrupt separation between the flat and the mountain. At the Bertha and Bullwhacker mines this fault, or a sympathetic fracture parallel to it, is from 50 to 100 feet wide and is mineralized by chrysocolla and other oxidized ores which are mined on the claims mentioned. The workings at these claims and on the Montgomery claim show that this fault is itself displaced by east-west fissures, so that this continental fault system is not the latest phase in the faulting of the region.

SUMMARY.

The facts may be summed up as follows: (1) The chain of detached knobs along the west slope of the East Ridge are not of ordinary erosion types. The White Notch is only explainable by faulting; (2) brecciation with slickensides has been noticed at several localities along the fault zones; (3) the reversed watercourses of the Elk Park Valley show a tilting of the region toward the north. The drainages have not been stolen by Boulder drainage, for the eastward-flowing stream, Bishop Creek, is relatively sluggish and meandering and does not begin actively to cut its channel until the north end of Elk Park is reached.

The faulting of the East Ridge with actual as well as relative uplifting seems the only reasonable explanation. The Butte area is actually as well as relatively thrown down and the flat is produced by the débris filling up the valley. The fault is not single, but is a succession of parallel faults, with overlapping ends, which probably split and branch out. This arrangement carries one of the fault lines directly to Meaderville and may have an important bearing upon the relationship of the veins and the vein faulting.

The evidence thus outlined seems to indicate the comparatively recent faulting of the region and may account for the absence of any rock in place in the surface of the Flat.

PRESENT-DAY FAULTING.

That faulting is taking place at the present time has been conclusively proved by comparisons of bench marks and lines of precise leveling. For many years there have been breaks in the water and gas pipes in certain sections of Butte, cracking in the walls of houses, and occasionally the formation of gaping fissures in the streets. As such displacements are frequent and troublesome in the vicinity of mine workings, little was at first thought of these occurrences. Later, however, it was remarked that there were no workings under the place where repeated breaks in the water pipes had occurred. Attention was also drawn to the peculiar and apparently recent fault scar or notch on East Ridge (p. 48). These facts led to the investigation.

Study at the Boulder Hot Springs showed that slight faulting and reopening of the veins formed and forming by these springs had taken place, so that it is probable that crustal adjustment is taking place throughout the region and is not confined to Butte.

To determine the amount of change taking place in the levels of different portions of the Butte district, as a result of faulting movements now in progress, a series of carefully determined bench marks were established in Butte and in the neighboring mountains. Bench marks had already been established throughout the district as a result of the topographical survey made in 1895 and 1896, but there having been considerable change in the levels, spirit leveling was undertaken again in October, 1904, by R. H. Chapman, United States topographer, every precaution being taken to make the work as accurate as possible. This work resulted in the establishment of many bench marks, which will make it possible in the future to determine, by means of releveling, the amount of surface movement in and about the city of Butte.[1]

Sixteen standard bench marks were left in the city of Butte and seven additional ones in adjacent regions. Most of the lines were run two or three times; a large circuit of about 12 miles was run and checked and was tied to the bench marks of the work of 1896 at Elk Park Pass (Woodville Summit). In the first week of the work an old Gurley 22-inch level was used, but owing to the difficulty in keeping this instrument in adjustment, a new Berger level was substituted and used till the end of the work. The rod used was of the New York type, and was found to be without appreciable error when tested by the Bureau of Standards. The levels showed considerable change in the bench mark at the city courthouse, and as this bench mark was the standard for all reference in 1896, all the elevations of the other bench marks were reestablished.

Bench marks were established from the Flat south of Silverbow Creek, at a point near the foot of Timber Butte, to one on the Walkerville Ridge, thus crossing the undermined area from south to north. A second line was run from Meaderville toward the Big Butte, which gave an east and west control.

In 1906 the Coast and Geodetic Survey brought a line of precise levels from the southwest (Pocatello, Idaho), and tied to nine of the benches of 1904. Though this work is not finally adjusted it is improbable that any changes will be made which will affect the relative elevations of the Butte benches. If the bench mark at the Butte Reduction Works be taken as a datum, the relative changes northward are as follows:

Relative changes in elevations of bench marks north from Butte Reduction Works.

	Foot.
1. Butte Reduction Works	0.000
2. Webster School	.017
3. Colorado State school	.051
4. Owsley Block	.436
5. Courthouse	.737
6. Government building	.888

[1] In this work the following precautions were observed: First, the instruments were examined for all adjustments every morning; second, equal length of foresights and backsights was, with very few exceptions, always used; third, the instrument was shaded from the sun and the bubble was under the constant scrutiny of a bubble tender; fourth, the rod used was kept in position by a level to insure verticality; fifth, the turning points were usually on steel pins, but when running on paved streets 20-penny nails were driven between paving blocks. When running on railroad tracks two turning pins were used, one of determined elevation being always in the ground.

This shows an increasing subsidence as the benches approach extensive underground workings.

A comparison in a northeasterly direction from the same datum shows:

Relative changes in elevations of bench marks northeast from Butte Reduction Works.

	Foot.
1. Butte Reduction Works	0.000
2. South Butte	.051
3. Braund House	.130
4. Florence Hotel	.791
5. Government building	.888

These figures show subsidence in the two years from 1904 to 1906, as follows:

Subsidence in Butte from 1904 to 1906.

	Foot.	
Actual subsidence:		
Owsley Block	0.218	per annum.
Courthouse	.368	
Government building	.444	
Differential subsidence:		
Owsley Block and courthouse	.150	
Courthouse and Government building	.076	
Owsley Block and Government building	.226	

In making comparisons between the levels of 1896 and 1899 and those of 1904 the results can not be accepted so confidently as the later figures, but it is found that between 1896 and 1904 the courthouse sank 0.895 foot, or 0.112 foot a year, more than the Owsley Block, though the latter must have sunk appreciably during that time. The actual subsidence of the courthouse between 1896 and 1906 was undoubtedly as much as 1.632 feet, or 0.163 feet per year. Probably this is made up of a constant slow sinking and of spasmodic greater movements.

In 1904 a circuit was run which crossed the great structural fault of the mountains east of Butte, and a bench mark was established in Elk Park Pass, which is probably east of this fault line. By combining the work of 1896–1899 and comparing it with that of 1906 it appears that the difference in elevation between the bench marks at the Owsley Block and Elk Park Pass was 663.161 feet in 1896 and 663.839 feet in 1904, showing in eight years a change of 0.678 foot, which is mostly accounted for by the sinking of the Owsley Block. By indirect comparison of the Owsley Block with a point to the west of it through a combination of the work of 1896 and 1899 and the application of a subsidence correction it is found that the Owsley Block has sunk 0.551 foot; the difference between this and the 0.678 foot obtained by comparison with the Elk Park bench is 0.127 foot, which may be assigned to possible movement on the fault plane in eight years. This figure, however, is of very doubtful value and can not be accepted except in a preliminary way. However, it indicates possible changes of such magnitude as to renew interest and affords a basis for more complete comparisons in the future.

STRUCTURAL RELATIONS OF THE ROCKS.

GENERAL RELATIONS.

The relations of the rocks to each other are of much economic importance. The oldest rock, the Butte quartz monzonite, is cut by dikes and overlain by or interleaved with lenses and broad though shallow masses of aplite. This latter phase of the aplite, however, appears to be a mere local segregation out of the mass of Butte quartz monzonite.

These relations are shown in the structure sections. The presence of much aplite in the deep underground workings, as, for example, on the 2,100-foot level of the High Ore mine, shows that the rock is not of superficial origin and is not confined to the outer borders of the mass. In fact, it was found impossible to map all the aplite found in the East Ridge region, owing to the transition of one rock into another. This is less marked underground than at the surface.

The rhyolite porphyry, so far as seen, is everywhere intrusive and later than the granitic rocks. Ball-like masses of this rock in the granite have been reported, but in the light of the relations shown in Plate II, *B* (p. 26), their occurrence seems hard to explain. The rock occurs both in the productive area and in the East Ridge as dikes cutting cleanly through granite, older than the vein, and dislocated by cross faults.

Nothing is known of the downward extension of the granite. It is probably very great, as the rock is an integral part of the great intrusive Boulder batholith.

The extrusive rhyolites blanket a large part of the silver area. A few veins worked on the border of the rhyolite have been followed beneath it by underground workings, but in general this part of the district is unexplored. Rich secondary ores, if present there, must be older than the rhyolite, which now prevents the access of oxidizing waters to the veins. The rhyolite dikes and the intrusive rock of Big Butte cut through the granites and mineral veins alike, but do not displace them. They appear to be the filling of fissures suddenly opened and filled and have no bearing upon the ore deposits save to interrupt their continuity.

The lake beds mantle all the older rocks and fill the depressions west of Butte to varying depths. The veins have not been unfavorably affected by their presence, and it is possible that future exploration may develop extensive mineral deposits in this area.

The alluvium and wash which cover the Flat are simply the filling of an old valley. The depth varies from place to place, reaching 400 feet at several points. The underlying rocks are decomposed granite carrying mineral veins in which rich copper ores occur (at the Pittsmont mines).

The evidences of recent hot-spring action in the Butte district are confined to the Oro Fino area, but the study of the Boulder Hot Springs, where quartz veins are now forming and the thermal waters are altering the rocks precisely as they are altered about the copper veins of Butte, indicates that the vein formation may in part be the result of hot-spring action. At Crystal Springs, 7 miles west of Butte, warm waters are still flowing. These springs and those of Boulder are deficient in hot-spring sinters, so that when dead the only evidence that they once existed lies in the rock alteration.

GRANITE AREA.

GENERAL FEATURES.

In a general view of the district from the east the abrupt slopes above Meaderville and the featureless floor of the Flat are strongly contrasted.

The granite area is an uneven plateau, presenting steep slopes to the south and east. Above Walkerville the plateau character is very marked, forming the highest part of the district and being preserved in the flat-topped spur which terminates in Anaconda Hill. Westward the surface is less regular, being scored by Oro Fino Gulch and its branches. A corresponding, somewhat lower, plateau lies south of Silverbow Creek. Throughout the district the granite is constant in character and composition (pp. 31–36). The surface is, however, varied in aspect, for the colors of the altered rock and the peculiarities of weathering are very unlike in different parts of the district. In the tract northeast of Walkerville the surface is covered by immense bowlders, monoliths, and castellated outcrops, due to the fissuring of the granite. In the Oro Fino Gulch area reefs or ridges formed by quartz veins are the only outcrops, but brilliantly colored débris, which looks very unlike the altered granite, is common in the many prospect pits that dot the slopes. In most of the granite areas about the producing mines a few bowlder outcrops occur, but the surface is mostly rounded and covered by the angular sand of disintegrated granite.

The differing features of the granite area are due to (1) jointing, (2) disintegration, and (3) decomposition; and as the effects of these agencies are most marked in the granitic rocks and produce the characteristic features of this district, they may be appropriately discussed here.

JOINTING.

The massive rocks all show fissuring, which is, however, most prominent in the granitic rocks. In the more intensely mineralized areas the joints are close together, but, owing to the general disintegration and alteration, they are prominent only on the exposed walls of artificial excavations, being especially so where they are occupied by quartz veinlets or stained with iron rust. In areas where the joints are less numerous, as above Walkerville and north of Meaderville, in the northeastern part of the district, the development of well-marked fissure systems splits the Butte quartz monzonite into very rugged and picturesque clusters of bowlders and monoliths. The jointing is prominent over a considerable area, but is not uniform, differing greatly in spacing and number of the fissures. (See fig. 5.)

The vertical joints belong to two sets running at right angles to each other, but one set, that corresponding in direction to the prevailing vein system, is best developed. The fissures may be seen in the railway cuttings, where they give the rock a sheeted appearance. In natural exposures they form great blocks whose surfaces are frequently as smooth as if sawn across. Plate V, *A*, shows fissured rocks, in part weathered to rounded bowlders, along the line of the Great Northern Railway near Meaderville.

Locally the nearly vertical joints are marked by slickensides, much of their surface showing an indurated crust or film and some of it a thin clayey coating. Some of them are clearly fault

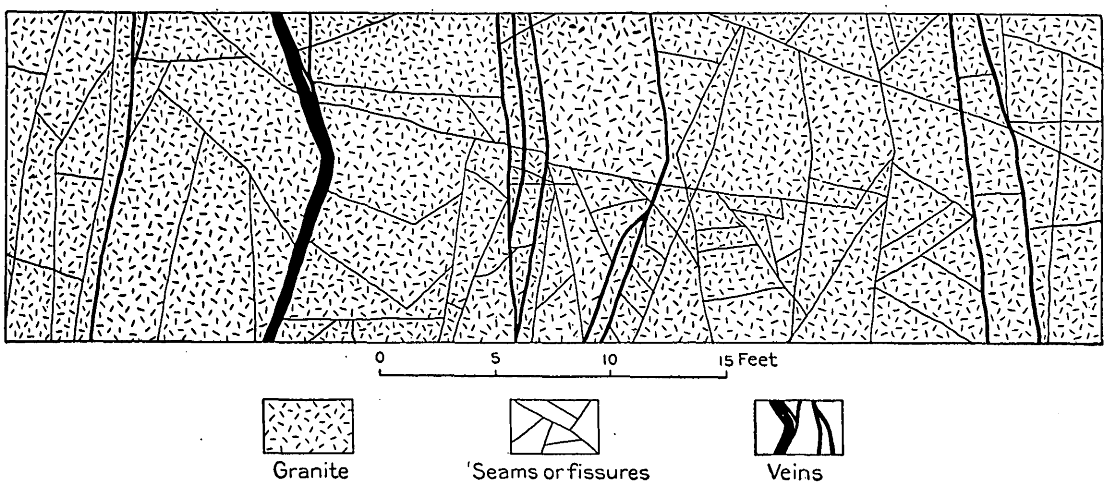


FIGURE 5.—Joints in shattered granite, 500-foot level of Leonard mine.

fissures, but the throw of these faults is slight and is measurable only where the Butte quartz monzonite is traversed by dikelets of the white aplite.[1] Where noted the throw was less than a foot, the downthrow being to the south.

Becker[2] has shown that such fissure systems may result from simple horizontal thrust. It is believed that the later fissuring was not confined to movement or renewed fracturing along preexisting lines, for the rhyolite porphyry is sheeted and the veins, which in part coincide in direction with the dikes of this rock, cross the dikes.

DISINTEGRATION.

Disintegration of the quartz monzonite, as shown elsewhere (p. 86) by analyses, is accompanied by almost no chemical change. It consists of a physical change in the rock due to heating, chilling, and the action of the wind, and results in a loosening of the grains, a so-called "rotting" of the solid rock into material which may be easily crumbled between the fingers. On rocky outcrops the surface scales off and the detached plates crumble to loose angular sand, which is blown away by heavy winds. Where the rock is netted with small fissures, as it is over

[1] Becker, G. F., Structure of the Sierra Nevada: Bull. Geol. Soc. America, vol. 2, p. 53. [2] Op. cit.

much of the district, disintegration is hastened and the granite is changed, in places to a depth of 20 feet or more, to a soft material easily excavated with pick and shovel.

Exposures in railway cuttings and in excavations for buildings show why rock outcrops and the bowlder masses are absent over so much of the Butte district. Commonly the granite is intersected by a network of fissures. Sheeting, as observed in the area north of Meaderville, is apparent in all the more prominent fissures, and the space between is netted with smaller cross fractures, which separate the rock into polyhedral fragments. These lesser fractures are commonly marked by iron rust, a few by minute stringers of quartz, and it is apparent that they have been planes along which percolating waters have altered the rocks. This relatively minute fissuring having facilitated disintegration as well as true rock decay, the rock is commonly rather loose and crumbly and yields readily to frost and wind and rain. The condition of the rock seems to result from close sheeting and from the development of the fissures noted in the less mineralized area with short connecting cross fractures. Typical reticulating of the granite by rusty veinlets and seamings is shown in a wall exposed in digging the foundation for a church at Butte (Pl. IV, *A*, p. 32). In some places, especially on Anaconda Hill, the granite appears shattered by these fractures. Where the upper parts of the big veins are exposed they show no mineralization, but are zones of decomposed claylike material and partly altered pyrite-holding granite.

The rate of the degradation of the granite surface is largely dependent upon the fissuring of the rocks. When the fissures are close together, disintegration is rapid, the blocks, being small, are rapidly worn away and the surface becomes smooth, with scattered bowlders. Where fissuring is less close, the rocks weather into great blocks. As disintegration proceeds the outcrop becomes a mass of isolated or partly detached blocks, and the area of exposed surface being thus increased, these are soon reduced to spherical masses.

DECOMPOSITION.

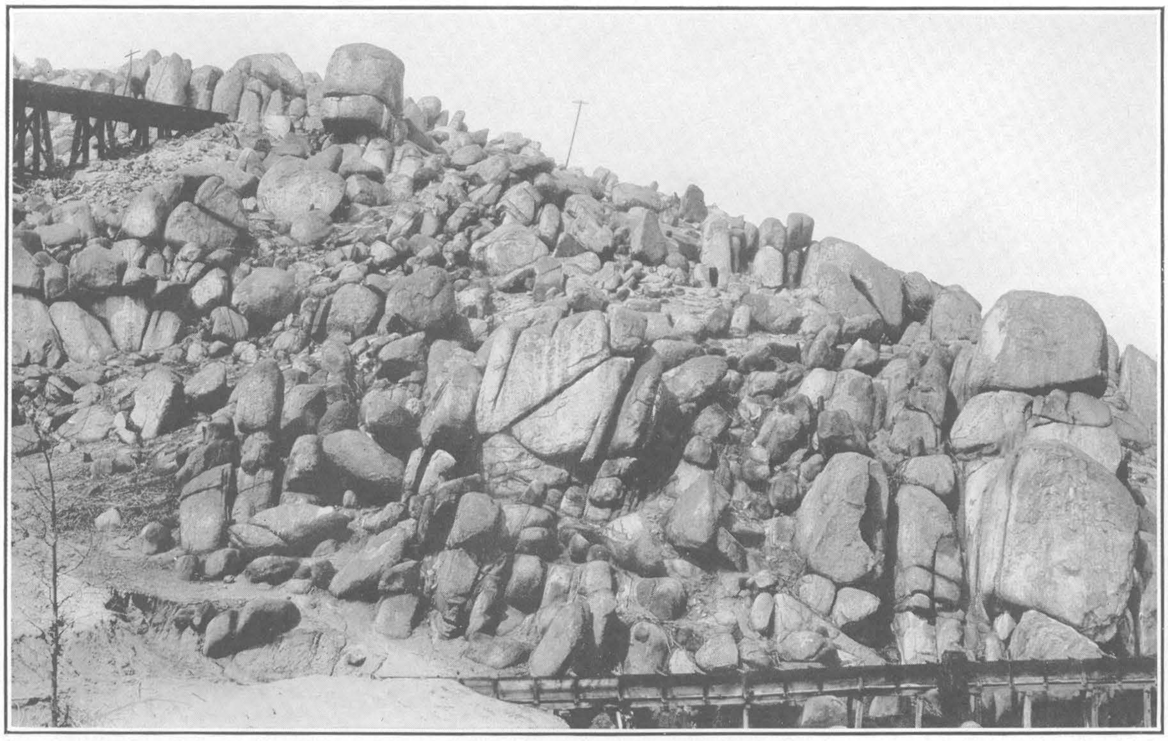
Where the disintegrated material is not removed as rapidly as formed, a condition prevailing over a large part of the Butte district, where the work of wind and rain can not keep pace with the secular disintegration, the rock is changed in place to a more or less coherent material containing spherical nuclei of the unaltered rock surrounded by shells of progressively more and more loosened material. This action may be seen along the Northern Pacific Railway line south of the city; for instance, in a rock cut near the Homestake tunnel. (See Pl. V, *B*.)

At the top of the cut, platy masses and bowlders of granite—harder residual masses left in relief by the removal of the loosened granite about them—rise above a gently sloping grassy surface. Lower down the bowlders are surrounded by concentric shells and the loose sandy disintegrated granite. The kernels of the bowlders are hard and resistant, the shells are more or less crumbly, and the interspace is so soft as to be easily removed with pick and shovel. These bowlders are undoubtedly a result of fissuring and not a ball or spherical structure of the rock.

Underground, rock alteration, the result of vein waters, forms similar bowlders out from the fissured granite. Plate VI, *A*, shows the granite of the north crosscut on the 800-foot level Gagnon mine closely netted by fissures, along which the polyhedral masses have been altered to rounded bowlder forms. The zonal character of the decomposition, which the iron oxide makes so prominent, shows that the bowlders are due to alteration proceeding from the fissures.

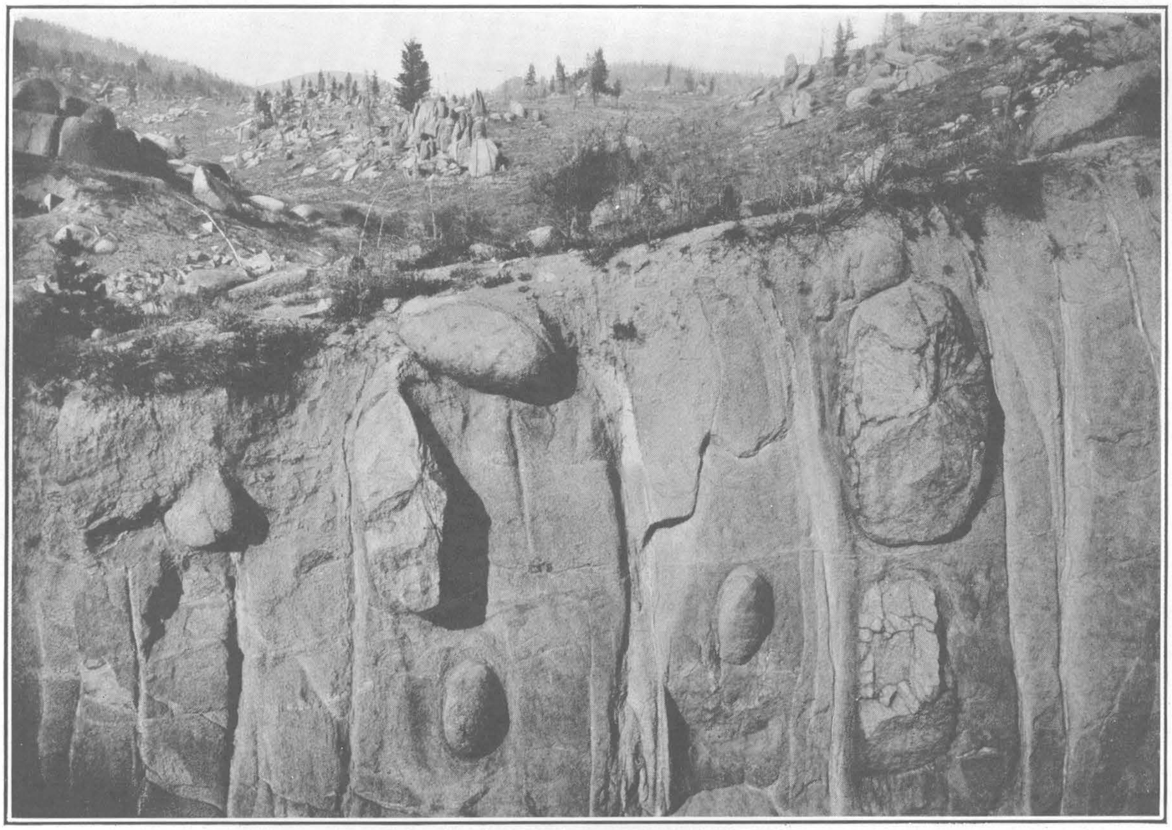
The prevalence of extensive disintegration accounts also for the lack of outcrops. In the absence of protecting vegetation erosion of the loose rock is rapid, and the drainage channels are choked with sand. The porous crust of the granite absorbs water readily and assists in the further disintegration of the rocks.

Throughout the productive area the rocks show few outcrops, the surface being either smooth and rounded, covered by granitic sand, or near the veins strewn with rusty silicified rock in fragments 1 to 4 inches across. Anaconda Hill shows neither granitic bowlders nor prominent vein outcrops.



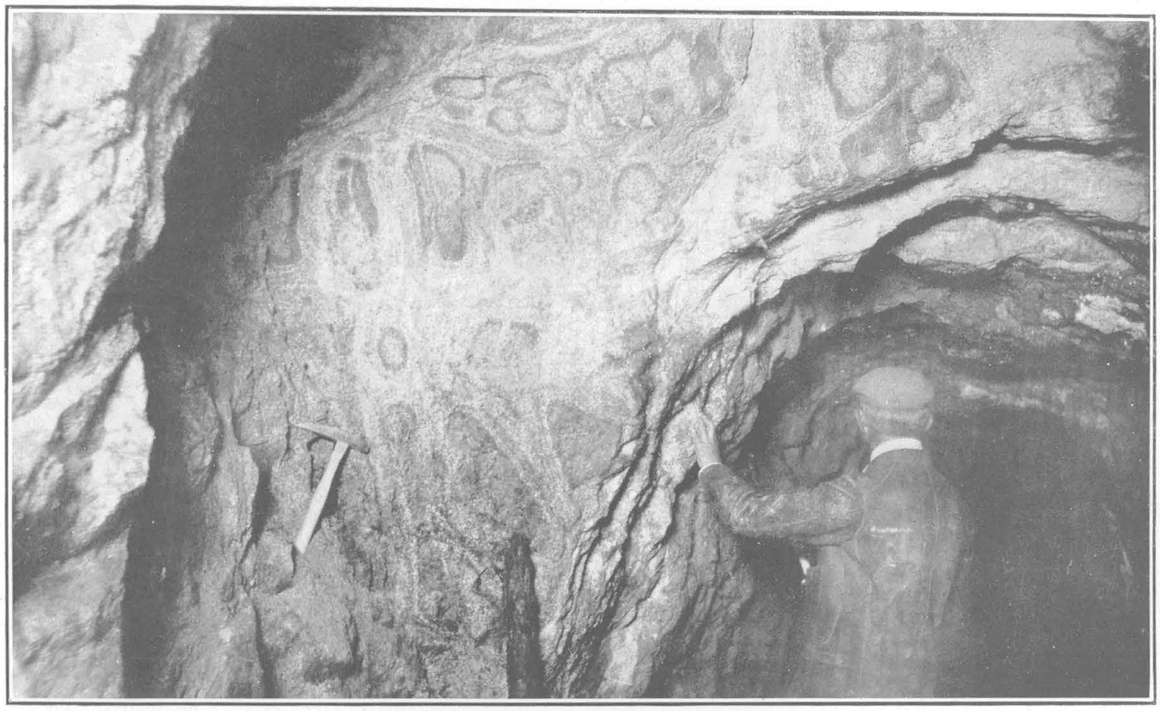
A. SHEETED GRANITE NORTH OF MEADERVILLE, ALONG GREAT NORTHERN RAILWAY.

Shows weathering along joint planes, some of which are mineralized and form veins. See page 53.



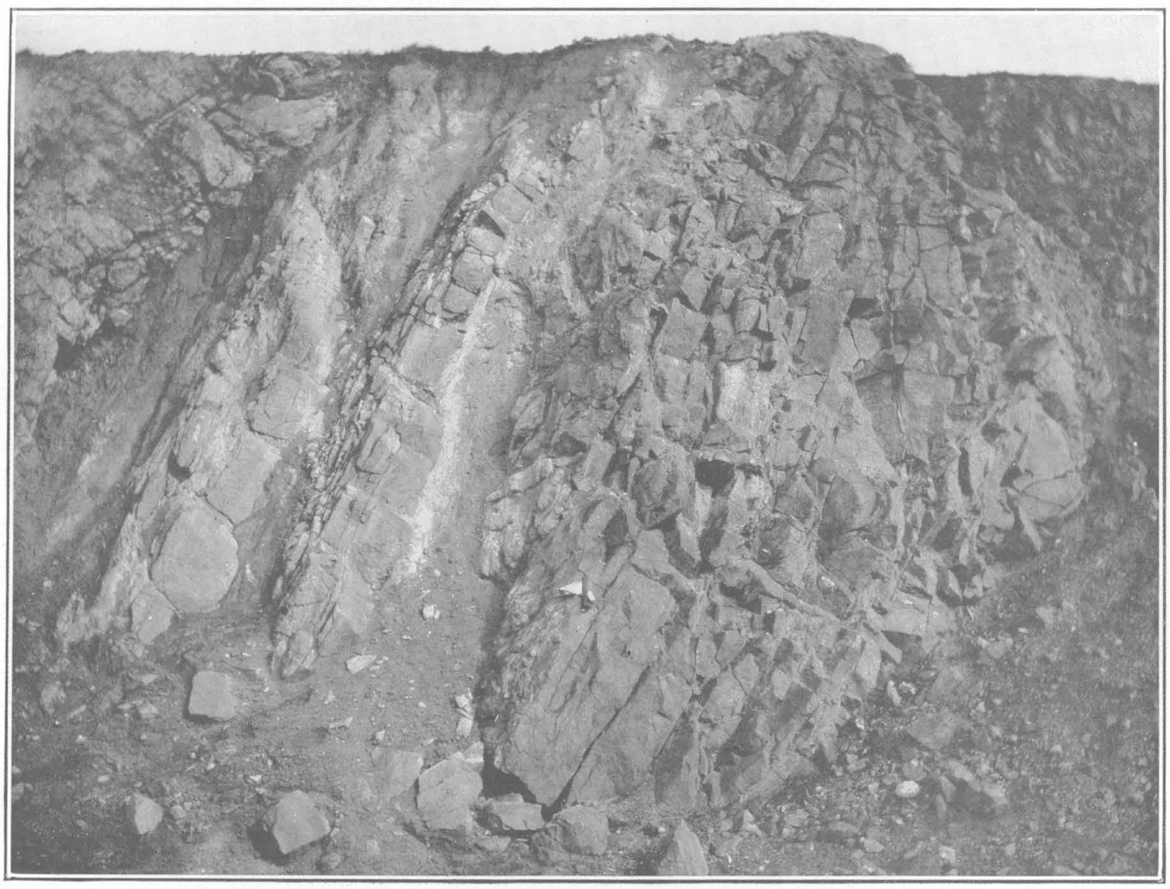
B. DISINTEGRATION BOWLDERS, IN PLACE, SURROUNDED BY SOFT SANDY DISINTEGRATED GRANITE.

Shows manner of formation of the bowlders and their relation to sheeting planes of the granite. Railway cut at west portal to Homestake tunnel, east of Butte, on Northern Pacific Railway.



A. DECOMPOSITION BOWLDERS FORMED BY VEIN-MAKING AGENCIES IN GRANITE.

North crosscut, 800-foot level, Gagnon mine.



B. VEIN OUTCROP NEAR BELL MINE IN GREAT NORTHERN RAILWAY CUT.

Shows clay slip cutting through granite altered by network of joint planes. The clay slip is faulted by a second fissure, seen on the left-hand side. See page 61.

EAST RIDGE.

The East Ridge area, though often spoken of as part of the Butte district, is distinct topographically and geologically, and though it contains copper-bearing silver veins they differ from those of the productive area of Butte. Topographically the locality consists of the long and steep mountain ridge which forms the Continental Divide, broken by the pass to Elk Park, but otherwise continuous, separated from the Butte district proper by the broad, nearly level expanse called the Flat.

Geologically this area consists of granitic rocks similar to those at Butte, but they are traversed by the so-called continental fault and other fractures, the term being popularly used to include a group of faults which combined have caused a difference in elevation of about 1,200 feet between the floor of Elk Park and that of the Flat. The rocks are similar on both sides of the fault, but they show local and important peculiarities and the veins are dissimilar. Two dikes of the rhyolite porphyry give in places conclusive evidence of the character and extent of the faulting, but unfortunately they can not be traced continuously. Clear evidence of this faulting is also shown by the topography, the foothill knobs and saddles, such as the flat-topped bench on which the ball grounds are located back of Columbia Garden, and the peculiarly isolated hillocks whose slopes make the portal of the gulch in which the gardens are situated.

In general the rocks of the East Ridge show an unusual development of aplite, with transitions to pegmatite on one hand and to Butte quartz monzonite on the other. This is so marked that the attempt to map the areas of aplite separately from the Butte quartz monzonite was abandoned after much time had been spent on the work. The surface in the vicinity of the Altona and Montgomery mines shows much quartz, which has led to much useless prospecting but which mining development proves to be local and due to patches of aplitic material passing into quartz and not to quartz veins. It is the "blout" of Lawson.[1] As shown by underground work, this quartz is not confined to the surface but occurs at depths of 200 to 300 feet; moreover, the present surface is elevated by faulting and represents a depth of 1,000 feet or more below what was the former surface. Study of the exposures, surface and underground, shows that the quartz is an extreme differentiation of the Butte quartz monzonite.

Another interesting feature of this part of the district is the rather basic character of the granite found associated with the quartz, aplite, and quartz monzonite just mentioned, at the Montgomery, Altona, Amazon, and vicinity. The granite when freshest contains an unusual amount of ferromagnesian minerals and a considerable amount of chalcopyrite, so much, in fact, that the rock often holds 0.75 to 1 per cent copper. The associated acidic rock is more or less sericitized and impregnated with scales and veinlets of molybdenite. The basic form is neither unaltered nor decomposed, but the basic minerals are still fairly fresh. The pyritization which prevails so generally throughout the copper district is wanting. The chalcopyrite has weathered, and oxidized copper ores are common in the zone of weathered rock, but there is no chalcocite zone and no glance except where veins are cut.

The veins of the foothills region include quartz-filled fissures with a general east-west course, and north-south fault fissures cutting and displacing the quartz veins.

The veins on the higher slopes of the mountain, east of the continental fault, are typical quartz-filled fissure veins carrying the usual ore and gangue minerals characteristic of the Butte silver veins, and in some cases notable quantities of copper glance. The quartz is usually glassy, coarsely crystalline or comby, and the veins show frequent vugs and long, narrow crystal-lined spaces in the middle. The rocks show sericitization, but in much smaller areas than across the Flat.

The flat benches lying behind what have been termed the foothill knobs, and the intervening ground along the line connecting these saddles, show no exposures; and frequent prospect pits show that they are underlain, not by solid rock but only by a mass of fine rock fragments. The benches evidently overlie a "crush" zone. To the north, near the limit of the

[1] Lawson, A. C., Copper deposits of the Robinson mining district, Nevada: Bull. Dept. Geology Univ. California, vol. 4, 1906, p. 324.

area shown on the map, a cut excavated in the lower slopes by a steam shovel shows only crushed rock and sand, although the bowlders and quartz veins of the mountain slope lie immediately alongside.

BIG BUTTE.

The most prominent single topographic feature of the district is a sharply conical hill that rises abruptly from the rather gently rounded slopes west of the city. This hill (Pl. II, *A*, p. 26), which has given the name to the city and district, is known as Big Butte.

Big Butte is of complex structure, which the simple representation on the geologic map does not express. In the structure sections an attempt to show its nature has been made, but it is impossible to do this fully on any single plane. Instead of a single mass of rhyolite cutting up through the granite or spreading over it as a flow, there are a number of bodies of massive rhyolites associated with predominating rhyolite tuffs, with brecciated (autoclastic) rhyolites, and with agglomerates. These relationships are far too complicated for expression on the map (Pl. X), and the narrow exposures do not afford sufficient data for the purpose.

The rocks of this hill are extremely variable in nature and in their relations to one another. In part they probably represent the filling of a typical volcanic vent and in part the remains of a volcanic cone, consisting of both breccias and massive intrusive forms. (See also p. 45.) Both surface and intrusive forms of the same rocks therefore occur in intimate association and in great variety of colors and texture.

The light-gray rock capping the butte resembles a lava flow, having a rough, irregular fracture with pale-buff streakings, emphasized by a ribbed surface where weathered.

The intrusives are very like the dike rocks; they are generally gray and like the fragments in the breccia described below.

The breccias are two—those found in the vent and those found outside of it. The vent breccias, as they may be called in contradistinction to the extrusive forms, are well shown in the gully scoring the south side of Big Butte, and exposing the granite walls of the old vent. In places the fragments are so large, some of them measuring 3 feet in greatest dimension, that the material might be called an agglomerate. They include granite and aplite, besides a great variety of rhyolitic rocks. The most prominent is a dark-colored glassy rock, itself a breccia of black glass cemented by a steely or brownish gray matrix.

On the east flank of the butte near the granite contact the rock, which has been opened by a quarry, is a breccia which for an area of 30 yards in diameter is bright green in color. Assay shows that no copper is present, and the color is probably due to the decomposition products of the ferromagnesian minerals of the rock. The breccia contains many fragments of gray granite and a few of aplite, as was also the case in the exposures of the south face of the butte.

The distribution of the two kinds of breccia forming Big Butte can not be shown on the map, and it is in places difficult to distinguish them in the field. The commoner forms, probably really extrusive, cover veins in aplite rocks which outcrop and have been prospected on the southern flanks of the butte.

The contacts of the granite with the massive intrusive rock and the intrusive breccias are very irregular, the granite itself being in part a fault breccia, though showing no recent alteration. The most interesting natural section of this mass is in the gully on the south slopes of the butte, where the contact is exposed about 300 feet from the road above the old shaft whose dump now partly fills the gulch. The porphyry is replaced by a dark orange brown, crumbly sand that is unquestionably decomposed granite in place. The exposure of this is not over 100 feet long and is seen only in the drain channel, as the adjacent slopes are of porphyry. The upper contact of the porphyry is a contact breccia of aplite fragments and bowlders in granite sand, the breccia forming a zone in few places more than 4 feet wide, and showing abundant rounded pebbles of aplite up to 8 inches in diameter. Careful search in this breccia failed to show any pebbles of porphyry, so that it is believed that the breccia has not been formed since the intrusion of the rhyolite. A dike 4 feet wide, of which but 15 inches is hard and glassy porphyry, cuts the decomposed granite not far from the contact.

Massive rhyolite, whose red color has frequently tempted prospectors to more or less extensive excavation, occurs in several places about the flanks of Big Butte; it weathers readily to a soft, clayey material which hides all contacts.

Sheeting, which is very prominent in exposures near the School of Mines, is due to recent fissuring; it shows evidence of movement along the fissure planes. Lamination of the rock, believed to be of different origin, is apparent in bands of denser material along the fractures; the evidence seems to indicate that the fissures represent shrinkage planes in the rock as it cooled from a molten state.

The contact between the granite and intruded rhyolite is well exposed in the railway cutting north of the Soudan mine. The granite block between the Soudan dike and the main mass of the intrusion to the east tapers to two thin wedges, one 30 feet and the other only 8 feet wide. The wider wedge, of pale rusty brown altered granite, is separated from the narrower wedge, of darker granite, by 7½ feet of white clay whose origin is uncertain and from the Soudan dike by 10 feet white clay that is certainly altered and leached rhyolite, since it shows remnants of a very dense form of that rock at the granite contact. Between the 8-foot granite wedge and the main body of the rhyolite to the east, a zone of breccia 30 feet across is composed of subangular rounded bowlders of dacitic and rhyolitic porphyry, with granite fragments near the contact. The rhyolite rocks are very dense and evidently represent a contact form of the intrusion; they are much decomposed and lie in a cement of similar but much finer fragmental material. The breccia is evidently a contact one.

SUMMARY OF STRUCTURAL HISTORY.

Granite forms the bedrock of the district and underlies its entire extent. It is of two kinds, which when fresh are unlike in color and composition, but when highly altered can be distinguished only with difficulty. The light-colored aplite is intrusive in, and hence later than, the dark Butte quartz monzonite, though both were formed from the same molten magma and in the same geologic period.

After the consolidation of the granite it was fissured by horizontal pressure due to movements of the earth's crust and was injected by dikes of the rhyolite porphyry. Another period of rock fracturing formed the fissures which mineralizing waters changed to ore veins. After the consolidation of the granites erosion removed the overlying rocks, whose nature is unknown, and eroded the region into a rugged topography of greater relief than that of to-day. A period of volcanic activity followed that of vein formation; the rhyolitic rocks were thrown out by explosive volcanic outbursts and fissures were opened which filled with molten matter that formed dikes. Big Butte is a small volcanic center.

The dynamic forces that caused the volcanic outbursts also warped the land, damming up the rivers and forming lakes in many of the valleys. Silverbow Valley was the site of a Neocene lake in whose waters ash showers from volcanic eruptions mingled with the waste of the land to form lake beds. More recent earth movements drained the lake and formed fissures which faulted the veins and raised the abrupt mountain wall east of Butte. Recent erosion filled and leveled up the valley floor, producing the hills and ridges that form the recent irregularities of the surface but not essentially modifying the larger topographic features.

CHAPTER V.—THE FRACTURES.

AGE.

As the Butte district lies wholly within an area of igneous rocks with no sedimentary formation save Neocene lake beds in the immediate neighborhood, it is impossible to determine definitely the ages of the different movements that have produced its multiple and complicated fissure systems.

One can indeed trace their actual or probable connection with the successive eruptions of igneous rock and thus determine their relative ages; but in a region of such complicated fracturing even this is more or less tentative. That there have been several periods of fracturing and fissuring is very evident, and though the relative ages of the different fissure systems have been satisfactorily determined by the mining operations of recent years, yet in many individual cases it is difficult if not impossible to determine positively whether the fracture—now occupied by a lode—is the result of one or several movements.

In a general way the fractures may be separated into two classes; the first, formed before the rhyolitic eruptions, trend either (*a*) east and west or (*b*) northwest and southeast; the second, accompanying or following the rhyolite intrusions, trend in the same directions as the first, but are most marked in a (*c*) northwest or (*d*) northeast direction. Still later, after ore deposition, northeast fracturing occurred.

The earliest fracturing recognized is that which is assumed to have taken place in the partly consolidated mass of Butte quartz monzonite, causing openings which were filled by the analogous but more acidic magma that cooled as aplite. The larger bodies of this rock, most of which are stocks of irregular form, are shown on the geologic map (Pl. X), but many small sheetlike bodies or dikes of it in the granite area are too small to be represented, and many other dikes of it are found in the deep underground workings. Where the rocks have been much altered it is, moreover, not easy to distinguish the small dikes. Most of them, however, trend east and west, showing that in this earliest system the tendency was similar to the later one that formed the mineral-bearing fissures. (See fig. 3, p. 39.)

The rhyolite porphyry intrusion, which probably took place after both the Butte quartz monzonite and the aplite had been consolidated, formed irregular dikelike bodies, often difficult to trace on the surface because of the difficulty in differentiating the altered and weathered forms from those of altered granite or aplite. These rhyolite porphyry dikes, some of which are of considerable size and extent, have mostly, so far as observed, a general northwest trend, though the one in the Anaconda mine runs east and west. At the best exposures, in the several railway cuts at the east point of the Modoc mine ridge, apophyses or small offshoots from the main body fill small joints and cracks which lead off into the granite in different directions, some of them almost horizontal (Pl. IV, *B*, p. 32). It is evident, therefore, that dynamic movement must have fissured and jointed the granite previous to or at the time of the intrusion of this rhyolite porphyry. Further evidence of some such early dynamic movement is found in certain seams of fine-grained breccia or fault material of distinctly earlier age than any mineral or ore deposit, which have been observed at a few points in the mines.

The most important fracturing—that which formed the fissures that admitted the original mineral-bearing solutions—occurred subsequent to both aplite and rhyolite porphyry intrusions. This is shown by the mineral-bearing veins cutting indifferently through both of these rocks as well as through the granite.

Subsequent to the original deposition of mineral along the vein fissures several later dynamic movements took place, each producing fracturing which affected the mineral deposits. These later movements have heretofore been designated secondary or postmineral movements, but inasmuch as these later fissures are also mineralized the term postmineral is really inappropriate. These later movements have formed cross fissures faulting the earlier veins and strike fissures coincident with or parallel to and reopening earlier veins.

The volcanic outbreak which caused the rhyolite intrusion occurred subsequent to the earlier vein fissuring, as is shown by the fact that the silver veins are cut off, in places even cut in two, by the intrusive dikes of rhyolite. The relation of these rhyolite dikes to the different periods of late fracturing is, however, not positively known. More than one postmineral movement certainly took place, for the rhyolite dikes have been markedly sheeted and somewhat fractured since their intrusion. The rhyolite intrusion itself, however, was probably accompanied by a certain amount of fracturing of the adjoining rocks. It is, therefore, not improbable that the secondary fracturing, which as will appear later has had an important bearing on the enrichment of the copper veins, was genetically connected with the intrusion of the rhyolite.

FISSURE SYSTEMS.

CLASSIFICATION.

The following fissure systems are recognizable throughout the district, both in joint planes in the rocks and in veins underground:

(*a*) Parrot system, N. 80° E., and its complement (*b*) Anaconda system, N. 80° W., occupied by the principal east and west veins of the district.

(*c*) Silverbow system, N. 60° to 65° W.

(*d*) Blue Vein or Nipper system, N. 40° to 45° W.; includes the Covellite, the Skyrme, Jessie, Edith May, and Blue veins, the Mountain View, and many other prominent faults.

(*e*) The Steward system, N. 64° E.; includes the Middle or Blue Jay fault, which becomes No. 16 in the Rarus ground, the Steward fault, whose vein is worked in the Gagnon, Original, and Steward mines, the No. 6 fault of the Parrot workings, and a number of faults having the same general course in the Bell and Diamond mines.

(*f*) Rarus system, N. 45° E.; faults which carry ore torn off from earlier veins.

The veins now occupying the first two systems of fractures are workable in the aggregate for several thousand feet; they include the great east and west lodes of the camp, the Anaconda, Parrot, and Syndicate, all of which follow intersecting fissures having these two directions. The first system approximates and in places coincides in direction with the secondary fissures (see p. 62), to which the existence of its great ore bodies is due. The first two systems are the oldest in the district; the third system is also old, but it has generally been reopened by later fracturing, and the value of its veins lies in their secondary ore bodies.[1]

REGULARITY OF THE FRACTURES.

The fractures of the Butte district are remarkably regular. Not only do individual fissures maintain a definite average course for considerable distances, but practically all the fissures belong to definite systems, in which the individual fractures are parallel. This regularity of the older fissures is disturbed by faulting, so that the persistency of the older veins is broken, as shown on the maps.

This regularity is due to the remarkable homogeneity of the rocks. The Butte quartz monzonite is uniform not only chemically and mineralogically but physically, and other rocks form but very subordinate parts of the mass. The conditions are therefore favorable for the development of coordinate fractures and the complementary fissures which result when a block of homogeneous material is submitted to pressure and the force is resolved into two components. The Butte veins do not show the conjugate fissures with identical strike but opposed dip, which often result from such force, but they do show a regular cracking or fissuring with definite opposed systems and simultaneous origin.

[1] The directions are determined in the long drifts run on the principal veins. The compass readings on fractures observed in crosscuts show an apparently greater variation in the strike of the first two systems than is given above, but owing to the difficulty of observing direction in short exposures and to local variations in the veins, the directions on crosscuts are less reliable than those taken directly from the mine maps.

DIRECTION.

The most striking feature in the vein fissure systems of Butte, as shown in the map (Pl. X, in pocket) is the presence of three first definite directions of fissuring noted above. The great veins worked for many years, including the Anaconda and Steward systems, are comprised in the quadrant of the circle between northeast and southeast. The Blue vein system, which in recent years has played so important a part in both ore production and litigation, is a later and independent system running northwest and southeast.

In most systems of rock fracture one major direction of fracture planes and one or more minor directions are observable, the fissures of the latter being usually cross fractures connecting two or more master fracture fissures. In the copper area, although in individual mines or groups of veins it is generally possible to distinguish two prevailing directions of strike, the one north of east and the other south of east, it is not possible to say that in all cases the fissuring in one of these directions is so much stronger than that in the other as to be called the major direction. The rule seems rather to be—if indeed there is a sufficient uniformity in such matters to constitute a rule—that the strongest and most persistent lodes are those which appear to be a resultant of these two directions. In a general way, it may be observed that the fractures (or the veins occupying them) in each lode group tend to strike north of east at their west ends and to diverge southward at their eastern extremities. Furthermore, that the divergence to the south is more common and greater in degree. The average divergence between the two directions may be taken at 30° and the maximum in one and the same vein system or lode at 45°. The veins named below show the following generalized courses:

Trend of the mineral-bearing fractures.

Neversweat-Anaconda	N. 87° W.
Silverbow	N. 67° W.
Johnstown (North Connecting)	N. 60° W.
Windlass	N. 63° W.
L. E. R.	N. 40° W.
High Ore	N. 60° W.
Blue Jay (Middle) fault	N. 70° E.
Steward fault	N. 62°–64° W.
Covellite	N. 35° W.
Clear Grit	N. 40°–51° W.
Caledonia	N. 70°–73° E.
Zinc (Original mine)	N. 76° E.
South Parrot or Virginius	N. 70° E.
Original fault	N. 80° W.
Syndicate	N. 80° E.
Shannon-Colusa	N. 70° E.
Blue	N. 40° W.
Mountain View fault	N. 45° W.

The fissuring in places produces a rhombohedral parting of the granite, which is well illustrated in the workings of the Parrot vein. It is not clearly shown on the level maps, but is well brought out by the stope sheets, which show an angle of 25° to 26° between the two sets of fractures along which the vein has been formed. These fractures run practically N. 76°–80° E. and N. 80° W. In a general way, the Steward vein corresponds to one of these fractures, as its course is N. 64° E., and the Neversweat-Anaconda vein, which has a course of N. 87° W., to the other. As a whole, however, the Anaconda ledge runs east and west, but this may be the resultant of vein formation along the two systems of fractures just noted—that is, N. 80° E. and N. 80° W.

RELATION OF FISSURE SYSTEMS TO JOINTING IN THE GRANITE.

In general, the fissures correspond to the jointing planes of the granite. This is well shown in the northern part of the district, where well-defined veins are seen to follow the direction of the main or master joints. It accords also with observations underground, which show that the earlier veins are replacements of sheeted granite. Outside of the producing copper area—as, for example, near the Black Rock and Niagara claims—the hard blocky granite is sheeted, and some of the sheeting planes have become veins. (See Pl. VI, *B*, p. 54.) Throughout the productive copper area the rocks are so altered that this relationship between joints and veins is obscured, but it is evident from surface cuts that the rocks are netted by many closely spaced fissures and that the veins are merely unusually well mineralized fissures. Plate IV, *A* (p. 32), shows a network of rusty fissures exposed in excavating for a church at Butte.

To determine whether the jointing planes in the granitic rocks agreed with the fissure systems, a careful observation was made of the joints in the granite area. This work showed two principal joint systems, one striking N. 10° E. with a dip of 70° to 80° W. or E., more rarely of 40° to 64°, and a second striking N. 80° E., with a dip of 75° to 85° S. and with conjugate fissures dipping at the same angle to the north. Somewhat rarely, flatter fissures were also observed, having the same strike but dipping 35°, 55°, and 60° S.

In the silver area the dip of the fissures is more uniform than their strike. The veins north of the Alice mine, including the north vein of the Rainbow lode, stand either vertical or dip 80° to 85° N. South of the Alice, both silver and copper veins, with but one or two exceptions, dip south, but at not more than 55°, except in the region west of Big Butte. The angle between the two directions of dip, then, is about 25° on an average with a maximum of 35°. These are the average dips of the fissures as a whole; in detail the profile or cross section of a vein is generally a wavy line. (See section of Anaconda vein, fig. 4, p. 42, showing at different points varying angles of dip, whose maximum divergence may equal the above.) When a vein sends off spurs—that is, smaller veins branching off at an appreciable and fairly constant angle from the main vein and not returning to it, similar divergences of 25° to 30° may in many places be noted between the dip of the spur and the average dip of the main lode.

The dip of a given fissure generally comprises two or more distinct directions, one nearly vertical, the other 60° to 70° S. Some subordinate planes of fracture have very shallow dips approaching the horizontal, whose inclination is prevailingly to the south.

SPACING OF FRACTURES.

In the spacing of the fissures a sort of rhythmic tendency is observable—closely spaced alternating with more widely spaced fissures. Comparatively few widely spaced fissures contain large or rich ore-bearing veins, the great productive vein fissures being closely spaced. The rich vein systems are made up of numerous veins, occupying fissures which follow two or more principal directions or strikes, the strike of the whole system not being exactly coincident with that of either of the constituent fissures. Thus the Moulton-Alice silver-vein system, which has a general direction of about N. 75° E., is made up of fissures running N. 80° W. to N. 75° E. and N. 65° E. The Rainbow lode, as this vein group is sometimes called, consists of parallel fissures which in general have a course similar to that of the whole group but which vary in direction in different parts of it, in places assuming more nearly one, and other places another of the constituent strikes.

The copper-bearing area comprises two great vein belts with a comparatively barren zone between. The northern belt consists of the Syndicate and Greyrock-Bell lodes and ends in the Modoc vein to the east. The southern belt includes the Gagnon-Parrot lode, the Anaconda-St. Lawrence lode, with the Blue Jay-Moonlight to the south, ending eastward in three diverging lodes, the Pennsylvania and Silverbow lodes, the Windlass, and the Mountain View and Colusa lode. In detail the main directions of the constituent fissures which make up the lodes of these two vein systems are N. 85° E., N. 55° W., and subordinately about N. 65° W.

DEGREE OF FRACTURING.

The evidence—though it must be admitted that in a rock of the nature of granite this evidence is rather unsatisfactory—shows that the original fracturing that resulted in the mineral-bearing veins was not accompanied by any considerable movement or displacement on the fissure planes. Slickensides and friction breccias are generally wanting in the primary fissures. In the copper-bearing veins little or no evidence is seen of original open spaces along the earlier fissure planes, such as would have been left had there been any considerable movement of one wall upon the other. It is probable, therefore, that although there was enough movement on the fracture planes to break the continuity of the adjoining walls so as to admit water freely and in some parts to leave small open spaces that have since been filled with vein material, the amount of this movement was very slight as compared with that connected with the secondary fracturing. In addition to the absence of striation and the small amount of brecciation, the absence of microscopic fracturing in the structure of the rock and the character of much of the vein filling indicates that the displacement on the earlier fissure was slight.

It is noticeable, moreover, that the fissuring and sheeting of the granite, though intense, extends over a comparatively small area and becomes gradually less as distance from the center of mineralization increases. This center of mineralization corresponds to a line running eastward from Big Butte through the middle of the copper-bearing area; that is, along this zone mineralizing action has been most vigorous and abundant. A tendency in the veins to wrap around this copper-bearing area or center of mineralization may also be observed.

The movement that produced the fissuring, it may therefore be assumed, was not an orogenic movement, a general warping and deformation of the earth's crust, which would be very widespread in its effects, but was rather a local and sudden one, like that accompanying an earthquake or an eruption of igneous rocks.

SECONDARY FISSURES.

Two principal kinds of secondary fractures, which fault the ore bodies and have apparently had important influence on their enrichment, have been recognized. These are (1) strike faults, or those which are for the most part parallel to, and in places are for considerable distances actually coincident with, the vein fissures; (2), dip or cross faults, which are more nearly at right angles to the vein fissures.

STRIKE FAULTS.

Strike faults are generally secondary fissures or zones filled with ground-up material and containing well-rounded fragments of country rock (quartz monzonite) and vein material (quartz and pyrite for the most part). They vary in width from a few inches up to many feet. Few of them conform exactly in course with the primary veins, but cross them at low angles in strike and dip.

Many of them contain so much moisture, especially in the upper levels of the mines, that their filling becomes a soft white pebbly mud which runs when they are opened by a drift. Many, too, are accompanied by clay seams or selvages; indeed, all the clay seams observed appear to belong to the periods of secondary fissuring, for all contain comminuted fragments of vein material. It is possible, however, that some of them were formed by original fissuring, and that during the secondary fissuring renewed movement along them brought in the finely ground-up vein material.

Strike faults are very widespread, especially in the copper-bearing area, having been noted at some point, generally near foot or hanging wall, of every well-explored vein. Most of them have the same or nearly the same average dip as the vein, but a few depart from it, at distinct angles. In the Lexington mine a series of such secondary fractures has produced marked step faulting in one of the veins. In the Gagnon mine a secondary fissure in the footwall country but near the vein (see Footwall or Steward vein, p. 136) is generally straighter than the vein itself and in places comes into actual contact with its footwall, which then carries a certain amount of secondary material.

Where a secondary fissure crosses the vein at a low azimuth angle, as in the west end of the Parrot mine, a slight displacement of the latter is noticeable. Elsewhere movement is indicated on the wall of the fissure by striation lines, which generally stand at an angle of about 45°; but there is no means of determining the amount of displacement, which is presumably slight.

In many places the secondary fissuring has produced a zone of broken and crushed material 25 or 50 feet wide, consisting of country rock when not in a mineral-bearing fissure and containing more and more vein material as it approaches ore. Such an instance occurs in the lower levels of the Original mine, where a breccia zone or wide fissure for some distance showed no sign of ore; then ore, at first only detected by assay, then in visible fragments, appeared mixed with the granite fragments; finally the breccia zone merged into a vein of solid rich ore.

That these secondary fissures are often coextensive in depth with the original fissures is very probable; it is known that they extend downward in connection with the veins to the lowest levels opened in the larger mines (2,200 to 2,800 feet below the surface).

CROSS FAULTS.

Cross faulting, so far as observed, is fully as extensive as the strike faulting and is usually more readily detected because its displacement is in many places across the strike of the veins. Whether the two or more systems of cross faults were practically contemporaneous with the strike faulting or were slightly later has not yet been definitely determined, but the writer inclines to the latter view. Their strike in some places is nearly normal to the direction of the veins, and their dip is generally very shallow, 65° to 45° or even less. In many places, however, the dip, which can be observed only in the underground workings, can not be detected, the presence of the fault being indicated only by the displacement of the vein.

These cross faults commonly throw the vein from a few feet to in places a hundred or more feet, beyond which, however, the vein is readily found again. Less commonly the fault cuts off the vein, which can not be found with certainty beyond. In still other places what may be called zones of disturbance are bounded on the east and west, respectively, by a series of cross faults, which are not strictly parallel to each other either in strike or dip; in the intermediate zone both vein and country rock seem to have been subjected to a sort of violent side thrust, which has not only broken the continuity of the veins but has pushed them, at certain depths, several hundred feet to one side and in places has shattered the whole rock mass within the zone, as shown in the Leonard mine (fig. 5, p. 53). Such zones, within the copper-bearing area, have received secondary enrichment by rich copper minerals. One has been traced in a direction about N. 30° E., through the Pennsylvania, Rarus, and Colusa mines. Another passes through the Colusa-Parrot and Neversweat mines.

RELATION TO RHYOLITE PORPHYRY DIKES.

In the eastern part of the copper area some secondary fissures follow or parallel dikes of the rhyolite porphyry for considerable distances (fig. 6). The earlier system of fractures, in which the dikes were intruded, has been evidently a line of weakness.

No positive genetic association of the ore and the rhyolite porphyry can be established further than the fracturing just noted, but it is believed by some observers that such association exists. If so it is possible that the rhyolite porphyry, which was part of a larger deeper-seated mass, supplied magmatic vapors which altered the granite and formed the veins.

RELATIONS OF EARLIER AND LATER FISSURE SYSTEMS.

From the intersection of so many fissures it is evident that the whole district is netted and that there has possibly been a mutual displacement by intersecting fissures of the same age, though such has not been observed in the great fault fissures, which are filled by crushed rock and ore balls. The difficulty is to reconcile the movements along similar systems at different periods. Thus, it is evident that the Northwest or Blue system of fissures, which is typically observed in the Blue, Mountain, and Skyrme, is later than and has displaced the quartz-pyrite veins of the east-west fissures. On the other hand, it is found that the Blue vein is itself faulted by a N. 70° E. fissure belonging to the Steward system. (Numerous other fissures having this same direction are observed, as, for example, the Bell fault fissure, which cuts and displaces all the veins in the Bell-Diamond workings.) This appears simple until it is observed that the Clear Grit silver vein fissure, a Northwest fissure greatly resembling the Blue and parallel to it, has cut and displaced the Steward vein and with it all the earlier veins. This, of course, means, for the evidence seems indisputable, that there were two periods of northwest fracturing and faulting, the earlier of which resulted in the formation of the Blue vein fault and the later in that of the Clear Grit fault. Observations in the neighboring mines show, however, that the Windlass and Johnstown (North Connecting) veins, and probably a number of others in the same neighborhood, were formed previous to the Blue Jay fault and are old quartz-pyrite veins carrying enargite and are probably later in age than the Anaconda vein. The argument, then, carried to its logical conclusion, proves three periods of northwest fracturing, which accords with the evidence that the Covellite, Skyrme, Jessie, and others of this northwest series carry remnants of the quartz-pyrite filling of fissures produced by the earlier and primary faulting. The second faulting, which shattered this filling, was followed by ore deposition, presumably from below, by which the rich ore bodies characteristic of these fault veins were formed at depths of 1,000 feet or more. The third opening along northwest fissures may have been a general or orogenic phenomenon due to the displacement of the block along the East Ridge fault line, and a consequent settling in which the earlier fractures formed planes of weakness. At any rate, the Clear Grit fissure and others of this type show that silver-bearing solutions followed this period of fracturing and formed typical silver veins and silver minerals in many of the fault fissures.

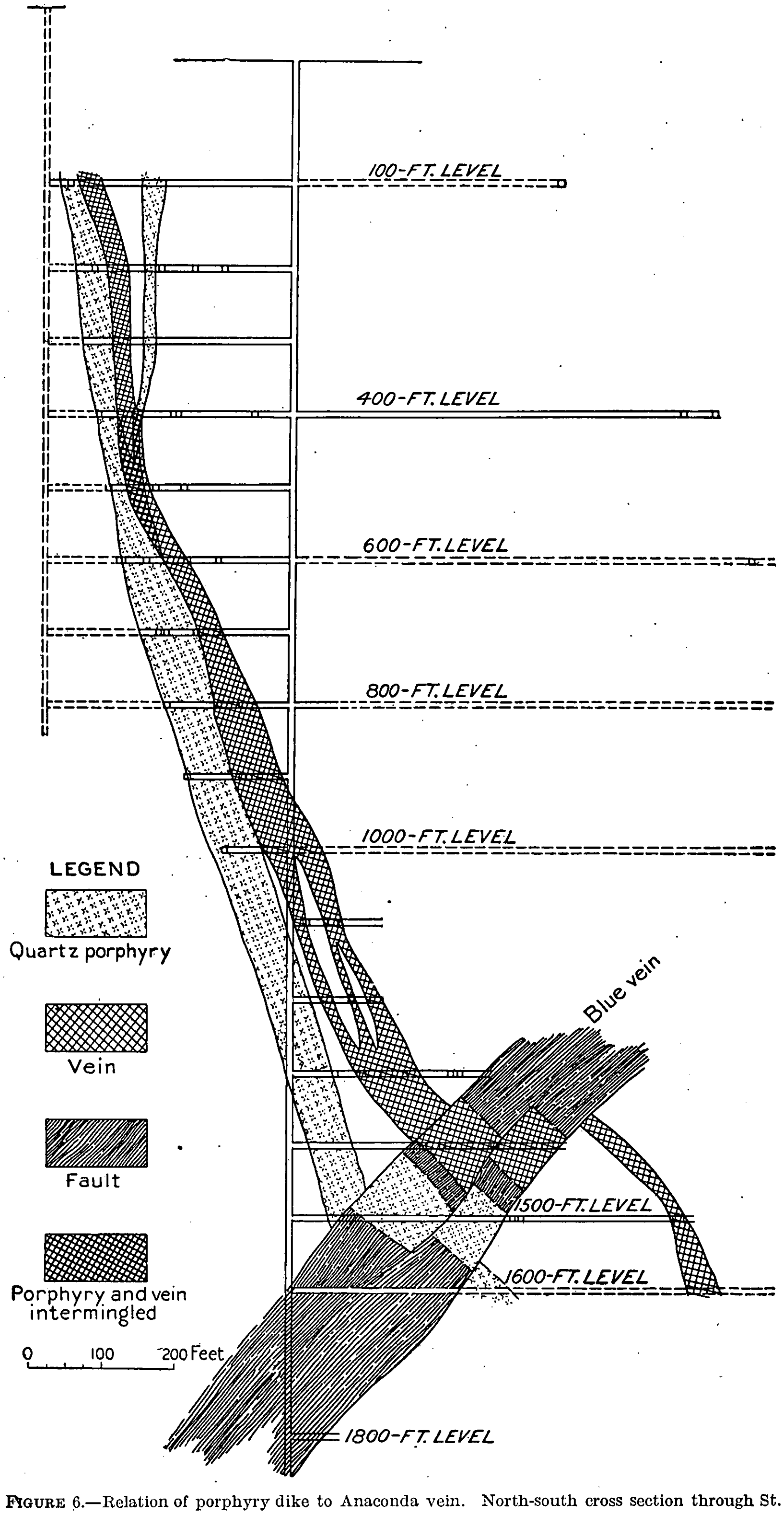


FIGURE 6.—Relation of porphyry dike to Anaconda vein. North-south cross section through St. Lawrence shaft.

CHAPTER VI.—THE ORES.

TYPES.

The metalliferous ores of the Butte district are of two distinct classes, copper and siliceous silver. The copper ores contain a little silver; the silver ores rarely contain copper; both copper and silver ores contain a little gold, and the high-grade silver ores contain it in important amounts.

The typical ores of the two classes are distinctive and are characterized by well-marked mineral association, but other ores occur which are not typical but are a mixture of both kinds. Some of the copper veins were originally worked for the residual-silver values in the oxidized material from which the copper had been leached, but the ores from such veins differ both in character and occurrence from the typical ores of the silver veins. Some of the silver veins on the border of the copper area contain bodies of copper ore, but generally in mineral composition and association differing from that of the typical copper ores of the district. The variation in the silver content of the copper ores is discussed later (p. 68).

DISTRIBUTION.

The ores of the Butte district occur only in the older rocks, the productive deposits being practically confined to the Butte quartz monzonite. A few silver veins have been productive in the aplite, and several of the largest copper veins cut through both the rhyolite porphyry and the aplite, but where the veins traverse the aplite they are lean. The association of porphyry and ore is certainly one of fracture, possibly of genesis by magmatic vapors. The porphyry occurs only in the copper area. The rhyolite dikes are younger than the silver veins and are found only in the silver area.

VERTICAL DISTRIBUTION.

The distribution of the payable copper ores is well defined and sharply limited. At pre sent (1906) nothing indicates that either the silver area proper or the area in which the ores are essentially zinciferous silver ores is underlain by copper ores. No evidence exists of a so-called iron zone, and the copper veins, from the Poulin mine of the Syndicate ledge on the north to the Blue Jay mine on the south (except in the Gagnon mine, whose copper ores extend exceptionally far west), grade rapidly westward into low-grade zincky, pyritic, silver-bearing ores. Recent development work in the fault veins has shown the existence of silver-bearing ore bodies which do not come within 700 or 800 feet of the surface.

The vertical distribution of the ores has not been definitely determined. Thus far (1906) the silver veins have been generally unprofitable at depths exceeding 900 feet beneath their outcrop. The Alice and Lexington mines have been opened to depths of 1,500 and 1,450 feet, respectively. The Moulton is 800 feet deep, the Bluebird 600, and the Nettie 650 feet, but none of the deep levels of these mines have been worked for years. According to current report the silver ores decrease in value with depth, but this could not be verified, nor is evidence obtainable to prove that the silver ores change into copper ores with depth. The Lexington, the Sisters, and a few other veins contain bodies of chalcopyrite ore, but chalcopyrite is almost foreign to the typical copper veins. However, as some copper veins have been broken and reopened and traversed by silver-bearing waters, composite ores occur in places.

The copper ores seldom extend upward to the outcrop. Their upper limit is extremely variable. In the Anaconda and other great east-west lodes, it lies at from 60 feet to 400 feet below the surface. In some of the more recently explored northwest veins, which cut and displace the others, few payable ore bodies are found in the first 1,000 feet. The downward limit of payable ore has not yet been determined for the copper veins. In some parts of the district the ore bodies become lean in depth and are composed of almost barren pyrite. On the other hand, the middle vein of the Anaconda mine contains large bodies of rich glance ore at 2,400 feet, and the same is true of the High Ore shaft at 2,850 feet. In general, however, many mines show a decrease in richness below 1,200 feet beneath the surface. This impoverishment does not begin at any definite horizon or elevation above sea level; it depends on the locality and the extent of the fracturing of the vein and the inclosing rock.

The lowest workings of the principal copper lodes are 3,700 feet to 4,000 feet above sea level, but several large mines have not yet reached this horizon.

AREAL DISTRIBUTION.

The areal distribution of the copper-bearing and silver-bearing veins is shown on the geologic map (Pl. X, in pocket). The copper veins are confined to a relatively small area lying north of Silverbow Creek, extending from Meaderville westward to the slopes of Missoula Gulch and northward to the high ground east of Walkerville. The most important silver veins lie northwest of this. In general, there is a remarkably sharp distinction between the copper and silver areas, but the silver area overlaps the copper ore somewhat, and the outline of the copper area is not regular. Roughly, it is 2 miles long by 1½ miles wide. A few productive silver veins occur in the copper area and at the western border the veins interlock.

COPPER AREA.

The copper veins are known to extend eastward beneath the alluvium filling the valley and to occur in the foot slopes of the mountain ridge to the east. This eastern extension of the copper area, however, is as yet more of prospective than of known value. East of the Continental fault in East Ridge the veins, though copper and silver bearing, appear to be of wholly different character.

In the western part of the copper area the copper veins separate into two belts, with an intermediate area carrying mostly lean veins, changing to silver veins west of Main Street.

The northern belt embraces the great Syndicate lode, worked in the Moscow, Poulin, Stella, Buffalo, Mountain Con., Green Mountain, and Wake-up-Jim mines, with a few other properties on neighboring allied veins. Eastward the belt is continued in wholly different clusters of veins in the Corra, Greyrock, Diamond, Bell, Speculator, and High Ore mines. The Modoc vein appears to be at the eastward end of this belt.

The southern belt commences on the west with the Gagnon-Original lodes and extends through the Parrot, Neversweat, Anaconda, and St. Lawrence workings, eastward to the Pennsylvania, Mountain View, and Rarus ground, with a branch to the Silverbow. South of this lies the Blue Jay-Moonlight belt and numerous other veins. Mining work has proved the breaking and displacement of all the great east-west lodes of these belts by cross veins, and it is not possible to trace a single vein continuously the entire extent of these belts. (See further, pp. 106 et seq.)

The Edith May, Jessie, Gem, Poser, and Elm Orlu lodes were formerly regarded as silver veins but are now (1906) copper producers, thus greatly extending the supposed northern limit of the copper area. Extensive prospecting work, in progress (1906–7) north of the area mapped, will determine whether or not the mostly barren-looking, supposedly silver veins of these areas are copper bearing. Silver ores carrying copper (usually as chalcopyrite) have been found locally in bunches in veins along the northern borders of the copper area, notably in the south veins of the Lexington and Magna Charta, in the Old Glory, Flag, Sisters, Moose, West Greyrock, and a few other mines. The Gem, Tuolumne, Mat, and neighboring veins are composite, containing a mixture of pyritic ores representing two periods of mineralization. Chalcopyrite occurs as a normal but not as a generally abundant constituent of silver ores, and reports of discoveries of bunches of copper ore are not rare. The large northwest fault veins carry valuable shoots of copper ore, with large silver values.

SILVER AREA.

The most important silver deposits have been developed immediately north of the west end of the copper area. The Alice, Moulton, and Lexington have been the largest mines. Very rich silver ores have also been obtained from the mines along the east bank of Missoula Gulch, especially in the intermediate belt included between the western wings of the copper belt; of these the Late Acquisition and Clear Grit lodes are the most important. Several rich veins have been worked directly south of Big Butte, and the system of veins running through the Nettie, Bluebird, and Independence grounds, in the aplite area west of Big Butte, have been important silver producers. In the northern tier of viens, north of the line of the Rainbow lode, the number of silver-bearing lodes is very large. Of the mines, all now abandoned, which flourished on these lodes in earlier days, many are said to have yielded large amounts of silver, individual producers running up into the hundred thousands of ounces.

METALLIC COMPOSITION OF THE COPPER ORES.

TENOR OF THE ORES.

Copper, silver, gold, and arsenic are the only elements extracted from the Butte ores. The small amounts of other metals present, though recoverable in the process of electrolytic refining, are of no economic importance. The average amount of copper per ton in the Anaconda ores mined from 1884 to 1898 was 111 pounds, or 5½ per cent, with 4½ ounces silver and 35 cents in gold per ton. In 1906 it was about 65 pounds of copper per ton of ore or 3¼ per cent for the entire district, with about 5 cents worth of the precious metals. High-grade ores are still produced, but in small amount; possibly 6 per cent of the ore carries as high as 6 per cent copper; the balance is concentrating ore. The tenor of the ore in the vein has not decreased as rapidly as is indicated by the above figures, but decreased costs and increased prices for copper have made it possible to treat lower-grade material, and the reduction works have been correspondingly enlarged.

The following analyses are representative of the ores mined about 1896 in the Rarus and Pennsylvania mines, where the veins carry more or less enargite:

Partial analyses of ore samples from Rarus mine, Butte, Mont.

Locality.	Ag	Cu	Au	Fe	SiO_2	S	As	Total determined
	Ounces per ton.	*Per cent.*	*Ounces per ton.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
A. North Connecting vein	3.35	37.87	0.015	11.6	0.8	35.4	5.55	91.37
B. South vein	5.85	25.87	.03	22.6	8.1	36.5	4.43	96.53
C. 77 raise. Middle ore streak above 450 feet, Snohomish	1.30	9.34	Trace.	32.5	13.0	42.5	1.88	99.22
D. Selected ore	2.50	23.78	.01	19.6	22.4	31.0	3.99	100.78
E. Southwest face	3.10	6.80	.015	38.8	7.6	46.5	.16	99.875
F. Small ore stopes	27.10	42.17	.045	5.5	6.3	32.2	4.45	90.66
G. No. 1 raise	4.40	36.21	Trace.	13.3	16.0	30.5	3.02	99.03
Average	6.00	23.05	.013	23.37	9.92	37.90	2.85	97.103

PRECIOUS METALS IN THE ORES.

GOLD.

Gold is universally distributed throughout the ores, but in such small quantities that it is not usually determinable in commercial assays. In the mines along the east bank of upper Missoula Gulch it has proved an important part of the value. The gold in the placer deposits was probably derived mainly from these veins since both native silver and copper have been found in company with it. In the silver mines the proportion of gold to silver by weight has run as high as 1 to 40 in mill lots. An average of five months' run in the Alice mill yielded 0.06 ounce gold to 21 ounces silver per ton treated.

In the Leonard mine the gold values have been exceptional; they are somewhat spotty and appear to depend on the occurrence of a peculiar bronze-colored tetrahedrite, a very rare mineral in Butte mines. A 200-ton shipment from the 1,200-foot stopes, which are 150 feet wide, yielded $5 in gold per ton, the highest yield being about $6. The gold values in the average ores appear not to shade off from the Leonard to the Colusa, or from the Leonard to the Pennsylvania mine. An average of 10,000 tons treated in the Great Falls smelter gave the following gold values per ton of ore:

Gold values in copper ores of Butte district.

Grade of ore.	Mountain View.	West Colusa.	Pennsylvania.	Leonard.
	Cents.	*Cents.*	*Cents.*	*Cents.*
First-class	70	30	25	50
Second-class	30	60	15	60

The higher gold values in some second-class copper ores indicates that the first-class ores may have come from a single ledge, and as the tetrahedrite occurs in streaks scattered through the second-class ore of the Leonard stopes, the relatively high value of the second-class ore is explainable.

The figures given above are more reliable than those based on a comparison of local details, but as they represent ore from different veins, they show the distribution of values in a general way only.

SILVER.

The average silver content of the ores extracted in 1905–6 from the Anaconda lode, extending from the Gagnon eastward, is 1½ ounces to each per cent of copper in the Gagnon ores; 1 ounce to each per cent of copper in the ores of the Original mine; three-fourths ounce to 1 per cent copper in the Parrot and Anaconda ores; one-half ounce to 1 per cent of copper in the Mountain View ores; and one-fourth to three-eighths ounce to 1 per cent of copper in the ores of the Leonard mine. These ratios, however, hold good only for the ores worked in 1905–6, for in the upper levels of the Gagnon mine the ore carried 3 ounces of silver to 1 per cent in copper.

On the 900-foot level of the Leonard mine the following variations in the amount of silver were noted:

Silver and copper per ton of ore, 900-foot level, Leonard mine.

Silver.	Copper.
Ounces.	*Per cent.*
½	2
¾	2½
½	4½
1¼	3
1½	1¾

These figures represent the averages of a large number of assays on sets of samples collected from different points, each set consisting of ore in one vein. The maximum results shown in the different assays on each vein were as follows:

Maximum assays of silver and copper per ton of ore, 900-foot level, Leonard mine.

Silver.	Copper.
Ounces.	*Per cent.*
3¾	8½
4½	9¾
1¾	3½
1½	6½

The following table was furnished by Mr. John Gillie, general manager of the Amalgamated properties. It shows the amount of gold and silver to each per cent of copper in the ore extracted from the principal mines of the Butte district. The figures are based on the smelter determinations for 1904.

Amount of silver and gold to each per cent of copper in different Butte mines.

[Ounces per ton.]

Mine.	Silver.	Gold.	Mine.	Silver.	Gold.
Anaconda	0.503	0.003	East Greyrock	1.117	0.003
Neversweat	.765	.004	Leonard	.484	.004
St. Lawrence	.351	.002	West Colusa	.313	.003
Mountain Con	1.064	.003	East Colusa	.444	.001
Bell	.793	.002	Pennsylvania	.400	.002
High Ore	.455	.004	Mountain View	.414	.002
Moonlight	2.000	.004			
Parrot	.884	.004	Average for Anaconda mine	.323	.003
Gagnon	1.676	.004	Average for Butte & Montana	.411	.0024
Silver Bow	.421	.002	Average for all mines of table	.755	.003

During the Colusa-Parrot trial before the United States court at Butte, Mont., expert testimony was introduced to show the actual value of the ore extracted. From this it appeared that on the 1,200-foot level of the Parrot mine a breast of ore 25 feet wide, carefully sampled and assayed, carried 25.4 per cent copper and 17.16 ounces silver per ton. Another breast on the same level, at the west face of the stope, 23 feet wide, yielded 9.3 per cent copper and 8.24 ounces silver per ton. On the 1,300-foot level a breast 10 feet wide yielded 7.1 per cent copper

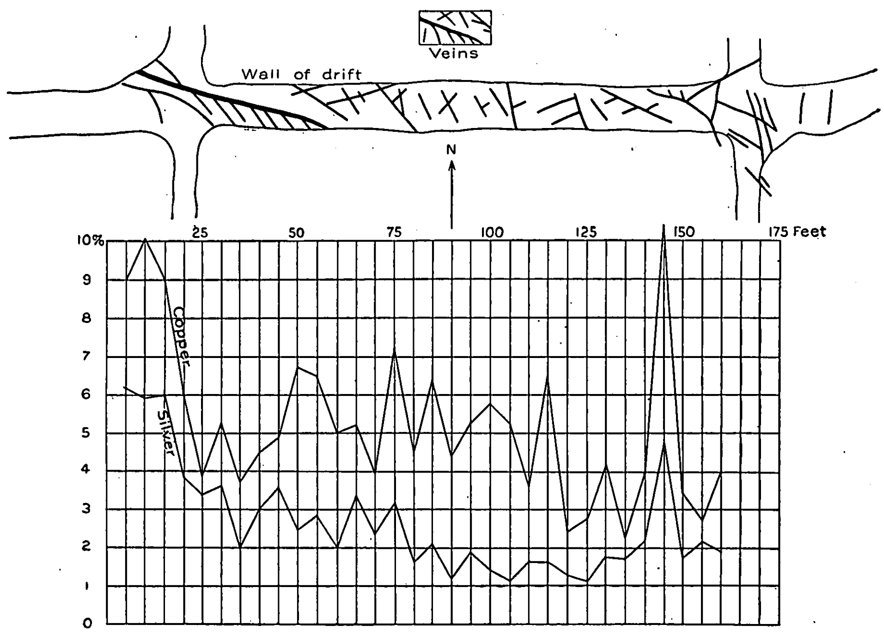


FIGURE 7.—Diagram showing relation between copper and silver values in a drift in the Leonard mine.

and 5.12 ounces silver per ton. These figures, representing the rich ore of the mine, show considerable variation in the ratio of silver and copper, and it is therefore certain that no rule for the ratio of gold and silver can be based on the assays of a few samples only. (See fig. 7.) On the other hand, the general samples from the whole mine represent such a variety of veins that the returns can not be used to deduce the relative ages of the veins.

BASE METALS.

MANGANESE.

Manganese is widespread in the silver veins, but is wanting in all the copper veins except those that form a transition phase between copper and silver veins. In amount it varies from 1 up to 20 or 30 per cent of the metal. It is especially abundant in the aplite area west of Big Butte, where the outcrops of the veins were primarily worked for the manganese oxides, which were useful as flux in smelting.

ZINC.

Zinc is also very widespread and is generally more abundant in the silver than in the copper ores. In the latter, except in certain veins south of the central area and in those at the western ends of the two belts, it is not usually distinguished in the ore. In some second-class ores it averages 2 per cent, and in an average of analyses of matte from a certain group of mines, extending over several months' production, it ran about 2½ per cent to 60 per cent of copper. In the silver veins it may be in considerable amount, many smelters' assays showing from 2 to 40 per cent. Its distribution is by no means uniform.[1]

LEAD.

Lead is relatively small in amount and is not usually taken account of by ore purchasers, nor is it generally visible in the ores. In the average copper matte above mentioned its proportion was about one-quarter that of zinc, with which metal it is generally associated. It is said that considerable amounts of galena were found in the Humboldt, in the Blue vein in the Little Mina claim, and in the Clear Grit.

NICKEL.

Nickel is present in minute traces. It was first detected in the copper sulphate crystals from the electrolyte and its presence was later confirmed by direct analysis.

ARSENIC.

Owing to the large and increasing amount of enargite in the Butte ores the amount of arsenic mined is large. Increasing litigation over the alleged poisonous effects of the smelter fumes condensed on vegetation and eaten by animals has led to the erection of extensive dust chambers, in which the arsenic is condensed and from which it is collected. From 3.3 to 5.5 per cent of the mineral is recovered from about 22,000 pounds of dust, the finest portion of the 60 to 80 tons collected daily at the Washoe works. The plant yields from 11 to 18 tons of arsenic a month.

SULPHUR.

As all the ores treated are sulphides the amount of sulphur in the great tonnage extracted daily is enormous. The Washoe plant at Anaconda, treating 7,000 tons of ore per day (in 1905), yielded 42,200 pounds of gases (693,000 cubic feet per minute) containing 1.5 per cent of sulphur, equal to 3 per cent SO_2 or 1.37 per cent sulphur by volume. This is equivalent to 494 tons of sulphur per 24 hours. Over half of this amount comes from the roasting furnaces.

AMOUNTS OF METALS IN THE ORE.

To determine the amount of each metal present in the ore, where such metals are present in traces only, it is necessary to use the percentages shown in the analyses of the electrolytic slimes, many metals not being otherwise detectable. With these percentages and a knowledge of the tonnage of ore treated, the amount of each can be fairly approximated. Due allowance must be made for losses in roasting, smelting, bessemerizing, and calcining. In a copper matte carrying 50 per cent copper, the lead, bismuth, antimony, arsenic, tellurium, and selenium will be largely eliminated in the bessemerizing process. According to Mr. E. Keller,[2] the average percentages eliminated in bessemerizing are lead, 96; bismuth, 91; arsenic, 78; antimony, 67; tellurium and selenium, 95.

The loss in calcining the matte, the process followed when these figures were obtained, amounts to 1 per cent copper, 1.8 per cent lead, 1.6 per cent bismuth, 8.15 per cent antimony, 27.16 per cent arsenic, and 2.8 per cent tellurium and selenium.

[1] Great bodies of it exist in the Butte Superior and Elm Orlu properties.
[2] The figures given in this and the next four paragraphs were furnished to the Survey by Mr. Keller.

The following table shows further losses:

Percentage loss by smelting calcined matte and by slagging.

Metal.	1	2	Metal.	1	2
Copper	1.00	1.00	Antimony	1.27	5.02
Lead	.13	7.58	Arsenic	2.99	1.74
Bismuth	2.08	1.06	Selenium and tellurium	2.70	None.

1. Loss in flue dust by smelting calcined matte. 2. Loss by slagging.

When, as in the practice from 1896 to 1900, a 60 per cent copper matte is derived from the 6 per cent concentrating ore, the percentage of gold and silver in the ore may be safely regarded as one-tenth of that in the matte. As to bismuth, selenium, and tellurium, one gets similarly reliable minimum figures. For arsenic and antimony the problem is complex; as to antimony, probably 50 per cent is eliminated in the reverberatory process; and as to arsenic, it is impossible to draw definite conclusions as the excess of pyrite greatly facilitates its volatilization. The following table represents an estimate which is a close approximation to the truth:

Average composition of matte and of the copper ore from which it was derived, based upon ores mined in 1897.

Metal.	Matte.	Ore.	Metal.	Matte.	Ore.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Copper	60.00	6.00	Selenium and tellurium	0.01	0.001
Bismuth	.04	.004	Silver	[a] .206	[b] .0206
Antimony	.10	.02	Gold	[c] .001	[d] .0001

[a] 60 ounces per ton. [b] 6 ounces per ton. [c] 0.3 ounce per ton. [d] 0.03 ounce per ton.

As stated on page 69, the ores now worked do not yield such high values in silver and gold.

The matte produced in 1897 by the Butte smelters and shipped east for treatment contained the following constituents:

Matte shipped from Butte smelters in 1897.

Metal.	1	2	3	Metal.	1	2	3
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Copper	60.76	49.34	61.42	Bismuth	0.042	0.0337	0.0049
Sulphur	23.25			Antimony	.079	.101	.133
Iron	11.43			Arsenic	.045	.0484	.128
Fe_2O_3	1.13			Selenium and tellurium [a]	.015	.0021	.0042
Zinc	2.41			Manganese	Trace.		
Lead	59	.0738	.037	Silver	([b])	14.6 [d]	18.2 [d]
Nickel	001			Gold	([c])	.05 [d]	.05 [d]

[a] The ratio of tellurium and selenium is from 1:1 to 1:⅓. [b] 61.2 ounces per ton. [c] 0.29 ounce per ton. [d] Ounces per ton.

1. Reverberatory matte from the Anaconda works.
2. Reverberatory matte from the Boston & Montana Great Falls plant.
3. Blast furnace matte from the Boston & Montana plant.

The mattes produced at present (1905) are much lower in grade, 40 per cent being usual and as low as 30 per cent being made.

WEIGHT OF THE ORES.

The weight of the ores from the different mines varies somewhat. Generally, however, about 9 cubic feet weigh a ton. Actual measurements show that the loose or shipped from the Leonard mine varies from 15.9 to 16.5 cubic feet per ton, and that from the Pennsylvania mine from 14.9 to 16.9 cubic feet per ton. Tests on the West Colusa ore showed that the ore carried from 3½ to 5 per cent copper and ran 16.8 cubic feet per ton. Broken ore carrying 8 per cent copper ran 16.04 cubic feet per ton, and broken ore carrying 20.4 per cent copper 15.37 cubic feet per ton.

STRUCTURES OF THE ORES.

The ores show several distinct structures, which may be roughly classed as follows:

1. *Crustified.*—Symmetrical crusts deposited in definite order as banded vein filling in silver lodes. (See Pl. VII.)

2. *Massive.*—Quartz-pyrite veins showing massive quartz and pyrite, with accessory sphalerite in irregularly distributed and patchy masses. Definite evidence of crustification is lacking, but here and there rude banding corresponds to the replacement of plates of granite along the zone of shearing.

3. *Ribbon.*—Plating due to sheeting of the vein filling by shearing stresses, resulting in drawn-out streaks of pyrite, the crushing of the quartz being recognizable only in thin sections; may be recognized by the branching veinlets and shattering of the pyrite. Throughout the entire district not only have these earlier quartz-pyrite veins been generally fractured and dislocated by cross fissures but they have also suffered from movement along the plane of the vein; and as this movement has been intermittent from the time of the vein formation to the present it is very difficult to decide at what particular period the ribbon structure was formed.

4. *Banded.*—Newer material superimposed on massive vein filling by the reopening of the faulted vein.

5. *Disseminated.*—Ore in which grains and films of glance and pyrite or of enargite occur scattered through the altered granite, either as a replacement of the pyrite, itself formed by the alteration of biotite and hornblende, or as a filling of a network of minute cracks which shattered the rock.

The normal quartz of the pyritic veins has a very characteristic granular hypidiomorphic structure, which is independent of the size of the vein. The quartz differs megascopically from that associated with either the glance or enargite ore. Drusy cavities occur in which crystals have developed, but in the ore proper the pyrite and sphalerite almost universally lack crystal form. Fluid inclusions are common in the quartz, but are small, of irregular form, and occur in lines apparently independent of crystal outline, though in places conforming to the boundaries of the sulphide minerals. These inclusions have not been tested chemically.

MINERALS OF THE ORES.

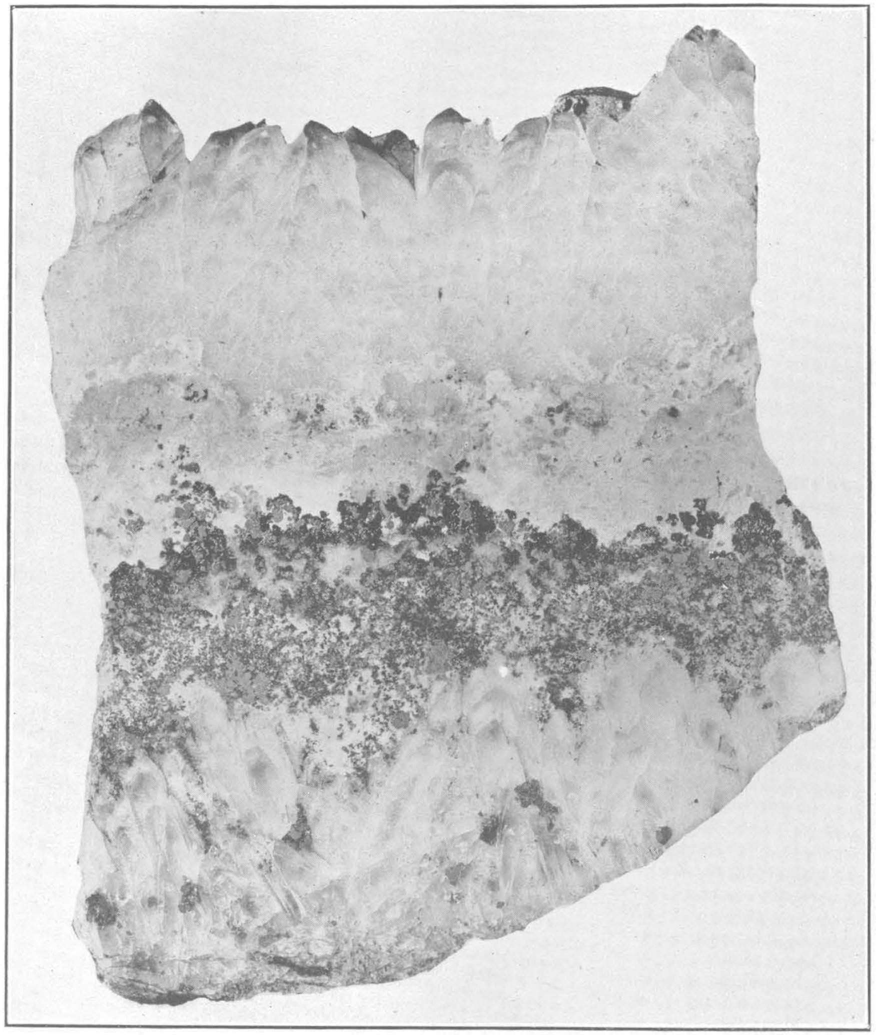
GENERAL COMPOSITION.

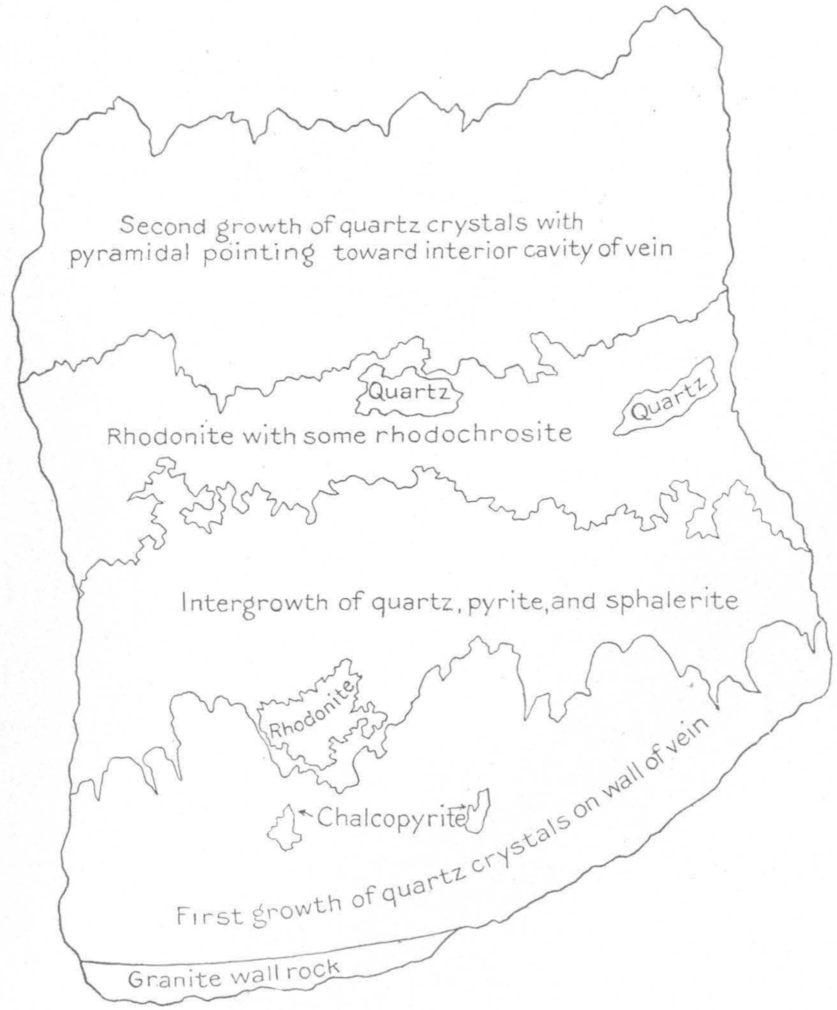
The minerals in the Butte ores are neither rare nor of great variety.

Chalcocite, bornite, and enargite are the most common copper minerals. Covellite occurs in large amounts in one mine and in small quantities in others. Chalcopyrite is present in workable quantities in a few properties but is an insignificant part of the total copper output. Tetrahedrite is found as a rarity in the deep workings of a few mines. Chalcanthite, or native bluestone, is common in the old workings. Pyrite is the most common sulphide. It is estimated that since the beginning of mining about 75 per cent of the copper production has come from glance, 20 per cent from enargite, 4 per cent from bornite, ½ per cent from covellite, and ½ per cent from chalcopyrite. The proportions in 1906 were different, being estimated at 49 per cent from glance, 49 per cent from enargite, and 2 per cent from other minerals, mainly bornite.

Silver occurs native in the copper ores, especially those from the upper levels. Ruby silver and indeterminable black sulphantimonites and arsenides occur in the siliceous silver ores. Free gold is rare, but occurs in some silver ores, and has been seen in specimens from the Leonard mine, where it is parasitic on glance.

The ores consist of ore minerals mixed with earthy and mostly worthless gangue. In the Butte silver ores the gangue minerals are abundant and decomposed granite is comparatively scanty. In the copper ores the gangue minerals are few, quartz predominating. The following notes omit technical descriptions, being confined to matters of general interest and to local peculiarities of character or occurrence.





BANDED ORE SPECIMEN, LEXINGTON MINE.

Three-fourths natural size. Diagram shows composition.

PRIMARY MINERALS.

PYRITE.

Pyrite is the most common metallic mineral of the district. It occurs as a primary constituent of the Butte quartz monzonite and in pegmatitic facies of the aplite. It is, next to quartz, the most abundant constituent of the copper veins and is abundant in the altered granite adjacent to the veins. It forms, with quartz, the great quartz-pyrite veins, whose enrichment by copper glance is directly due to the pyrite. It also occurs intermixed with all the other metallic sulphides of the district. (See fig. 8.)

Pyrite also forms nearly pure massive veinlets of different ages. The pyrite carries some copper and is supposed to be the mother copper mineral of the district. Numerous qualitative

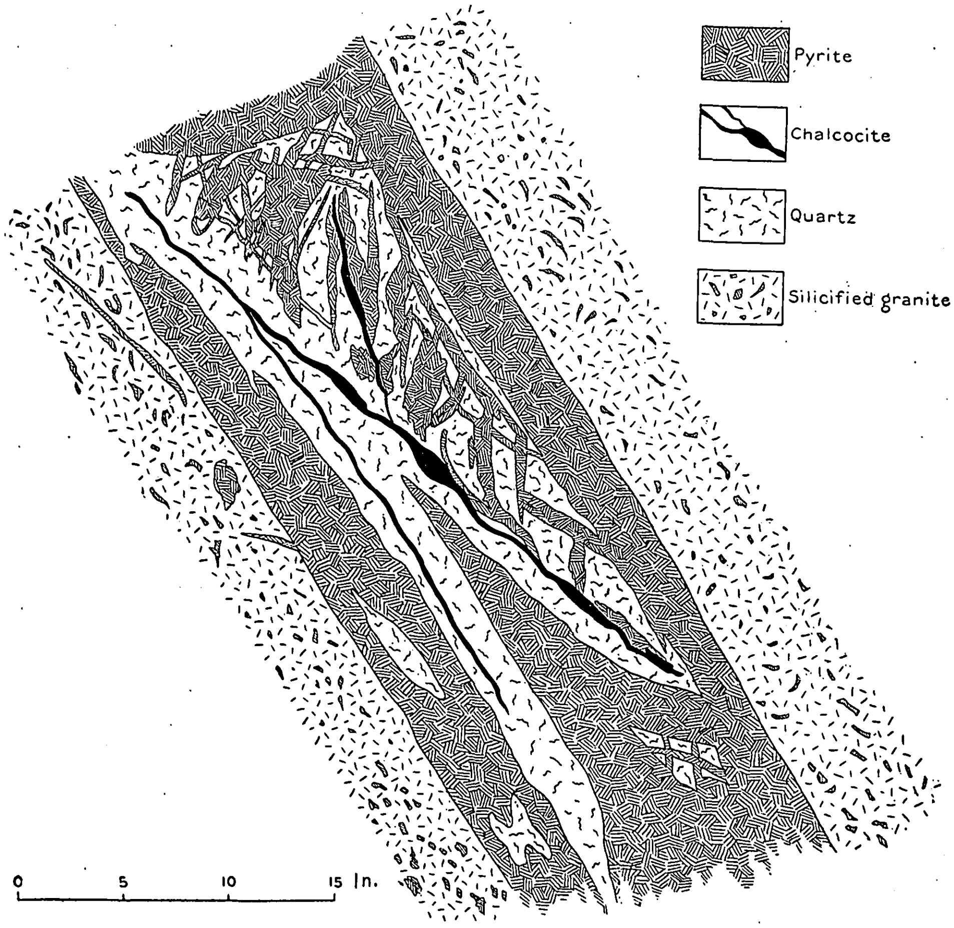


FIGURE 8.—Pyrite vein in granite, 1,000-foot level, Leonard mine.

and a few quantitative tests were made on pyrite from different parts of the district to determine the copper content and to ascertain whether it contained arsenic and antimony. The quantitative results follow:

Copper, arsenic, and antimony content of pyrite from Butte copper mines.

Locality.	Depth.	Copper.	Arsenic.	Antimony.
	Feet.	*Per cent.*	*Per cent.*	*Per cent.*
1. Flat seam, Mountain View	500	0.10	....	....
2. No. 3 vein, Pennsylvania	1,100	2.76	Trace.	1.00
3. Mountain View mine	900	None.	None.	None.
4. St. Lawrence	1,400	None.	None.	None.
5. Mountain Con	1,800	None.	None.	None.
6. Pennsylvania	1,200	.5	None.	None.
7. East Gray Rock	....	.2	Trace.	Trace.
8. Green Mountain	2,200	.7	None.	None.
9. Green Mountain	2,000	.86	.005	None.

Nos. 1 to 7 were examined by A. B. Rombauer, Butte, Mont.; Nos. 8 and 9 were examined by Dr. W. F. Hillebrand, in the Survey laboratory.

The samples were generally taken from pyrite seams or from perfectly pure material free from other minerals. Most of the seams were in granite and were not parts of the main lodes, except as noted. Samples were also assayed for gold and silver; generally they gave negative results, but an apparently pure pyrite from Cambers mine, 200 level, gave 0.70 ounce silver per ton, and 0.01 ounce gold per ton.

MARCASITE.

Marcasite (white iron pyrite) is common in the Butte mines.[1] It differs from pyrite in crystallization, lower specific gravity, and color. It tarnishes and decomposes more readily than pyrite, and hence may be important in promoting secondary enrichment. It is found admixed with pyrite and also in aggregates of imperfect crystals lining vugs and generally associated with kaolin. Though no detailed studies have been made it is assumed that much of the material decomposing so readily on the dumps of the different mines is marcasite.

BORNITE.

Bornite (peacock copper, $FeCuS_2$) is a common ore mineral in several lodes, especially the Parrot, Original, Gagnon, Jessie, and Edith May mines. It also occurs sparingly in a few of

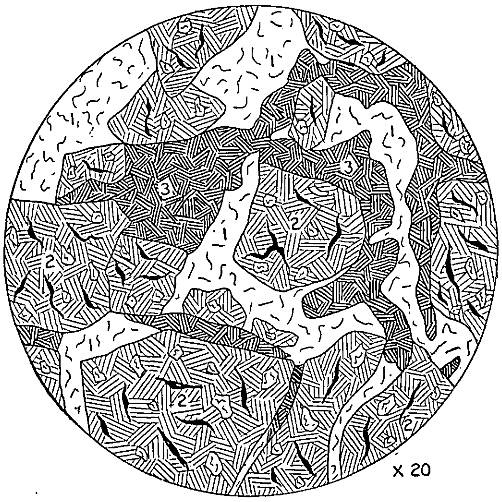


FIGURE 9.—Thin section of bornite ore: 1, White quartz; 2, massive pyrite with quartz; cracks and interspaces where quartz grains and crystals join filled with bornite, which also replaces part of the pyrite; enargite fills minute cracks in the pyrite; 3, bornite.

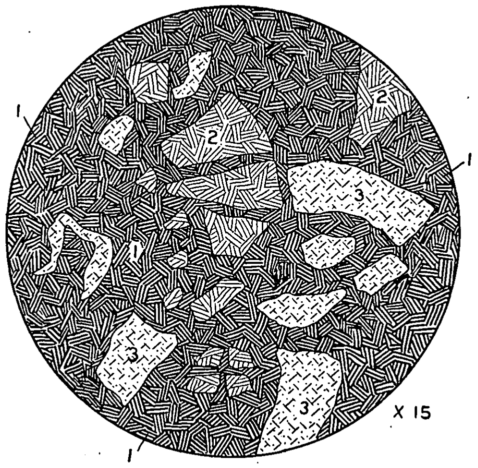


FIGURE 10.—Thin section showing fragments of (2) shattered pyrite and (3) enargite that appear to be secondarily inclosed in (1) bornite.

the silver veins. It is always massive, with a recognizable crystalline structure. On fresh fracture it has a silvery luster that tarnishes quickly to copper red, and this in turn to indigo blue. Much of the Parrot ore contains large amounts of this mineral; in it small cavities one-sixteenth to one-fourth inch across containing wires of native silver are often seen. (See fig. 18, p. 80.)

Bornite occurs both as a primary and as a secondary mineral, hence its presence does not necessarily mean secondary enrichment. It appears in rounded masses or cobbles in the fault breccias of the Original, Gem, Jessie, and other fault veins, and in these veins is of earlier formation than the chalcopyrite and other minerals typical of the silver period. Microscopic studies show a close association between it and chalcopyrite, and also that it occurs as a secondary filling in altered and fractured enargite. It occurs mostly above the 1,000-foot level. (See figs. 9 and 10.)

[1] Winchell, A. N., Econ. Geology, vol. 2, 1907, p. 292.

CHALCOPYRITE.

Contrary to common belief, chalcopyrite is not common in the Butte copper ores. It has been supposed to occur mixed with pyrite in the big veins of the district, but study of the ores under the microscope discredits this idea. It does occur in quantity in a few of the northwest fault veins, where it is indigenous, notably in the Blue vein at the Little Mina mine, at the Clear Grit mine, and in the Gem vein. The mineral is clearly related to the pyrite of the silver veins, and occurs mainly in a pasty, clayey vein filling in the copper ores of fault veins. In the silver veins it occurs together with quartz in isolated ore bodies. It is especially abundant in the Lexington mine above the 800-foot level, and in the neighboring properties.

Chalcopyrite is a primary mineral in the Butte quartz monzonite, a study of thin sections and of polished specimens showing that it is intergrown with the rock minerals in the perfectly fresh rock. It was first noticed in a specimen kindly forwarded to the writer by Mr. H. V. Winchell from a quarry near Elk Park, but has since been noted in other specimens and is particularly abundant near the Altona mine. Primary chalcopyrite is also found in abundance in an aplite granite band 60 feet wide between the main body of granite and the bordering sedimentary rocks near Anaconda. At the Altona mine and vicinity the granite from the 200 and 400 foot levels is dark, fairly fresh, and full of what appears to be original chalcopyrite, the sulphide being associated with biotite and hornblende and also intergrown with feldspar. In the fault fissures chalcopyrite occurs in dendritic bunches of intergrown crystals lining vugs and as loose aggregates associated with tetrahedrite in the fault clays of the Gem mine. The mineral is believed to occur in recently formed veins; in the deep levels of the Leonard mine it is found under conditions which indicate very recent deposition, forming brilliant and readily determinable coatings on fractures and in fissures in the covellite. (See fig. 11.)

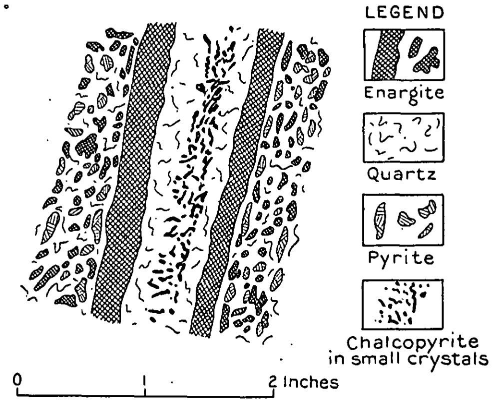


FIGURE 11.—Chalcopyrite in quartz in enargite veinlet, Leonard mine, 1,100-foot level.

CHALCOCITE.

Chalcocite (copper glance, 79.8 per cent copper) is the most abundant and characteristic copper mineral of the district. It is lacking in the strictly silver-bearing veins but is typical of the copper area and also in large amounts in fault veins of composite character. In the exceptional veins of the Clinton and Homestake mines east of Butte it occurs as a recent mineral, filling the spaces about and upon the large quartz crystals which line the veins.

In the great ore bodies of the Butte mines chalcocite forms steely-gray masses having a pronounced conchoidal fracture. In the upper 600 feet of the Anaconda and Syndicate lodes it has a leaden color and fracture. At lower levels down to 2,400 feet it shows a massively crystalline structure and is dotted with included crystals and masses of pyrite. It occurs filling crevices and cementing a breccia composed of fragments of enargite and of earlier quartz-pyrite veins. It envelops and incloses well-formed and large quartz crystals; it cuts pyrite grains and also fills fractures in pyrite and in bornite, and therefore is certainly the latest ore mineral formed and is in large part a replacement of pyrite. (See p. 102.) It forms most readily as a replacement of pyrite but is also pseudomorphic after sphalerite. A specimen of banded ore from the Colusa mine, submitted to technical analysis, gave 79.2 per cent copper and 20.8 per cent sulphur.

Some interesting specimens of very coarsely crystallized and peculiarly banded chalcocite from the deep levels of the Leonard mine possess unusually brilliant luster and have much more perfect cleavage than any other mineral from the district. The fractured surfaces show that the chalcocite includes bornite crystals. The surfaces of the chalcocite crystals are etched and corroded by nonoxidizing solutions.

The bulk of the ore mined at Butte consists of altered granite carrying disseminated

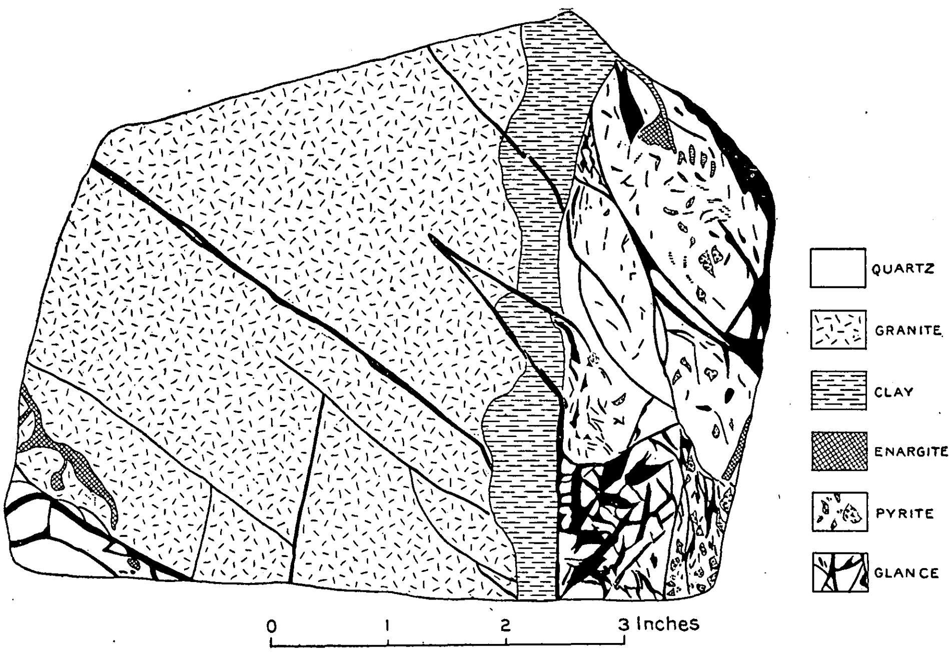


FIGURE 12.—Chalcocite (glance) specimen from 1,000-foot level, Leonard mine; natural scale. Shows pyritized granite alongside of quartz vein, with pyrite grains. Stringers of glance cut through quartz, granite, and the fault clay between them. (Sketched by Bard.)

grains and veinlets of chalcocite (copper glance), intergrown with pyrite or replacing that mineral partly or completely. The chalcocite is seldom found as distinct crystals, but in a few vugs well-formed crystals have been found coated with quartz and etched by later solutions. From the studies made of thin sections it is believed that the mineral is almost universally secondary but that it also occurs as a primary mineral in some veins. It is undoubtedly in process of formation by descending waters at the present time, but as the great ore bodies found at deep levels are far below the present level of ground water, they can not have been produced by the reactions commonly offered in explanation. (See figs. 12 and 13.) The replacement of zinc blende by chalcocite has also been noticed at Morenci, Ariz., by Lindgren.

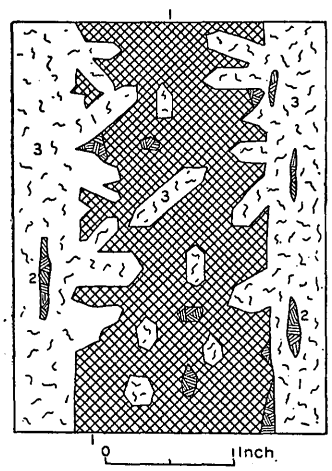


FIGURE 13.—Veinlet of chalcocite (glance) and quartz. The (1) chalcocite fills the central cavity of an open fissure or vug lined with comb quartz. Crystals of (3) quartz and (2) pyrite occur, isolated, in the chalcocite. Leonard mine, 1,000-foot level. After Bard.

COVELLITE.

Covellite (indigo copper, CuS), a beautiful and brilliant indigo mineral, is abundant in the Covellite vein and occurs locally in some other copper veins. It is rather rare outside of Butte, which makes its presence there the more interesting. In the Butte ores it is always massive and shows a perfect cleavage, with a platy structure. It occurs as a secondary ore, either derived from chalcocite or deposited under exceptional conditions in the crushed and clayey matter of fault veins. (See figs. 14 and 15.) The mineral has not been found in the attrition breccias of the fault veins, but some of it is undoubtedly the result of decomposition of masses of glance broken and dragged by fault movements. An analysis made in the Survey laboratory by Dr. W. F. Hillebrand gave the following results:

Analysis of covellite from Butte, Mont.

Copper	66.06
Iron	.14=0.30 pyrite.
Sulphur	33.87
Insoluble	.11
	100.18

Specific gravity at 16° C. (uncorrected for pyrite and for insoluble material) 4.76

The material tested contained a very little pyrite and was as pure as could be obtained. It came from the covellite stopes of the East Greyrock mine on the 800-foot level.

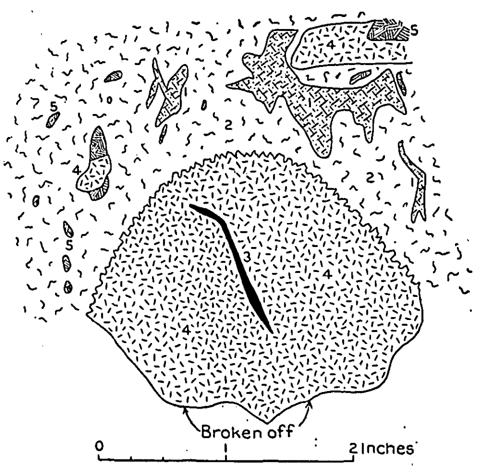


FIGURE 14.—Vug in a quartz-pyrite vein that has been filled by covellite. (1) Enargite occurs in sac-shaped replacements in the (2) quartz. (3) Chalcocite is seen in center of (4) covellite mass. (5) Pyrite. Natural scale. Leonard mine, 1,100-foot level, Butte, Mont. After Bard.

ENARGITE.

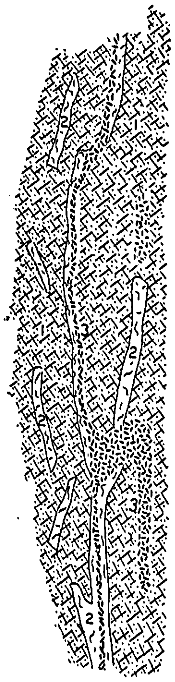


FIGURE 15.—Veinlet of (1) enargite penetrated by (3) later covellite seam. (2) Quartz. Natural size. Leonard mine, 1,100-foot level Shows secondary character of the covellite.

Enargite is, next to glance, the most abundant copper mineral, greatly exceeding bornite in quantity. It occurs in veins which differ in many ways from the quartz-pyrite veins carrying great masses of chalcocite. It does, however, occur in the latter veins, particularly in the deepest levels, and it is abundant in the fault veins. It is a primary mineral, and in some veins, as in the Gambetta and neighboring veins of the Leonard group, it extends upward to the base of the oxidized ground some 20 feet beneath the surface; in general it becomes increasingly abundant with depth. Many small veins of this ore, formerly unrecognized or regarded as zinc blende and left untouched, are now diligently sought for and mined.

In general, enargite is massively crystalline, with well-developed cleavage, but without crystal outline. Well-formed crystals have, however, been found in vugs in a number of veins, and it is notable that the terminal face (basal pinacoid) has a clean, mirror-like surface and the prismatic faces a mossy coating of copper glance. The mineral completely fills many fissures in altered granite, generally separated from the granite by a narrow band of comby quartz. A breccia of enargite, cemented by glance, has been mined in considerable quantity in the Colusa property. In the old quartz-pyrite veins the mineral generally occurs at a depth of 2,000 feet or more.

A sample of enargite from the Rarus mine, analyzed by Dr. W. F. Hillebrand in the Survey laboratory, showed the following composition:

Analysis of enargite from the Rarus mine.

Copper	48.67
Iron	.33
Zinc	.10
Arsenic	17.91
Antimony	1.76
Sulphur	31.44
Insoluble	.11
	100.32

Enargite is an original mineral in the veins of the eastern part of the district. It is subsequent to pyrite, but earlier than glance. (See figs. 15 and 16.)

Enargite pseudomorphs after hübnerite have been observed in the Leonard mine. Specimens received from Mr. R. H. Sales show prisms of enargite surrounded by radial quartz, the basal pinacoids of the prisms being clear and mirrorlike, and the remainder of the crystal coated with mossy glance. The white quartz penetrates the massive enargite and both the quartz and the included enargite fill spaces between fragments of the earlier quartz-pyrite vein filling. The difference between the two forms of quartz is marked, as the mineral of earlier formation has a dull, greasy luster and lacks the coarse crystallization and glassy look of the later one.

Enargite occurs abundantly in scarf-like masses in the fault clays and breccias of the Original, Leonard, and other veins, under conditions where bornite and the earlier quartz-pyrite vein filling are invariably crushed and broken. Enargite also forms solid veins, sometimes as much as 3 or 4 feet thick, in which the mineral carries included particles of pyrite and a very little quartz, but is practically free from gangue matter. Study of thin sections shows that the enargite is later in formation than the pyrite, and that it is associated with fluorite, barite, rhodonite, and other minerals commonly due to thermal waters. The great abundance of the minerals in the fault veins of the St. Lawrence and Leonard mines is particularly noticeable. It must, however, be noted that in the Johnstown vein the mineral is of earlier formation, so that two periods of enargite deposition appear to have existed.

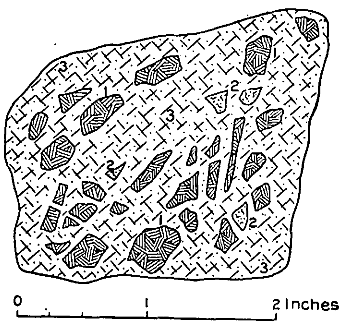


FIGURE 16.—Block of ore showing relations of enargite and pyrite in ore from the 1,100-foot level of Leonard mine. Natural size. The two minerals (2) quartz and (1) pyrite, appear to be broken and the fragments cemented together by (3) enargite. After Bard.

TETRAHEDRITE.

Tetrahedrite (gray copper) occurs in the northeast silver belt and in the fault veins, particularly on the upper levels of the Jessie, Gem, and similar veins on the northeast border of the copper area. It is an original mineral which corresponds to enargite in its position in the sequence of vein minerals. In the deeper levels of the Leonard mine the mineral is relatively abundant as a bronze or brown variety carrying low values in silver and appearing to be of comparatively recent formation, more recent in fact than the enargite and other copper minerals. It is everywhere massive, but occurs intergrown with other minerals. On the 1,200-foot level of the Leonard it is found as a streak about 3 feet wide near the west end line of the claim. A carload lot containing much gangue yielded 4 per cent of copper, 2 ounces per ton in silver, and $13 per ton in gold. A little tellurium is present and it is believed that the tetrahedrite holds inclusions of some gold-silver telluride, whose decomposition may have supplied the native gold found in mossy aggregates, parasitic upon glance. Similar ores occur in the deep levels of the mines at Cripple Creek, Colo. Tetrahedrite also occurs in the silver veins east of Butte, particularly in the Clinton, Homestake, and other mines adjacent to Columbia Garden.

TENNANTITE.

Tennantite occurs sparingly and only in the copper veins, where it appears to be a product of the decomposition of enargite, with which, so far as known, it is always associated.

SPHALERITE.

The sulphide of zinc (sphalerite) is common in the veins, both in the copper and silver areas. Commonly it is associated with pyrite (fig. 17), but veinlets of solid blende also occur in the wall rock of the Syndicate lode. The blende of the quartz-pyrite veins is a primary mineral, deposited simultaneously with the sulphide of iron. In some veins it is very abundant, both near the surface and in depth, but is absent in the enriched copper glance ores. A specimen kindly given the writer by Mr. H. V. Winchell shows the different stages of replacement by glance. As blende is replaced before pyrite, it is probable that some of the glance seen in the Butte mines is a replacement of this mineral. This is also indicated by the abundance of zinc sulphate in the mine waters. This replacement has been observed by Lindgren at Morenci, Ariz.

Zinc blende is also common throughout the silver area and is so abundant in the ores of the Alice and Moulton mines that a zinc extraction plant was erected for its recovery. South of the copper area proper the veins carry large amounts of zinc blende and the ores are penalized when sent to the smelter. Veins southwest of the Emma mine and those of the silver belt generally contain ores high in zinc, which has proved a serious detriment in their treatment. The current belief that the fault veins northeast of the copper area carry galena and zinc near the surface, and that beneath this zone of worthless sulphides bodies of commercial copper ore will be found, has not yet (1906) been substantiated, though observations by Mr. E. Waller, of the Tasmanian Government Survey, show that the zinc and galena bearing veins of North Dundas, Tasmania, change in depth to copper-bearing ores.

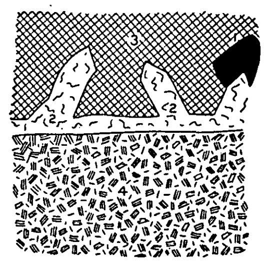


FIGURE 17.—Zinc blende (3) and galena (1) on quartz crystals (2) attached to pyritized granite (4) south of Colusa vein, 500-foot level of Leonard mine.

GALENA.

Sulphide of lead (galena) occurs sparingly in the silver veins and in considerable amount in some of the fault veins of the copper area, notably in the Blue vein, from which many carloads of lead ore were extracted within the limit of the Little Mina claim. It seems not to be present in the old copper veins but to be confined to the later fault veins.

MOLYBDENITE.

Molybdenite, a disulphide of molybdenum, is found in a number of places east of the Flat and in the Gagnon mine. The mineral, which resembles graphite, occurs in small black shiny scales having a bright metallic luster and lying in fracture planes and veinlets in both fresh and altered granite. It is abundant alongside the veins on the Montgomery, Altona, and neighboring claims.

MANGANESE MINERALS.

Manganese minerals are characteristic of most of the silver veins and occur in the copper veins where these have been broken and mineralized by later fractures. Rhodochrosite and rhodonite appear to be the chief sources of the manganese; but oxidized ores, which are clearly the result of a normal decomposition of the silicate and carbonate of manganese, are abundant in the outcrops of all the silver veins. Pyrolusite, too, is common in these outcrops, and its sooty black stains many of the great quartz reefs seen throughout the district. Wad, which is the commonest of the oxides, is usually disseminated through the vein quartz, mostly as an extremely finely divided powder arranged in curly, grotesque forms around crystals and along cracks. The other oxides of manganese are in some places crystalline, but they usually occur in botryoidal, reniform, and massive forms, in which it is hard to distinguish the separate minerals.

GOLD.

The constant presence of gold, together with tellurium and selenium, in the blister copper produced by the smelters, suggests the probable presence of minute quantities of some gold-silver telluride. Native gold has, moreover, been found by Mr. Reno Sales as distinct and fairly good-sized particles on the surface of glance crystals from the 1,000-foot level of the Leonard mine.

SILVER.

Native silver is common in the silver veins and also in the oxidized portions of the copper veins. It has been observed in mossy aggregates and coatings, in fracture planes in glance ores, and in bornite. Wire silver and fibrous silver also occur in cavities in bornite and glance, particularly in the upper levels of the Parrot mine (fig. 18).

PYRARGYRITE.

Pyrargyrite has been observed in the ore from the Springfield mine, where its crystals line fractures in the altered granite of the vein walls. Elsewhere in the district it has not been positively identified, although there is reason to suspect its widespread occurrence, as indicated by the red streak when many of the massive silver ores are scratched.

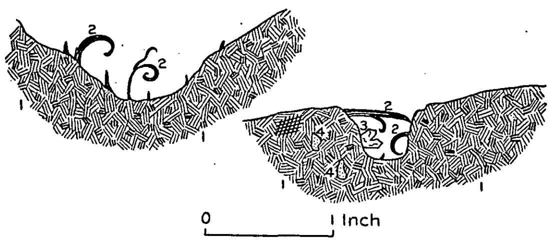


FIGURE 18.—Wire silver (2) and masses of silver in vugs (4) in bornite (1) from 600-foot level, Parrot mine; (3) quartz crystal. The conditions closely agree with those noted by Vogt in the Norway silver deposits.

HÜBNERITE.

Hübnerite (tungstate of manganese) has been found in both the Gagnon and Leonard mines, forming many perfect but deeply altered monoclinic crystals of considerable size associated with sphalerite, copper minerals, and quartz. On the 300-foot level of the Gagnon mine it formed an ore shoot of argentiferous material and passed over into cupriferous massive wurtzite.

Hübnerite is regarded as an original vein mineral, which occurs in bands of quartz inclosed by sphalerite and copper sulphides.

WURTZITE.

Specimens of wurtzite have also been obtained from the 1,600-foot crosscut of the Gagnon, where it formed about 1.29 per cent of the ore mined. The following analysis was made:

Analysis of wurtzite ore from 1,600-foot crosscut of Gagnon mine.

Copper	per cent..	6.18
Zinc	do....	19.10
Gold	ounces per ton..	.05
Silver	do....	11.60

OXIDIZED MINERALS.

DISTRIBUTION.

In general the veins of the district lack the abundance of oxidized surface ores seen in so many copper camps. Such minerals occur, but they have never furnished even a small percentage of the ore mined. In the area east of Butte they are more common, having been mined for a few months at the Bullwhacker and Bertha claims. In these mines seams of the red oxide are common both in the veins and in the country rock adjacent to the veins; the chief ore, however, is a green chrysocolla, which occurs in great abundance in the north and south fault vein, which crosses the Bertha, Bullwhacker, and Maggie Fraction claims. In the early history of the camp the outcrop of the Parrot ledge is described by Raymond as being marked by an abundance of bright-colored carbonate ores.

CUPRITE.

Cuprite (Cu_2O, 88.8 per cent copper), the dark-red oxide of copper, occurs sparingly in the upper portions of many of the veins lying along the foothills of East Ridge but is not important commercially and has not contributed materially to the copper output of the region.

CHRYSOCOLLA.

Chrysocolla (hydrated silicate, 36.05 per cent copper), is found in small amounts in many veins, but forms commercial ore only in the claims east of Butte along the foothills of East Ridge. The mammillary crusts common in other districts are rare at Butte, the mineral occurring as a light, extremely porous, corklike material of a bright-green color that was mined in considerable quantity in 1907–8.

MALACHITE.

Both green and blue carbonates of copper occur sparingly along the copper outcrops, and are particularly noticeable in the East Ridge claims. The ores have not, however, been important, and are of more mineralogic than economic interest.

COPPER PITCH.

Material which appears to correspond to the copper-pitch ore, observed in Arizona, has been found on the Montgomery, Ida, Amazon, and other eastern claims, where it occurs as a lustrous coal-black or dark-brown crust, associated with other copper ores. No analysis has been made, and it is uncertain whether the material corresponds exactly to that collected in Arizona.

CHALCANTHITE.

Chalcanthite (bluestone or copper sulphate) is by far the most abundant recent mineral of the oxide zone. It occurs in old mine workings, forming crusts or crystalline tufts on mine timbers and wall rocks. It coats rock fragments in old stopes, in some mines so abundantly that it has been found profitable to collect these from time to time. Chalcanthite occurs in the mine waters, from which many tons of metallic copper have been precipitated by contact with metallic iron. In the old drifts of the Mountain View mine it forms clear blue stalactites of considerable beauty, which appear to be perfectly pure, different in this respect from stalactites found in other mines. A specimen of an aluminous copper sulphate forming stalactites on the 600-foot level of the Anaconda mine was analyzed by Dr. W. F. Hillebrand, who reports its composition as follows:

Analysis of cupro-alum stalactite, Anaconda mine, Butte, Mont.

Copper oxide	9.32
Ferrous oxide	.18
Al_2O_3	10.67
MgO	.08
Alkalies	Trace.
SO_3	35.05
Phosphoric acid	1.13
Arsenious oxide	.07
Water	43.44
	99.94

As the material is wholly soluble in cold water it is readily carried off, but as the acids in the above analysis are far in excess of the amount required for a normal salt, the material is probably a mixture of acid salts and free sulphuric acid, with a little phosphoric and arsenic acid.

In the Silverbow mine pure chalcanthite is so abundant as to almost fill some of the old drifts. Plate VIII, *A*, shows the stalactites extending from roof to floor on the 200-foot level. In the material from the Mountain View mine only copper sulphate was found, but most of the material gathered elsewhere contained admixed iron and zinc sulphate.

PISANITE.

Pisanite, commonly regarded as a mixture of copper and iron sulphates, is common in many of the unworked drifts of the mines where seepage waters come down through old stopes and carry both copper and iron sulphides in solution. It usually occurs in stalactites in deserted drifts.

GOSLARITE.

Goslarite (zinc sulphate, $ZnSO_4 + 7H_2O$) is extremely common in old mine workings, where it forms an efflorescent coating of long and delicate hairlike needles on walls, air pipes, and other exposed surfaces. It occurs somewhat rarely in seams in the dry stopes and drifts of the upper levels of the Rarus and other mines.

LIMONITE.

Limonite is extremely abundant throughout the district, but is rarely found in quantity at any particular place. In the mines it is deposited by the mine waters and coats the walls of both crosscuts and drifts or forms stalactites (Pl. VIII, *B*) which in some places extend from roof to floor. It is the most common oxidation product of the mine waters, which deposit limonite wherever they emerge into the open air. It is also common in small quantity in the vein outcrops and throughout the zone of oxidation generally. The great limonite outcrops of other localities are, however, wanting at Butte. On the slopes near Park Canyon it occurs as a surface coating, capping the veins and extending down the slope below the vein outcrop, but in Butte it is notable for its absence rather than its abundance.

A sample of a limonite stalactite from the 900-foot level of the Silverbow mine (Pl. VIII, *B*) was submitted to Dr. W. F. Hillebrand and analyzed by him in the Survey laboratory.

Analysis of limonite stalactite from Silverbow mine, Butte, Mont.

Silica	2.55
Ferric oxide	68.53
Zinc oxide	.40
Lime oxide	.28
Magnesia	Trace.
Alkalies	Trace.
Phosphoric pentoxide	4.06
Arsenic pentoxide	Trace.
Sulphur trioxide	3.24
Water	20.01
	99.58

MELACONITE.

Melaconite, the solid black oxide of copper, occurs in several of the East Ridge claims, notably the Bullwhacker, Montgomery, Amazon, and others near by. The mineral forms seams and small bunches in the altered surface rock. It is jet black, has a glistening conchoidal fracture resembling coal, and lacks crystalline form or texture. It occurs associated with cuprite, generally in seams or fracture planes or as coatings about nodules.

TENORITE.

Tenorite, the earthy black oxide of copper, occurs sparingly at a number of localities throughout the copper district proper.

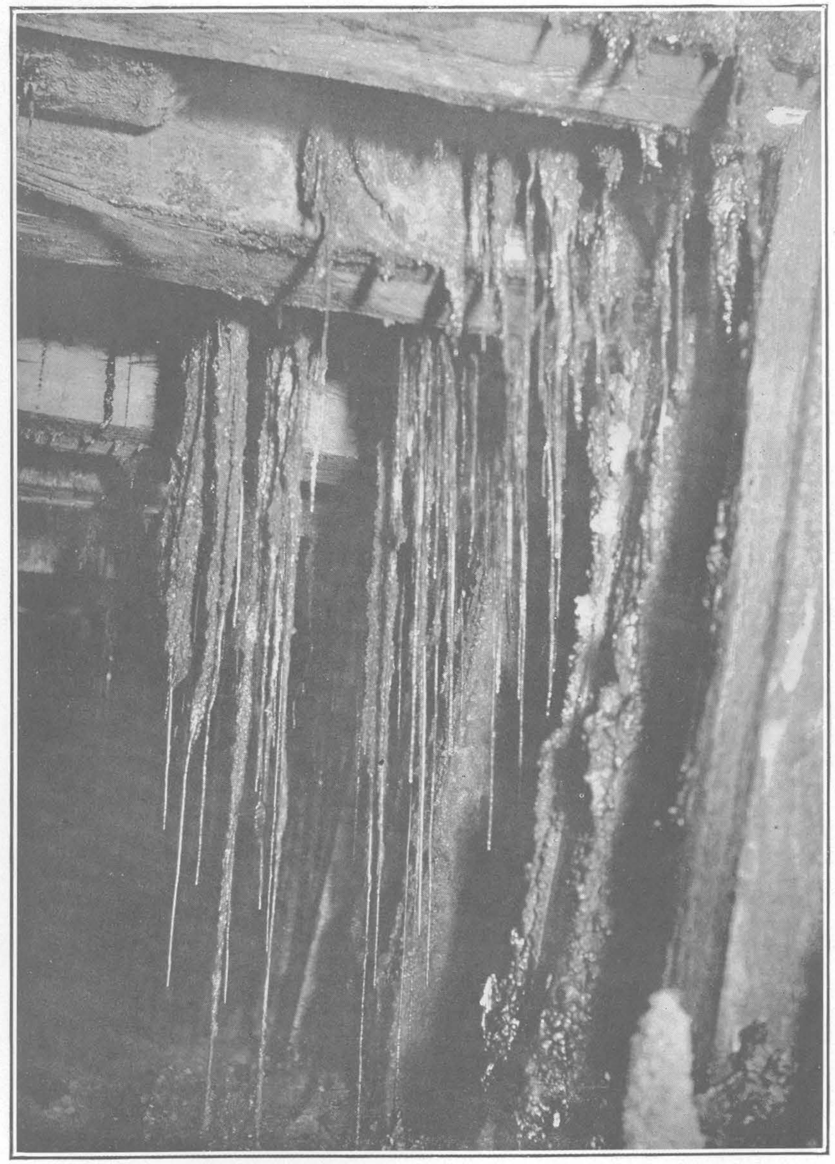
MINERALS OF THE GANGUE.

QUARTZ.

Quartz is the common gangue mineral of the veins, being abundant in both copper and silver veins. In the copper veins it is a replacement material and has a dull greasy look, even when crystalline. In the silver veins it is commonly massively but coarsely crystalline and shows a comby structure, in many places with lines of vugs running through the center of the vein. It

A. STALACTITES OF CHALCANTHITE WITH SOME ADMIXED FERROUS SULPHATE, SILVERBOW MINE.

200-foot level. See page 81.



B. STALACTITES OF LIMONITE IN SILVERBOW MINE.

also occurs in well-defined crystals embedded in glance and as a coating about enargite veins. It is clearly a mineral of several generations, being one of the earliest and possibly also the latest of all the minerals of the district. In the western part it occurs in great reefs which form ridges and hills. One of these, the outcrop of the Ancient vein, is shown in Plate IX, *A*. In the silver veins the quartz is commonly stained black by manganese oxides when subjected to oxidizing influences. Below the water level, however, it occurs mixed with rhodonite and rhodochrosite, from which it is distinguishable with difficulty. Silica also occurs in opaline and chalcedonic masses in the so-called silicified granite found about many of the vein outcrops. Here, however, it is due to the formation of amorphous silica as a result of kaolinization.

CALCITE.

Calcite is not abundant in the Butte mines. It occurs somewhat rarely in the silver veins, and more often in the fault veins, notably the Blue, Clear Grit, and other northwest veins. Good crystals of dog-tooth spar deposited upon chalcopyrite and intergrown with that mineral were found in the vugs of the Blue vein, where opened by the Little Mina workings. Calcite is one of the most recent minerals formed; it is still being gathered by rock waters in little veinlets in granite remote from the mineral veins; for instance, in north crosscuts driven from the Original mine. The character of this alteration is noted elsewhere (p. 89), but it is significant, as the calcite is readily replaced by quartz in a later period of mineralization.

GYPSUM.

Gypsum has been noted in many places as incrustations in old mine workings and on mine dumps. It is believed to result from the decomposition of lime-bearing feldspars and of pyrite, being due to the action of the sulphuric acid on the feldspars in the presence of oxygen and water.

SERICITE.

Sericite, the finely felted form of muscovite, is the most abundant mineral of the altered rocks, not only in the vein walls but also in the gangue of the enargite veins. The bulk of the concentrating ore sent to the mills is a decomposed sericitized granite, speckled with minute grains of pyrite, either partly or wholly replaced by glance. This sericite, when acted on by acidic waters coming from the oxidation of pyrite, alters readily to kaolin.

KAOLIN.

This mineral is common in the weathered zone of the altered rocks of Butte. It occurs also in the veins and as a constant associate of glance, particularly in crystals lining vugs in the veins. Its formation is due to the same processes which have oxidized the glance ores near the surface and carried the material downward to be deposited as an enrichment at greater depths.

RUTILE.

Needles and prisms of dark-brown rutile are common in the sericitized Butte quartz monzonite. They are most frequent where biotite is decomposing, but probably result from the alteration of titaniferous magnetite.

MAGNETITE.

Magnetite is a common constituent of the Butte quartz monzonite, occurring in irregular grains and poorly formed crystals, in many places intergrown with the ferromagnesian minerals but also standing alone. It has been observed interlocked with pyrite, the two together forming an irregular crystal (figs. 19 and 20). It has not been observed in the veins.

FLUORITE.

Fluorite has been found by the writer in both the Original and Gagnon workings, where it is associated with enargite in the fault clays. It is a result of a late mineralization, which has deposited rhodonite and other minerals characteristic of the silver veins. It has also been noted in the Leonard mine and the Gem mine, where it is associated with barite and tetrahedrite. (See fig. 21.)

BARITE.

Barite (barium sulphate) occurs only in the fault veins. It has been noted in fine crystals of a clear yellowish-brown color and tabular form lining vugs in the Blue vein and cavities in the veins of the Leonard mine. It occurs incrusting all the other minerals characteristic of the vein and seems extremely recent. Its occurrence is limited to vugs and water channels.

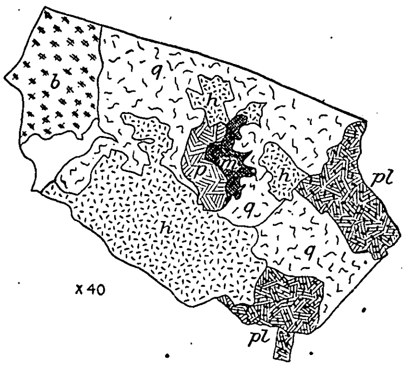


FIGURE 19.—Intergrown pyrite and magnetite in fresh Butte quartz monzonite. *b*, Biotite; *q*, quartz; *p*, pyrite; *h*, hornblende; *pl*, plagioclase; *m*, magnetite. × 80.

RHODONITE.

Rhodonite, the silicate of manganese, is, next to quartz, the most common gangue mineral of the silver veins. It occurs in crusts and bands alternating with quartz, the layers being made up of microscopic rhombs. It also occurs disseminated through the quartz, so that it is clearly of the same age as the quartz, and some of it is younger than the metallic minerals. Rhodonite is found only in the silver veins and in the fault veins of the copper area. In the latter it forms concretionary masses and rather loose aggregates filling little seams in the fault clays. It has been observed in the Original, Gem, Clear Grit, and other fault veins of the copper area.

RHODOCHROSITE.

Rhodochrosite is less abundant and less widely distributed than rhodonite. In places its relations indicate its formation from rhodonite, of which it appears to be a decomposition product. In many veins it forms a cementing material, filling fractures in the ore and binding together fragments of country rock. It is typical of the silver veins and of the reopened, faulted copper veins. It has been observed in the fault veins of the Gagnon mine, associated with bornite and other copper minerals.

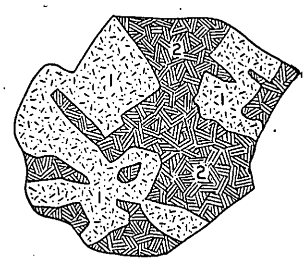
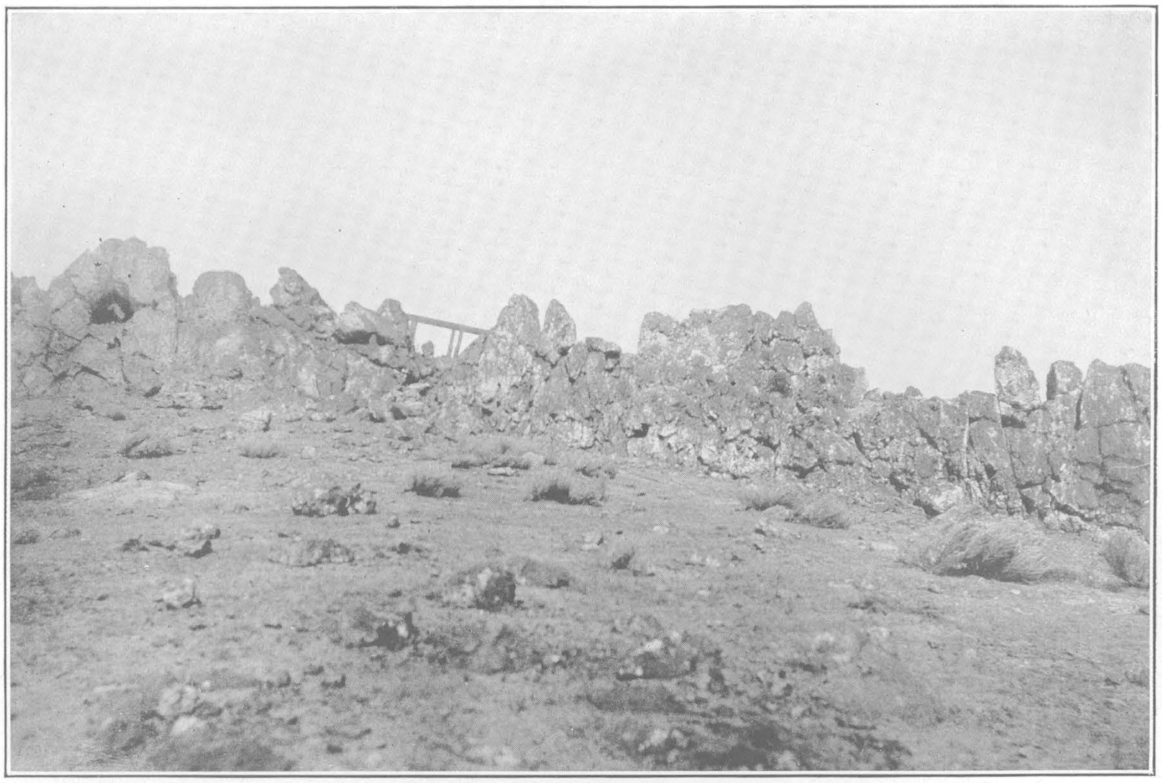


FIGURE 20.—Thin section of altered quartz monzonite, showing grains of intergrown pyrite (2) and magnetite (1); 1,900-foot level Mountain Con. mine. Plagioclase completely, orthoclase partly, and biotite about half sericitized; hornblende wholly gone over to chlorite; magnetite, pyrite, and hematite as accessories.

PARAGENESIS.

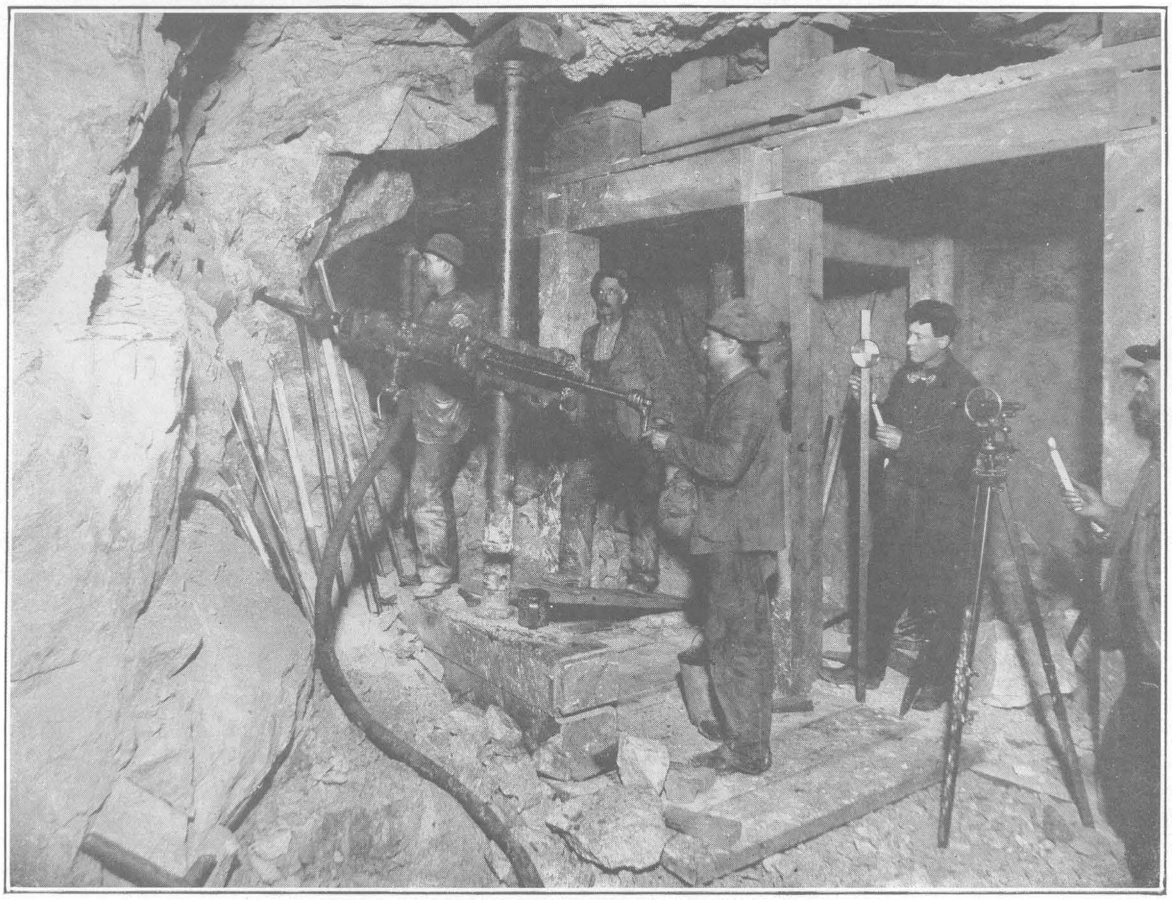
The relations of the ore minerals to each other are well shown in the Leonard and Gagnon mines. In the Gagnon, bornite cements crystals of quartz in the middle of the ore body and fractured quartz-pyrite ore in vein walls. It is the last mineral formed in vugs. With depth it becomes more abundant and carries an increasing amount of silver. It is particularly plentiful in the 400 to 800 foot levels of the Gagnon and in the middle vein on the 800-foot level. In all the veins blende is abundant, but appears to be somewhat less so in depth. Enargite comes in with depth and in the westward workings. It carries a large amount of silver and is distinctly associated with the fault veins. Glance is not characteristic of the Gagnon workings, although found in much of the ore. In the fault veins pyrite is argentiferous, carrying an average of 300 ounces of silver per ton; in the normal quartz-pyrite veins it carries no silver.

The ore from the Greyrock vein (1,600-foot level of the Diamond) shows radiate clusters of quartz crystals in a high-grade ore composed of a dense mixture of glance and bornite intergrown with pyrite. The bornite is not crystalline but occurs in scattered grains whose surface indicates etching. The pyrite from this vein shows evident shearing; the breaks are cemented by numerous parallel barlike masses of intergrown and later-deposited quartz, spotted



A. OUTCROP OF ANCIENT LODE, A SILVER QUARTZ VEIN, BUTTE, MONT.

See page 83.



B. PARROT MINE, FACE OF 1,600-FOOT DRIFT EAST.

Shows solid quartz-pyrite ore. See page 107.

with glance. On the same level the first station north of the shaft shows a vein composed of bornite and pyrite replacing granite, with little or no quartz.

The following conclusions concerning the paragenesis of the different minerals is based on all the observations so far made in the Butte district:

Chalcocite is generally secondary, but in places primary.

Enargite is generally primary, but in places in part secondary.

Bornite is partly primary, but largely secondary. Chalcocite altered to bornite is very common.

Chalcopyrite is largely secondary, but is also primary in veins and is certainly primary in granite.

Tetrahedrite is primary, but is found only under conditions indicating mineralization by later waters. Fractures in it are filled by enargite, glance, and quartz, so that it must be older than these minerals. It occurs in the 1,600-foot level of the St. Lawrence mine and in lower levels. It is also found in the 1,000-foot and 1,200-foot levels of the Leonard and the Mountain View.

Hübnerite and wurtzite are found in the Leonard and West Colusa and in the Shannon mines, as well as in the Gagnon. Everywhere they are associated with fault veins. They occur only in the deeper levels, the highest occurrence being in the 600-foot level of the Leonard; mostly they are found from 900 feet down.

Wulfenite is found in the Anaconda vein in little seams in the 1,200-foot and 1,400-foot Pennsylvania workings east of the Mountain View fault.

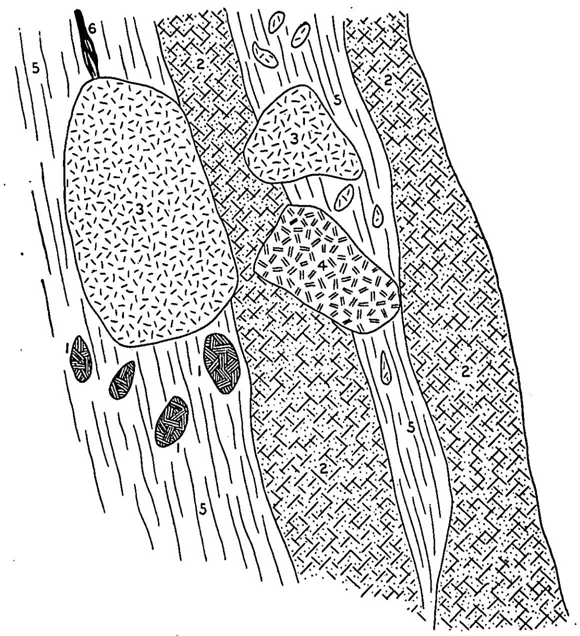


FIGURE 21.—Enargite (2) and chalcopyrite (1) in a quartz-pyrite vein; granite (3), zinc blende (4), crushed rock and clay (5), fluorite (6); 1,100-foot level of Leonard mine, Butte, Mont. Natural scale. After Bard.

Chalcopyrite pseudomorphic after glance occurs as a change from glance to bornite and bornite to chalcopyrite.

Specimens show enargite crystals entirely inclosed in a blanket layer of chalcocite and mossy glance; some cracks in this enargite are filled by gypsum crystals.

Some crystals of copper glance an inch in diameter occur, especially in the deep levels of the Leonard mine. These are commonly cracked and altered, and the cracks sometimes contain chalcopyrite. It is believed that these large crystals are now decomposing as a result of saturation by mine waters and that chalcopyrite is being deposited in these cracks by descending ferruginous waters.

CHAPTER VII.—ROCK ALTERATION.

Throughout much of the district the rocks are altered both on the surface and in the underground workings. The areas of altered rocks are more fissured and the rocks in them more shattered than those of the less altered or fresh rocks, but the later fault veins cross all of them indifferently. Generally the surface rocks, both granite and rhyolite porphyry, are thoroughly decomposed and netted with irregular quartz seams. In general, it may be said that the alteration is not confined to the immediate vicinity of the lodes, that it is not uniform, and that, although it extends over a large part of the district, it is most intense in the productive areas; fresh normal granite, however, is found in places between the highly altered rocks.

ALTERATION OF BUTTE QUARTZ MONZONITE.

WEATHERING.

To determine what changes, if any, are accomplished in the ordinary weathering of the Butte quartz monzonite, an analysis of a coherent but quite friable rock has been made. The material, which is typical of that commonly seen in natural exposures, is rather lighter in color than the perfectly fresh rock and has a clayey odor when moist. The greenish plagioclase and pinkish feldspar have been bleached to a dull white or waxy tint. In the still more altered rock and in the sands formed by its crumbling the white minerals are stained by iron rust. In the rock analyzed the biotite is partly fresh and unaltered, but many of the grains are dull and lusterless and others are altered to green chlorite; more rarely the cleavages are coated with iron rust. The hornblende shows most alteration. Some of the grains are fresh, but most of them show masses of ocher and are penetrated by films of it along cleavages, and the grains all show more or less chlorite as the first stage of alteration. These changes all indicate simple hydration and oxidation of the rock and should accordingly be revealed in the analysis.

The following tables show (1) the average composition of the fresh Butte quartz monzonite, (2) the composition of the disintegrated material, (3) the percentage of each constituent lost, and (4) the percentage of each gained.

Analyses showing effects of alteration of Butte quartz monzonite by weathering.

Constituents.	1. Fresh rock.	2. Altered rock.	3. Loss (—) or gain (+).
Silica	64.03	65.14	+1.11
Titanic dioxide	.60	.59	— .01
Alumina	15.58	15.63	+ .05
Ferric oxide	1.96	2.37	+ .41
Ferrous oxide	2.83	2.13	— .70
Manganese oxide	.11	Trace.	— .11
Lime	4.20	3.62	— .58
Magnesia	2.15	1.85	— .30
Potash	4.11	4.29	+0.18
Soda	2.76	2.63	— .13
Moisture combined	.73 } .96	.75	+ .02
Moisture below 110°	.23	.37	+ .14
Baryta	.07	.10	+ .03
Strontia	.04	Trace.	— .04
Phosphoric pentoxide	.18	.16	— .02
	99.58	99.63	....

The fresh rock contained a little chlorine (0.17 per cent); the disintegrated rock has none. The fresh rock held 0.06 per cent sulphur (as pyrite), the altered rock 0.05 per cent SO_3.

The changes in the character of the rock are largely physical, and its disintegration is due to the rapid expansion and contraction to which it is subjected by the extremes of temperature characteristic of the climate and to the few chemical changes that result from the penetration by moisture of the minute cracks formed by this expansion and contraction. Yet the chemical changes themselves, slight as they appear to be, aid this disintegration, as there is an increase of volume when the molecules become oxidized and hydrated.

The analysis shows remarkably small chemical alteration. It is evident also that the process is not the normal one of weathering, since silica is not lost. The presence of sulphides in the rock itself, the proximity of mineral veins, and the almost constant presence of sulphurous acid formed in the atmosphere, which would of course acidulate the rainfall, probably account for this abnormal nature of the weathering. Under such circumstances none of the constituents of the rock are constant, since they could all partly go into solution. As, however, an increase of silica could not take place, this substance must either decrease or remain constant, and the analysis can be best compared by assuming it to remain constant.

VARIATIONS NEAR BORDERS OF MASS (CONTACT ALTERATION).

The first two analyses of the table (p. 33), the principal constituents of which are given below, represent the compositions of two lamprophyric contact facies of the batholith. The rocks grade into the granite, though the transition is rapid. More often such rocks occur as intrusions in the altered sediments about the border of the batholith. The rock of the first analysis might be called a diorite. It consists mainly of stringy green hornblende which appears to be derived from augite, of small zonally built basic plagioclase feldspars, and of a very little quartz. It is a nearly black, coarsely crystalline rock and is of an unusual type. It is intrusive in phyllites and schists on the summit of Red Mountain, 16 miles south of Butte.

The rock of the second analysis is fairly typical of that at the batholith contact in many localities. It is dark gray and granular and is rather finer grained than the granite, into which, in some places, it insensibly grades. In composition it is a very basic diorite, approaching a hornblende gabbro. The hornblende is stringy and uralitic, its pale green passing into deeper green and into colorless forms. Brown biotite is rare. Orthoclase is present in small amount and only in interstices between more idiomorphic plagioclase. The latter, which shows an extremely fine zonal structure, varies between labradorite and albite, and perhaps generally has an average composition corresponding to andesine. A very little quartz is also present. Apatite and iron ore are present as accessories.

The rock grades into one consisting of zonally built basic plagioclase, in small idiomorphic crystals equal in amount to that of the combined dark-colored constituents, and containing some brown pleochroic biotite and hornblende derived from light-colored pyroxene, remnants of which still remain.

Analyses of basic border phases of the Butte quartz monzonite mass.

	Montana.		Basic quartz diorite of Sierra Nevada.		Montana.		Basic quartz diorite of Sierra Nevada.
	1	2	3		1	2	3
Silica	49.22	56.41	57.00	Lime	10.56	8.66	6.24
Alumina	12.02	17.62	17.46	Soda	1.90	3.25	2.94
Ferric oxide	2.77	1.24	1.12	Potash	1.70	2.61	2.02
Ferrous oxide	8.80	3.55	5.08				
Magnesia	9.20	3.97	4.06		96.17	97.31	95.92

1. Basic diorite from Red Mountain, 16 miles south of Butte.
2. Dioritic rock, Red Mountain, 16 miles south of Butte.
3. Rock described by Turner.

METASOMATIC ALTERATION.

The metasomatic alteration of the rock, called sericitization by Lindgren,[1] consists in a more or less complete transformation of the hard dark-colored rock into sericite, the microscopically fine-felted variety of muscovite, which forms a softer, bleached, dull-white or gray claylike or talcy mass. In this process the biotite and hornblende are the first minerals attacked; chlorite

[1] Lindgren, Waldemar, Metasomatic processes in fissure veins: Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 578.

is formed, which also alters to sericite; the feldspars become clouded, the plagioclase suffering before the orthoclase, and both finally alter to a mass of sericite fibers; the iron of the magnetite combines with biotite and hornblende to form pyrite; and the titanite alters to rutile. Much of the altered rock seen at the surface is silicified, but this is a later phase, rare in depth. The minerals are usually attacked along cleavage planes and cracks, all stages of alteration being seen in the less-altered rocks. The development of kaolin is a different and later process, probably due to surface waters, and it is accompanied by chalcocitization.

Under the microscope the altered Butte quartz monzonite is a mass of sericite and quartz. In intermediate stages the outline of the feldspar crystals is still recognizable, although the feldspar itself is completely changed to sericite and the ferromagnesian minerals are indicated by pyrite grains clustered about remnants of chlorite. The original quartz is partly etched and replaced by sericite, but in all cases a large proportion of the original material is still present. The hornblende and biotite have altered to sericite and limonite. The rock as a whole is peppered with pyrite, either arranged in chains around nucleal remnants of the altered ferromagnesian minerals or scattered without order through the quartz-sericite mass. In some specimens secondary quartz is seen in threads and saclike masses scattered through the sericite. The sericite itself varies in structure from fine to coarsely fibrous forms and as a whole has a mottled and patchy appearance. Plagioclase alters more readily than orthoclase, apatite and zircon are unchanged, ilmenite alters to rutile, and fluorite is introduced in a few cases. The ferromagnesian minerals, though completely altered, have left traces of their former presence by a slight green tinge presumably due to chlorite, by the occasional presence of limonite, and by the coarseness of the sericite formed as the final product of decomposition. In the change of hornblende to sericite, epidote and chlorite form as a transition product. The same is true of biotite and of the earlier stages of the alteration of pyroxene. In the advanced stages of decomposition the rock is merely a mass of coarse and fine sericite fibers, laced together with abundant interstitial quartz. In such rocks no trace remains of the former iron-bearing minerals, but pyrite is abundant; apatite, zircon, and rutile are accessory.

Analyses of the altered Butte rock illustrate the variations in the process of alteration. All the rocks, even the most altered, retain a clearly recognizable structure, so that there is no doubt concerning their derivation. The analyses were made by W. F. Hillebrand and E. A. Allen in the Survey laboratory.

Analyses of fresh and altered rocks from the copper mines of Butte, Mont.

	1	2	3	4	5	6
Silica (SiO_2)	64.03	64.81	56.80	62.09	66.90	54.30
Titanic dioxide (TiO_2)	.60	.73	.60	.51	.68	.61
Alumina (Al_2O_3)	15.58	19.44	21.02	15.49	15.83	13.63
Ferric oxide (Fe_2O_3)	1.96	1.82	3.06	8.52	4.37	1.89
Ferrous oxide (FeO)	2.83	.16	.90		(Fe)	2.22
Lime (CaO)	4.20	.18	.35	.20	.05	7.36
Magnesia (MgO)	2.15	.19	1.21	.42	Trace.	2.13
Potash (K_2O)	4.11	5.30	4.78	4.34	.03	4.41
Soda (Na_2O)	2.76	.21	.50	.37	.08	.16
Water below 110°	.48	1.41	2.88	1.20	.87	2.19
Water above 110°	.73	5.25	7.68	3.01	3.88	4.09
Manganese oxide (MnO)	.11	Trace.	Trace.	Trace?	None.	.71
Sulphur (S)	....	....	.17	5.47	5.46	....
Sulphur trioxide (SO_3)	....	.31	None.	None.	None.	None.
Iron disulphide (FeS_2)	....	....	....	....	....	.49
Phosphoric pentoxide (P_2O_5)	.13	.10	.05	.13	....	.20
Baryta and strontia (BaO,SrO)	.11	.10	(Ba.) .05	Trace.	....	Trace.
Copper (Cu)	....	....	.10	.25	Present.	....
Carbon dioxide (CO_2)	.15	None.	None.	None.	None.	5.50
	99.93	100.01	100.15	102.00	98.15	100.01
Less O	....	....	.06	2.05	....	....
	....	....	100.09	99.95	....	....

1. Fresh unaltered Butte quartz monzonite. The figures given represent the average of four analyses.
2. Altered Butte quartz monzonite. Specimen from the railway cut near Wake-up-Jim mine.
3. Altered granite from 300-foot level of Colusa mine.
4. Sericitized granite, Parrot mine, 1,300-foot level, forms the footwall of vein; specimen 6 inches from vein wall.
5. Altered granite, 1,000-foot level, Leonard mine, forms wall of enargite-bearing vein.
6. Altered granite, north crosscut from 700-foot level of Original mine.

The analysis of the altered rock (No. 2) shows a slight increase in silica, a large increase in alumina, potash, and water, and a loss of almost all the ferrous iron, lime, magnesia, and soda. The almost total extraction of soda is a condition characteristic of the alteration of rocks by vein waters and in accord with the abundance of this element in hot spring waters generally.

These analyses represent practically every important phase of the altered granite of the district. The principal results effected by the alteration consist in a reduction of the rock to a mixture of sericite, pyrite, and quartz. Kaolin occurs in only two of the analyses, Nos. 3 and 5. Calcite occurs in the specimen from the Original mine in a rock in which calcite veinlets are now forming. The silica content shows considerable variation. Compared with the normal granite it shows no change in the kaolinized rock, is increased in the rock of the Leonard mine, and is decreased in all the other rocks analyzed. Alumina has increased in analyses 2 and 3, is constant in analyses 4 and 5, and has decreased in No. 6. Titanium, zirconium, and phosphoric acid are supposedly constant, but the presence of phosphoric acid in the mine waters and in the material deposited by them shows that these elements are attacked during the process of oxidation. Lime and soda have been practically eliminated from the sericitized rocks, and potash either remains constant or shows a marked addition.

The alteration of the rock from the Original mine shows that the waters have been rich in carbon dioxide. The alteration of the other rocks indicates waters deficient in alkaline carbonates, but rich in silica and iron. The evidence indicates that the alteration is similar to that observed in the Morenci copper deposits by Lindgren, whose study showed that the alteration at that place was due to thermal waters. In the present instance the probable source of the deep-seated waters appears to be the rhyolite porphyry. Thin sections of these rocks examined under the microscope show that the alteration of most of the specimens has been normal, and that sericite, quartz, and pyrite make up the rock, with some specimens showing accessory rutile. Analysis No. 6 indicates an entirely different character of alteration, and one which is in operation at the present time.

Study of several hundred thin sections collected from the surface downward to the deepest levels showed no difference either in the character or in the intensity of the alteration. An attempt to outline the areas of decomposed and pyritized granite, as disclosed by the crosscuts from the High Ore, Diamond, Bell, Green Mountain, Mountain Con., and Buffalo shafts, as well as by the great drainage tunnels driven across country, showed in a general way that alteration has been effected in broad zones of somewhat irregular outline not conforming to the course of the veins. This irregularity is observed both in vertical and in horizontal sections. In studying this feature all changes in the granite were marked on the mine maps, and specimens were taken at 50-foot intervals, or nearer, where changes in the rock occurred. Plotting these observations, it is found that the mineralizing waters have spread out through cross fissures from the main trunk channels; thus, on the 1,600-foot level the crosscut between the High Ore shaft and the Bell mine shows almost no normal granite. The altered rock extends for 500 feet west of the Bell shaft and then gradually lessens, and the rock between the Green Mountain and Mountain Con. is a fresh normal granite, with intrusions of aplitic material. As many of the zones of decomposed rock are entirely lacking in veins, it is evident that the alteration has been far more extensive than it would have been had it been confined to the veins themselves.

The altered rock when exposed about the surface weathers readily and crumbles. It has been assumed that this is due to a change of volume, inasmuch as calculations indicate a reduction of 13 per cent in volume in the alteration of orthoclase to sericite and quartz. The formation of pyrite in veins will offset this loss of volume, but it will not be an important factor in the decomposition of the Butte quartz monzonite.

As sericite has not the same specific gravity as muscovite, and as the calculations are based on determinations of the muscovite, it is possible that the rock has visibly increased in volume, owing to porosity due to the leaves and foils of sericite; and hence that the actual bulk of the sericitic rock is equal to that of the sericite plus its accompanying spaces and is therefore greater than that of the unaltered normal granite.

Analysis No. 2 represents a rock that has been sericitized and subsequently altered by surface waters acidified by the oxidation of the pyrite. When collected, the rock was soft and coherent, showed a normal granite texture, in which the outlines of the original grains were still recognizable, but the dark minerals were altered to a very pale-brown lusterless mica, and the feldspar to quartz and an opaque white material soft enough to cut with a knife. Seen in thin sections under the microscope the quartz grains are slightly corroded, crackled, and dull, and the rock is highly altered and opalized, with strings and patches of opaline silica replacing the other minerals. This is in accord with observations at other localities in which the sericitized rock has been changed to kaolin by changes incident to the weathering and degradation of the veins.

ALTERATION OF APLITE.

The alteration of the aplite is entirely similar in nature to that observed in the quartz monzonite, but owing to the different composition of the rock the resulting material is somewhat different in appearance. So far as observed, the process of decomposition has never been carried far enough to prevent the recognition of the prevailing character, the greater proportion of quartz and its peculiar texture being quite sufficient to distinguish it from the bleached and altered forms of the Butte quartz monzonite.

ALTERATION OF RHYOLITE.

The rhyolitic rocks alter readily to decomposition products similar to those of the granite. The dike rocks are found to be largely changed to a white clayey material in which no trace of the original structure remains, and of which origin can be determined only by careful study of the field relations. This alteration has most frequently taken place along planes parallel to the walls of the dike, from which the alteration has extended outward to a degree varying with the density and texture of the rock. In the decomposition of rhyolite, biotite is the first mineral to disappear, and its alteration is accompanied by devitrification of the groundmass. Biotite changes to green chlorite, which in turn alters to limonite; the feldspars change to sericite, and eventually the entire rock is reduced to a claylike, structureless, white mass of sericite and opaline silica. This silica shows a tendency to gather and form irregular masses colored red and yellow by iron oxide.

The rhyolite porphyry has also been sericitized by the vein-forming waters. Analyses of the fresh and altered rock of the Anaconda dike on the 1,800-foot level of the Anaconda mine are given below:

Analyses of fresh and altered rhyolite porphyry (toscanose) of Butte, Mont.

	1	2	3		1	2	3
Silica	69.95	71.01	+1.06	P_2O_5	0.10		
Alumina	15.14	14.37	−.77	S			
Ferric oxide	.38	.18	−.20	SO_3			
Ferrous oxide	.83	.26	−.57	Pyrite	.39	4.37	+3.98
Magnesia	.56	.58	+.02	Cl	Undet.		
Lime	1.45	.10	−1.35	MnO_2	.08	(?)	
Soda	2.70	1.56	−1.14	SrO	.02		
Potash	6.36	4.53	−1.73	BaO	.13		
Water at 110°	.40			SiO_2	Trace.		
Water above 110°	.91			Cu	.03	Undet.	
TiO_2	.24	.24	Const.				
ZnO	.02				100.06	97.20	
CO_2	.37						

Analysis 1 represents the composition of the normal rhyolite porphyry. This rock (toscanose) is not absolutely fresh, as the feldspars are crowded together, and in some places show a little sericite, but the biotite is still fresh and the sample represents the least-altered material of the dike. Analysis 2 represents the composition of the altered rock, whose chief constituents are sericite, quartz, and pyrite. The third column represents the additions and losses of material incurred during the decomposition of the rock. The analyses were made in the Survey laboratory by Dr. W. F. Hillebrand. Examined in thin section under the microscope the altered rock (No. 2) shows sharply defined phenocrysts of quartz in a groundmass of sericite. The latter material is patchy, showing faintly the outlines of former crystals of orthoclase. Elsewhere the sericite is fine and the fibers have no definite order. Pyrite is abundant, occurring in crystals that are often surrounded by a rim of quartz or by a halo of fine sericite. Pyrite occurs mixed with sericite in linear arrangement, as if derived from a prismatic crystal of some iron manganese mineral. Zircon, apatite, and kaolin are present as accessories. From thin sections and from analyses it is apparent that there is a positive increase in pyrite and a great decrease in lime, soda, and potash. Lime has been practically extracted; magnesia has gone to form chlorite; iron has united with sulphur to form pyrite and much more has been added; alumina, generally assumed to be constant in the alteration of rocks, shows a loss of three-fourths per cent; the remainder is all in the form of sericite.

From the analyses and from the study of the rocks it is noticed that the normal sericitized rock shows practically no opaline silica; nevertheless, it is well known that when carbonated waters attack the feldspars of an igneous rock, with the production of sericite, silica is freed. If open spaces exist, silica will migrate and be deposited in the open fissures. If, however, no opportunity offers for migration, the silica will remain and form a finely granular quartz, in places mixed with opal and chalcedony. The silicified rocks found on the surface of the copper-bearing area are, however, mainly due to a secondary change or alteration of the sericitized rock. In this form silica has not been added, but has been freed from its combination with alumina and other elements.

PYRITIZATION.

An important feature of the alteration of the Butte rocks is the formation of pyrite. As already shown, the normal fresh rock contains a very small amount of primary pyrite, estimated at 0.04 to 0.07 per cent. The altered rock, on the contrary, contains from 4 to 6 per cent of pyrite, derived partly from magnetite and partly from the alteration of the ferromagnesian materials. The importance of the formation of pyrite from magnetite is believed not to have been previously understood. The normal rock, when fresh and unaltered, contains from 0.75 to 1.25 per cent of magnetite, and this is the first mineral to change to pyrite. Tiny veinlets from one one-thousandth to one thirty-second inch in width may be seen in rock which is but slightly altered. Under the microscope the alteration is seen to extend outward from these veinlets along minute fractures. The particles of magnetite lying in the one-half to three-fourths inch zone on each side of the veinlet are next entirely changed to pyrite, while farther away, outside of this zone, the magnetite remains unchanged. A comparison of the thin sections of the fresh and altered rock from the same specimen indicates that the pyrite replaces the magnetite and also runs out into the rock itself in thin films and threads, marking microscopic fractures. Such films of pyrite are seen both in the plagioclase and crossing aggregates of biotite and hornblende, and the microscopic fractures are only recognizable when pyrite shows their presence. The veinlets appear to be filled not with quartz but with a recemented crushed material containing zinc blende. As the magnetite of the original rock is almost entirely inclosed by ferromagnesian minerals, the same fissure which afforded access to the magnetite and caused its pyritization would also serve for the replacement of the dark-colored mineral.

The amount of pyrite which could be obtained by the replacement of biotite, hornblende, pyroxene, and magnetite of the unaltered rock may be estimated quantitatively. The mineral composition of the Butte quartz monzonite as determined from thin sections obtained from a surface excavation 20 feet from the Parrot vein is as follows:

Mineral composition of Butte quartz monzonite.

	Per cent.		Per cent.
Quartz	23.17	Hornblende	3.78
Orthoclase	18.62	Pyroxene	1.97
Plagioclase	43.10	Magnetite	.40
Biotite	8.87	Pyrite	.04

Dividing each of these by the specific gravity of the mineral and recalculating to 100 we have the following volumes:

Composition, by volume, of Butte quartz monzonite.

	Per cent.		Per cent.
Quartz	22.55	Hornblende	4.44
Orthoclase	17.57	Pyroxene	2.37
Plagioclase	42.47	Magnetite	.76
Biotite	9.77	Pyrite	.07

From these figures it can be calculated that if all the dark-colored minerals were replaced by pyrite, and no other pyrite introduced, the pyrite would amount to 15.36 per cent of the total volume. This assumption is evidently not correct, because the biotite, hornblende, and pyroxene only yield the iron to form pyrite, their remaining constituents forming other minerals.

VARIATIONS IN ALTERATION NEAR THE VEINS.

In general the country rock is less altered along the hanging wall of the veins than along the footwall side. At the Green Mountain mine the alteration is intense for about 25 feet from the hanging wall; on the foot wall side it extends for a very much greater distance, 50 feet or more at the mine mentioned. The country rock forming the horse between the two streaks of the Syndicate lode shows much more intense alteration than that of the vein walls.

The character of the claylike material in the fault slips, presumably a wet rock powder due to grinding of the walls of the slip, has been determined by analyses, which follow:

Chemical composition of vein and fault clays.

	1	2	3	4	5	6	7	8
Silica	51.6	45.46	51.7	51.3	58.5	46.96	66.9	71.01
Alumina	26.6	39.01	[a] 31.4	....	[a] 26.4	[a] 27.86	15.83	14.37
Magnesia	Undet.	Trace.	1.7	....	....	Trace.	Trace.	.58
Lime	2.9	.1	....	....	....	7.9	.05	.10
Soda	.2	Trace.	.1	Trace.	.1	.8	.08	1.56
Potash	5.1	Trace.	8.2	2.34	4.5	3.67	.03	4.53
H_2O-	1.4	.8	....	.6	2.9	....	.87	....
H_2O+	9.6	[b] 13.98	[b] 6.4	[c] 9.88	6.2	[b] 12.95	3.88	....

[a] Includes a little iron and possibly P_2O_5 and TiO_2. [b] Ignition. [c] Includes sulphur from sulphides.

1. Clay from fault slip in main vein, Original mine.
2. Clay fifth floor above 1,400-foot level east; hanging-wall side of horse and foot wall of vein; Anaconda mine.
3. White clay from glance ore, Middle ledge, Anaconda mine, 1,600-foot level.
4. White clay from vug, 1,200-foot level, Pennsylvania mine.
5. Clay 1,800-foot level, Anaconda mine, O'Neill ledge fault; finest float analyzed.
6. Clay 1,400-foot level, Anaconda mine, O'Neill ledge fault; finest float analyzed; contains 4.37 pyrite and 0.18 Fe_2O_3+0.26 FeO.
7. Altered granite of an enargite vein, Leonard ore body.
8. Altered rhyolite porphyry, 1,800-foot level, Anaconda mine.

CHAPTER VIII.—GENESIS OF THE COPPER ORES.

Study of the Butte ore deposits naturally involves speculation concerning the genesis of the ores and particularly concerning the ultimate source from which the copper has been derived. It is therefore advisable to review the evidence afforded by the mines and to see what conclusions may be drawn from the facts.

PRIMARY SOURCE OF THE COPPER.

CONCENTRATION FROM THE WALL ROCKS.

The wall rocks of the veins contain copper. Chemical analyses of fresh unaltered material show that the Butte quartz monzonite holds copper, though in less amount than the altered rock.

PYRITE.

Almost all specimens of the fresh Butte quartz monzonite show a little pyrite, which, by study of polished surfaces and of thin sections under the microscope, is shown to be primary and an original constituent of the rock. Studies by Cross, Iddings, Pirsson, and Washington[1] show that pyrite is a constant constituent of the Butte rocks to an extent of 0.6 to 1 per cent. Quantitative tests show that this pyrite contains copper.

CHALCOPYRITE IN THE WALL ROCKS.

The presence of primary chalcopyrite in the Butte quartz monzonite was first brought to the writer's attention by H. V. Winchell, who forwarded to him a polished specimen of the rock from the Elk Park quarries, a few miles from Butte. Chemical tests showed this specimen to contain chalcopyrite intergrown with primary rock minerals, and a thin section, examined under the microscope, showed the rock to be fresh and unaltered and the copper mineral to be indigenous. Reexamination of the rocks in the vicinity of the mines resulted in the finding of numerous specimens, which had been previously mistaken for pyrite. On the whole, however, chalcopyrite is present in few places and in scanty amount.

To this general statement one notable exception must be made. The Butte quartz monzonite along the base of East Ridge in the vicinity of Columbia Garden shows a tendency to shade into aplite, with corresponding basic modifications of the magma. In the basic rock pyrite is absent or nearly so, but chalcopyrite is abundant. This is best seen in the material from the deep workings of the Altona, Montgomery, and Bullwhacker mines. So abundant is the mineral that much of the rock contains between 0.5 and 1 per cent of copper. It is notable that in this section of the district copper oxides and carbonates are found in the altered surface rocks, but that chalcocite is a minor constituent, if present at all. The chalcopyrite is largely, if not wholly, primary and shows a marked and constant association with the augite and hornblende as well as intergrowths with magnetite, this last being characteristic of the pyrite.

This occurrence of chalcopyrite as a primary rock constituent is not unique, as it has been previously observed by Lindgren in the rocks of the Grass Valley district, California,[2] and has been reported by Boutwell as probably present in the rocks of Bingham, Utah. In most places, however, where present, it has been assumed or proved to be a secondary result of agencies altering the rocks.

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[1] Quantitative classification of igneous rocks.

[2] The gold quartz veins of Nevada City and Grass Valley districts, Cal.: Seventeenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1896, pp. 36, 94.

COPPER IN BASIC MINERALS.

To determine whether the rocks contain any copper other than that belonging to the sulphides just noted, a sample of the fresh and perfectly unaltered rock, free from sulphides, from the Walkerville quarry was examined in detail. Rock weighing 136.6 grams was crushed, passed through a 100-mesh sieve, and separated as follows by Dr. E. T. Allen in the Survey laboratory: First part, magnetic portion, 2.7 grams; second part, mica, hornblende, etc., 9.9 grams; third part, quartz and feldspar, 124 grams. The mica and hornblende were separated from the quartz and feldspar by Thoulet solution and the magnetic portion by the use of a horseshoe magnet. These samples when carefully tested showed that the rock, as a whole, was 0.006 per cent copper, portion No. 1 was 0.009 per cent copper, and portion No. 2 was 0.047 per cent copper. In other words, the percentage of copper in the basic minerals was nearly eight times as great as the percentage in the whole rock. Expressed quantitatively, the first or magnetic portion contained 0.0243 gram copper and the second or basic portion 0.4653 gram, leaving the remainder (0.33 gram) to be contained in sulphides in the quartz and feldspar. The basic minerals, or 6.5 per cent of the rock, contained over one-half the copper in the sample.

It is therefore believed that the Butte quartz monzonite carries copper, present both as chalcopyrite and associated with or in the ferromagnesian silicate.

SUMMATION.

Although it is known that the unaltered Butte monzonite contains copper it is not probable that the veins derived their metallic contents from the leaching of the adjacent wall rocks, for if this were true the altered rocks must carry less copper than the fresh ones. Hundreds of assays of wall rock and intervein rock made by expert chemists for use in the various lawsuits over mining rights have as a rule shown the presence of a greater amount of copper than is present in the fresh rock. This argues that the hydrothermal alteration of the rocks not only formed the veins by metasomatic replacement but also mineralized the wall rocks to a slight degree.

VEIN FORMATION.

All the evidence seems to point to rock alteration as an early phase of vein formation. Mining operations have shown that the alteration is similar in character at all depths yet attained throughout the copper area, and that it has been carried further quantitatively in the upper levels; that is, intervein rocks that are merely altered at lower levels are converted to ore in the upper levels of some properties.

This alteration is solfataric and is attended by the absorption of potash and sulphur from the vein solutions and the formation of pyrite from the magnetite and iron of the ferromagnesian minerals. Sodium and some silica was lost and, as already shown (p. 87), the granite of the district became a mass of quartz and sericite peppered throughout with pyrite cubes and particles. The fault movements which broke and displaced the earlier veins also strained the country rock and, with the shifting of the fault blocks, produced numerous fractures and a netted jointing, in which circulating waters were able to extend downward to depths of 1,000 feet or more. As a result surface waters are not entirely confined to the veins but, deriving their mineral contents from the oxidation of the upper portion of the veins, pass outward along the fractures into the country rock, where their copper content is reduced by the pyrite of the rock. This condition has led to much controversy in mining litigation, as it is possible in the upper levels of many of the mines to obtain high assay values from the altered rock between the veins, and these values when platted have been used in an attempt to prove an extension of the veins, although no vein structure proper might be recognizable. In the Gagnon mine altered rock between the Steward (or Gagnon) fault vein and the main ledge was carefully sampled and was found to contain not only copper glance, but quartz, pyrite, and sphalerite. The samples showed from 0.4 to 1.7 per cent copper, from a trace to 10 ounces per ton in silver, and from 8.6 to 31.6 per cent zinc. Such rock is properly designated ledge matter, and together with the bounding veins constitutes a lode.

The earliest copper veins of the Butte district are the east-west quartz-pyrite veins that have been formed along lines of fracture by replacement of the country rock. In the eastern part of the district the transition from vein to wall rock is indistinct, the mineralization fading gradually into the wall. In the western part the evidence is complicated by the presence of fault slips and clay selvages. The observed facts show that the primary ores were formed by hot ascending solutions, which not only attacked the rocks and replaced them by quartz and pyrite (see fig. 22), but also formed the broad zones of decomposition or sericitization of the granite that constitute the most pronounced feature of the mineralized area. In the region about the Rarus mine, where mineralization has been intense and the veins are close together, the entire country rock is altered, pyritized, and more or less impregnated with copper (fig. 23); practically no fresh unaltered granite remains. Farther north the belts of decomposition are separated by narrow strips of unaltered granite, which becomes increasingly abundant northward until in the vicinity of the Black Rock and Niagara claims the rock shows well-marked jointing, the dominant fissures running parallel to the veins and sheeting the rock. In this locality the mineral veins are merely mineralized joint planes and the intervening rock is but slightly altered.

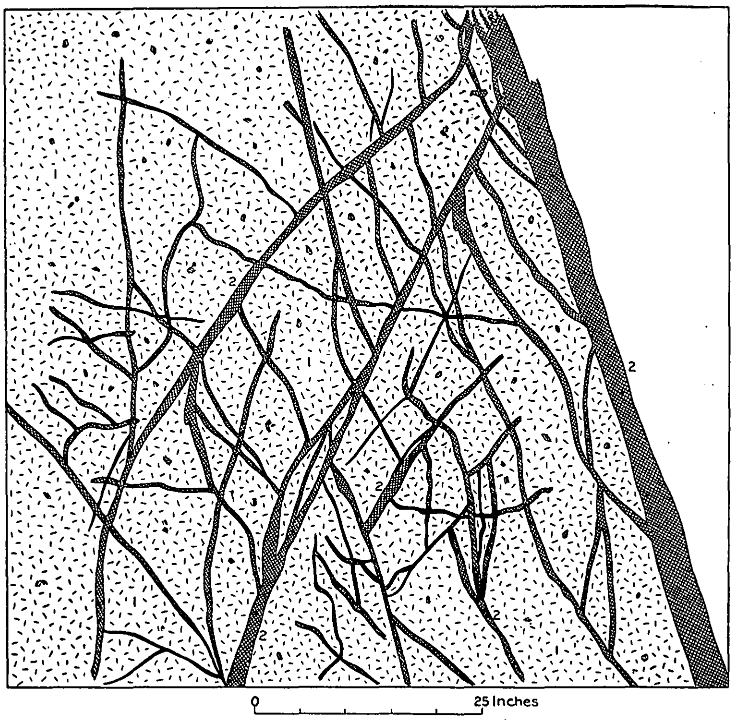


FIGURE 22.—Veinlets of chalcocite (copper glance) (2) netting pyritized granite (1), on 1,000-foot level of Leonard mine; one-tenth natural scale. Only the larger veinlets are shown, the small ones being too numerous for representation. (Sketch by Bard.)

As already stated (p. 87), this solfataric decomposition antedated the fault fissures. It is true that the latter have been accompanied by more or less rock decomposition, but it was neither as intense nor as widespread as that of the earlier period. The earlier quartz-pyrite lodes carried comparatively little copper in the primary vein filling. In fact, many of these veins were unfractured and consequently not enriched; the vein filling is unworkable, consisting of a mass of pyrite and quartz, carrying less than 1 per cent of copper. The evidence indicates, however, that the gradual weathering and degradation of these great masses of extremely low-grade material has furnished the copper for the down-seeping waters which have formed the ore bodies that have made these veins the greatest copper producers of the entire world.

GENETIC RELATION OF THE RHYOLITE PORPHYRY TO THE COPPER.

Several observers who have investigated the Butte copper mines, particularly those who know them best, believe a genetic relation to exist between the rhyolite porphyry and the ore deposits. It is, however, difficult to adduce convincing grounds for this belief, though the fact that the porphyry occurs in dikes whose course corresponds in general to that of the principal veins, gives some basis for assuming that it was the ore-bringer. The rhyolite porphyry, however, is found only in the eastern portion of the copper area, where it is younger than the granitic rocks and older than the veins, since even the oldest veins cut through it. It has been altered by sericitization, but less profoundly so than the granite. Moreover, where the veins cut through the porphyry, they are lean and narrow; and the big ore bodies of the Parrot, Gagnon, Steward, and Syndicate mines are not very near any known bodies of it. The porphyry may possibly have supplied the mineralizing vapors which altered the rocks and which caused vein formation, but no such evidence has yet been found as that observed by Lindgren in the Morenci (Ariz.) deposits, where the quartz phenocrysts of the porphyry contain fluid inclusions similar to those in the vein quartz.

GENETIC RELATION OF THE APLITE TO THE COPPER.

Careful observations throughout the mine workings have failed to establish any relationship between the occurrence of aplite and ore or to show that the aplite has played any part

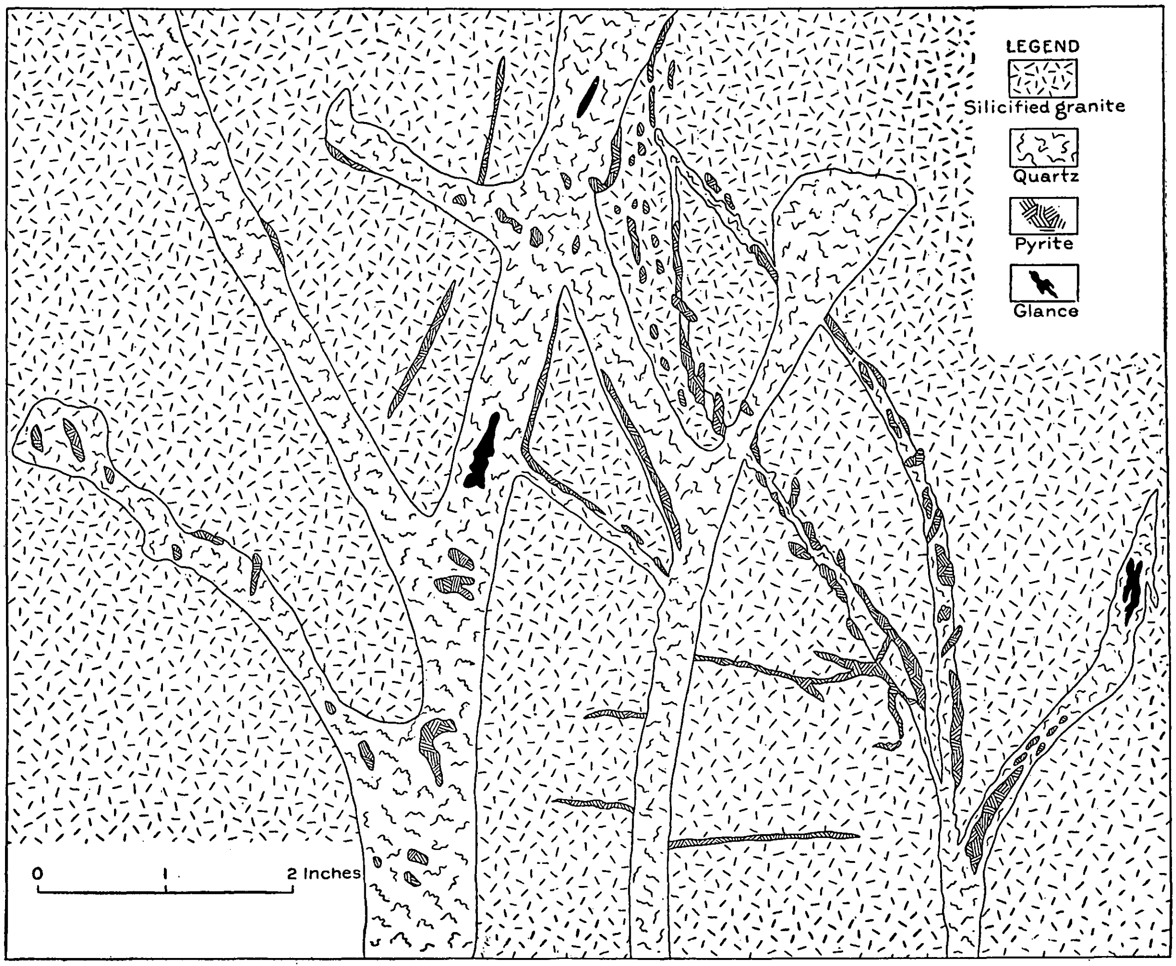


FIGURE 23.—Quartz veinlets in silicified granite; 1,000-foot level, West Colusa mine; natural scale. The saclike terminations of the veinlets are typical of replacement. Pyrite appears later than quartz, and chalcocite fills minute vugs in veins. (Sketch by Bard.)

whatever in the mineralization of the district except to act as an uncongenial country rock which fractures with difficulty and in a different manner from the granite, and, not being easily replaceable, always serves to impoverish the veins. In the northern tier of veins the aplite appears to be much more abundant in the deeper levels than on the surface, but its relationship is the same and no conclusions can be based on its presence. The mere fact, however, that the aplite is abundant 2,000 feet or more beneath the surface is conclusive evidence that the aplite bears no definite relation to the former cover of the granitic mass, and that consequently the theory advanced by Lawson for the Ely (Nev.) deposits, is not applicable here.

CONCLUSIONS.

The question as to the source of the copper in the lodes is complex, as the amount of copper present in the altered rocks is in excess of that in the fresh rock and there is no body of leached rock from which this excess of copper could have come. The evidence seems to indicate that the alteration of the rock and its impregnation with copper are due to a common cause, and that copper has been added to the rock, together with silica and iron, the two other constituents which are so abundant in the altered granite.

Though the evidence is not conclusive, it is believed to indicate that the copper and other metals of the quartz-pyrite veins are derived from magmatic emanations coming from a deep-seated mass of igneous magma. The rhyolite porphyry intrusion appears the most probable. A second and later mineralization occurred at the time of the rhyolitic eruption, forming the silver veins and the ores of the Blue vein and other fault vein series.

CONCENTRATION PROCESSES.

UNDERGROUND WATER.

AMOUNT.

The annual precipitation in the district is meager, averaging less than 20 inches, and the run-off is great, owing to the bare and steep slopes, so that much of the local rainfall and snowfall either runs off or is evaporated before sinking into the ground. The disintegrated granite and the sandy débris, however, form an extremely porous receptacle, catching and holding much of the rainfall. Moreover, the district is depressed compared to its former altitude above sea level, so that the old valley that held the trunk drainage is now filled to a depth of several hundred feet with débris, making a vast natural reservoir. These facts account both for the water encountered at the shallow depths in all the mines first opened and for the large amounts of water pumped from the deep levels, inasmuch as the fault fissures form open channels by which the deep-seated waters have access to the mine workings.

MOVEMENT OF UNDERGROUND WATER.

Practically all the mine waters are actually descending (fig. 24). In a few places rising water was encountered at the deep levels, for instance, on the 2,200-foot level of the Mountain Con. mine and on the 1,600-foot crosscut of the Anaconda (where uprising waters were encountered some 2,000 feet from other workings), but the outflow diminished in a few weeks and finally all but ceased, indicating that the area from which the water came was probably drained. The long crosscuts driven to connect various mines all indicate descending water. In opening new ground along a vein the workings, no matter how wet at first, gradually dry out, and the minerals indicate arrested deposition of material. These facts all show that the underground waters are descending. Their distribution, however, is not as uniform as would be natural if the ground were uniformly or equally fissured. The long crosscuts north from the Speculator mine cross a belt of dry granite before encountering the second wet belt, in which the Jessie vein occurs.

In the Green Mountain and Mountain Con. veins the mine waters are all descending. In opening up new ground the amount of water always seems to be proportionate to the block of ground opened up—that is, the ground between the new level and the old working above. If the waters were ascending the deepest level would always be wet, whereas, in fact, it becomes quite dry soon after being opened; water comes into it only at the heading where new ground is being opened. In the 2,000-foot level of the Mountain Con. the vein at the "face" and near-by shows by its very distinct watercourses, its loose and open texture, its content of skeleton crystals in vugs, etc., that it has been but recently the seat of descending currents of water which have both dissolved out mineral matter and deposited mineral matter. The quartz is the latest-formed mineral, but bunches of glance occur with it. The ore body shows skeleton-like residuals (?) of rich mineral and nests of newly deposited mineral. As the face dries the quartz loses its vitreous character and assumes a frosted, somewhat opaque appearance resembling ground glass, similar to the siliceous hot-spring deposits of the Yellowstone, notably the sinter deposits of the Coral Spring at the Norris Geyser Basin. This hot-spring deposit when removed from the water is a pellucid glassy substance, but on exposure to the air for a few weeks becomes dull and opaque and generally cracked, through changes incident to the loss of water. An attempt was made to sketch the face of the 2,000-foot Mountain Con. level, but it was abandoned owing to the excessive amount of detail and the impossibility of showing it for the entire vein. Its appearance was exactly that of a saturated body from which the water had suddenly drained away.

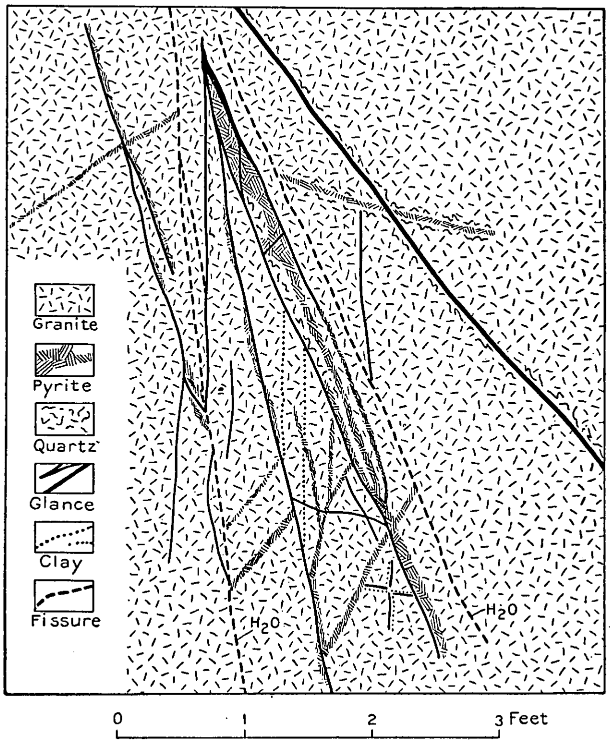


FIGURE 24.—Successive fracturing of pyritized granite, 1,000-foot level of Leonard mine. The earliest fractures are filled with pyrite and quartz; these are broken by later fissures now filled by glance, and these in turn cut and dislocated by joint or movement planes carrying water. (Sketch by Bard.)

The few records of "first water" for the older mines appear to locate it at about the upper limit of the sulphide ores. This upper limit varies greatly, ranging from about 20 feet to 400 feet, being in part independent of the surface level but varying with the degree of fracture.

In the granite, the network of lesser fractures, and the veins and faults are apparently all filled with water and serve as a vast reservoir. That this water has a natural level not far below that of the neighboring valleys is evident, and that it is moving slowly downward can not be doubted, though it can not be readily proved. The conditions of mineralization afford some evidence; and in the East Ridge region, where higher collecting ground exists, the springs became dry when the Altona mine was pumped out to a depth of some 200 feet, proving a connection between the mine waters and surface drainage. The drying out of the upper workings of some of the mines when the surface seepage is eliminated shows that in these mines the waters come from above. In short, all the evidence shows that the waters are surface waters seeping downward. They come, however, from a broad area, and not from the surface of the Butte mines alone.

OUTCROPS.

Surface waters decomposing the abundant pyrite of the Butte quartz monzonite, with the formation of sulphuric acid and ferrous sulphate, have produced most important results not only in the country rock itself but also in the mineral veins. Oxidation processes in the sericitized granite produce mainly kaolin and free silica, but in the veins and in the mineralized rock adjacent to them they attack the unoxidized pyrite and any other sulphides that are present. At the same time the ferrous sulphate oxidizes to ferric sulphate, which also attacks the pyrite and other sulphides, and the series of chemical changes thus initiated usually results in the formation of limonite.

At Butte iron caps are wanting in the copper area, but it is probable that they were formed during the earlier stages of alteration and removed by subsequent erosion. At one point on the East Colusa vein there is a gossan outcrop, but in general the copper veins have inconspicuous or ill-defined outcrops. The recognizable outcrops show but little limonite or other iron ore, and in most cases but little copper staining. The Parrot and Original claims showed an absence of vegetation, and scattered fragments of copper carbonates were prominent along its course. The Syndicate lode has a scanty scattering of carbonates and oxides. The other great veins of the camp on Anaconda Hill show no indication of the copper below, their upper portions consisting of more or less crackled or broken, somewhat rusty quartz, rather solid, though often showing pitting due to the oxidation of pyrite. This indicates that the waters seeping downward soon lost their oxygen and that subsequent changes were due to ferrous sulphate and dilute sulphuric acid. Such waters attack other sulphides, and the oxidation of blende, glance, chalcopyrite, etc., is a small but far from negligible factor in the changes that result.

The absence of an iron gossan on the outcrop of the veins, or between the surface and the sulphide zone, shows that the upper part of the vein now seen is not the residual material of a lean pyritic ore. It is therefore probable that the conditions here are similar to those observed at Morenci and to some extent at Bingham, and that gradual erosion worked down and removed the true gossan, thus exposing a secondarily enriched part of the vein to oxidizing waters, the copper going into solution and seeping downward; the iron having already been removed by replacement no limonite was left to mark the change.

At Rio Tinto in Spain the ore body, which consists of solid pyrite devoid of silica, carries films and specks of glance in the pyrite. In this ore the copper is readily leached out by water alone, and in fact water is now used for the extraction of copper.[1] The reactions involved are simple; ferrous sulphate, cupric sulphate, and sulphuric acid are formed by oxidation, and the abundant pyrite keeps the iron in a ferrous state, so that no gossan is formed. It is evident that similar conditions prevail in the enriched portion of the Butte veins. At any rate the vein outcrops can not always be definitely located at present. The quartz-pyrite veins are often distinct, though not conspicuous, but the glance-enargite veins in altered granite can rarely be determined in outcrop; where upraises have been driven to find their apex, it is found to consist merely of kaolinized granite cemented by stringers of quartz. Indeed, one may infer from the absence of limonite that the barren quartz found between the surface and the big ore bodies is the result of oxidation of chalcocite and pyrite only.

The descending waters became charged with ferrous, cupric, and zinc sulphates and have an acidic reaction. All three of these salts are easily soluble in water and all three are carried by the moisture of the air circulating in the mine workings. Such air deposits its moisture by chilling, and as a result many of the old mine workings are coated by efflorescent deposits of zinc, iron, and copper sulphates.

It is important that the exact nature of the mine waters be understood, as it is evident from the field relations that the rich ores, the bonanzas of copper glance which have made the district so famous, are the result of descending waters either wholly or in part.

COMPOSITION OF MINE WATERS.

By W. F. Hillebrand.

In the following table the analyses represent practically every type of water found in the underground workings. The waters represent a wide variety in derivation and in composition and the analyses are therefore of more than ordinary interest. The waters analyzed were collected by G. W. Tower, then of the Geological Survey, but not all at the same time. Samples A to E were collected and analyzed in 1897 and I and F in the winter of 1901–2. Samples I and F were filtered in the mine into clean glass-stoppered bottles and promptly sealed. It is not known whether the others were filtered or not, but the analyst's notes show that the

[1] Jones, C. H., Trans. Am. Inst. Min. Eng., vol. 35, 1905, p. 3.

bottle containing A was closed by a cork stopper, and the inference is plain that the bottles containing B, C, D, and E were similarly closed.

In Washington it was found that sediment varying in color and amount had formed in each sample. The solution and sediments were analyzed separately except as to the free sulphur deposit from sample A, but the data thus obtained are combined in the analytical tables, since the sedimentary matter was originally in solution. The analyst has considered in his calculations the iron to be in a ferrous state, except in E, where it was found to be ferric. Where the bicarbonate radicle appears the amounts have been calculated to meet the requirements. Samples E and F are acid waters and naturally carry no carbonates. Samples I and D showed by analysis enough carbon dioxide to form bicarbonates with all of the available metals and to leave an excess of free carbon dioxide. A trace of bicarbonate with much free carbon dioxide is indicated in A, but in this case there was considerable reduction of sulphates after bottling. Samples B and C contain both carbonates and bicarbonates and as it was impossible to fix the relative amounts neither the normal nor the bicarbonate radicle is entered in the analytical summation. Where total carbon dioxide is represented in excess of that required for bicarbonates the excess is assumed to be free. Because of evident decomposition in sample A, as evidenced by the character of the deposit formed after bottling, no great importance is to be attached to the calculated values for the bicarbonate and sulphate radicles.

No better illustrations can be offered of the futility of making detailed analyses of waters that have not been collected by an experienced chemist, who alone can be depended on to observe all necessary precautions. The use of a cork stopper, for instance, makes impossible any conclusion as to the cause of the chemical changes in sample A. The origin of much of the deposit in F is likewise put in doubt by the fact that common gray filter paper was used for filtering the water in the mine.

Sample I, from the 2,200-foot level of the Green Mountain mine, was taken to represent as near as practicable the composition of the water of the deep levels of the district. It is from a fissure in normal granite remote from any known veins and far from any old mine workings, coming from a fissure tapped by a newly opened crosscut the day before the sample was taken. It is a very weak water carrying sulphates and some carbonates of calcium and magnesium, sodium and potassium, stated in their relative order of abundance. Its specific gravity at 15° C was 1.00105 and its reaction faintly alkaline. The water is unlike river water in that it contains calcium sulphate in large amount. Sample A came from the 220-foot south crosscut of the Glengarry mine and represents water from the upper part of the earth's crust in the vicinity of the workable ore deposits. The water deposited some ferrous sulphides and sulphur. Sample B came from the 800-foot level west of the Anaconda mine. It is faintly alkaline and may be fairly assumed to represent the water descending through that great vein at a point beyond the reach of oxidizing influences. Sample C, taken from the Gagnon, on the 1,800-foot level 1,125 feet south of the shaft, is also a rock water and not a vein water in the ordinary sense. Sample D from the Nettie mine, taken from the 300-foot level at the end of the crosscut north, represents the composition of the waters found in the silver mines. Sample E, from the 1,200-foot level of the crosscut of the St. Lawrence mine 90 feet from the shaft, is faintly acid and represents the waters descending along the quartz-pyrite vein. Sample F from the Mountain View mine, second level, is exceptional; it is perfectly clear, deep blue in color, and comes from surface waters seeping down from old stopes. The water has formed stalactites and stalagmites of perfectly clear and transparent chalcanthite, showing that it is probably a saturated solution. In comparing the analyses taken from these different points and representing such very unlike conditions, there is a wide variation observable in all the constituents, particularly in the amount of zinc, alumina, and iron. Sodium chloride is present in small amount. Aluminum is absent from five of the samples. Iron. manganese, and zinc occur in these five in small amounts.

Analyses of underground waters from the mines of Butte, Mont.

[Parts per million. Analyst, W. F. Hillebrand.]

	I.	A.	B.	C.	D.	E.	F.
SiO_2	23.2	27.2	36.1	29.5	55.8	47.7	67.4
TiO_2						None.	Trace.
Ca	151.2	92.7	49.0	512.1	39.1	132.5	307.7
Mg	28.2	17.9	10.3	102.6	6.7	61.6	149.2
K	7.1	30.5	3.5	11.4	5.0	13.1	6.8
Na	16.2	176.9	11.1	82.8	30.1	39.6	41.7
Li	Trace.						Trace.
Zn	.3	1.8	1.9	None.	Trace?	852.0	411.2
Cd						41.1	
Al	None.					83.5	85.2
Fe''	1.8	1.4	.9	.4	.4		49.8
Fe'''						159.8	
Mn	.5	Trace.	2.5	1.4	.8	12.0	13.2
Co						.5	4.6
Ni							3.5
Cu	Trace.	.4	Trace.	Trace.	None.	59.1	45,633.2
Sn						17.0	
Pb		Trace.	Trace?	None.	None?		
AsO_4	Faint.	Trace?	Trace.	None.	None.		Trace.
PO_4	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	1.5
SO_4	406.5	544.7	90.6	593.4	67.2	2,672.0	71,053.3
Cl	6.8	118.5	11.8	842.8	15.0	13.0	17.7
Organic matter		Consid.	Little.	None.	Trace.	Considerable.	
HCO_3	13.5	Trace.	(a)	(a)	132.0		
	655.3	1,012.0	217.7	2,176.4	352.1	4,204.5	117,846.0
Total CO_2	76.5	167.2	a 59.9	a 73.3	102.0	23.7	9.0

a Calculation shows insufficient carbon dioxide in the bicarbonate state to satisfy the bases, hence both normal and bicarbonates are to be assumed as present and the summation raised to correspond.

I. Green Mountain mine, 2,200-foot crosscut south; from normal granite not near vein. Specific gravity at 15° C., 1.00105. Reaction faintly alkaline.

A. Glengarry mine, 220-foot crosscut south; temperature 70° F. when collected. Very slightly alkaline. Black deposit containing FeS, much free S, and perhaps ZnS, since practically all the Zn found was in the sediment. Sediment black and slimy, stopping the filter pores and turning brown by oxidation before the filtration was complete. The free sulphur was presumably due to the decomposition of sulphates by organic matter. Whether this organic matter came from the cork stopper or was already present the analyst was unable to determine.

B. Anaconda mine, 800 feet west. Very faintly alkaline. Deposit dark brown, probably from manganese, of which it contained one-fourth of the total as well as all the iron.

C. Gagnon mine, 1,125 feet from shaft. Very faintly alkaline. Nearly all the iron but no manganese deposited.

D. Nettie mine, 300-foot crosscut north. Very faintly alkaline.

E. St. Lawrence mine, 1,200-foot crosscut south; 90 feet from shaft. Very faintly acid. Iron all in the ferric state; over one-half of it (but no manganese) in a copious reddish-brown deposit found in the bottle. Titanium, antimony, arsenic, lead, and bismuth could not be detected. The source of the cadmium and tin is a mystery. The tin was all found in the deposit in a condition readily soluble in hydrochloric acid. Over half the iron was found in the deposit, where it existed as a basic sulphate. The excess of basic over acid radicles may be accounted for, in part at least. Possibly, however, the value given for zinc is somewhat high.

F. Mountain View mine, second level; slow drip, forming chalcanthite. Specific gravity at 15° C., 1.1317. Deposit reddish and very flocculent. On treating it with hydrochloric acid a voluminous network of fibers was left which suggested fiber from the coarse filter paper that had been used in collecting the water in the mine. However, after standing in the glass flask in the laboratory for a few weeks the freshly filtered water began to deposit a whitish flocculent sediment which gradually became reddish from iron. Except for the iron it was found to be of organic nature and of fibrous structure as if an organized growth.

The analyses give no proof of the presence of cuprous sulphate. Winchell has, however, found it in testing the mine waters, and his artificial production of glance depends on its presence.

The chlorine content varies widely in the different waters. In analyses I, B, D, E, F, it is no greater than in many surface waters. In analysis A it is high for a surface water, but not abnormal. In analysis C we have a water in which chlorine and sulphuric acid are very high and wholly unlike surface water, there being large amounts of sulphates of calcium, magnesium, sodium, and potassium.

Analyses E and F are the only ones showing appreciable amounts of copper, the latter being a saturated solution of copper sulphate. Analysis E is abnormal. Zinc sulphate is the most abundant salt present, with calcium, magnesium, and alkaline sulphates in lesser quantity. The amounts of tin and cadmium suggest that the waters have attacked some pumping machinery before collection. Iron, aluminum, and manganese sulphates are present.

SECONDARY ENRICHMENT.

GENERAL PROCESS.

The most important work of the sulphate waters is the formation of copper glance by the action of cupric sulphate upon pyrite and to a limited extent on zinc blende. This process, now generally known as secondary enrichment,[1] depends on the reduction of the metals from sulphate solutions by pyrite. The order of the affinity for the common metals for sulphur is

[1] Weed, W. H., Bull. Geol. Soc. America, vol. 11, 1900, p. 179. Emmons, S. F., Trans. Am. Inst. Min. Eng., vol. 30, 1901, p. 177.

as follows: Mercury, silver, copper, antimony, lead, zinc, iron, arsenic, and manganese; the salt of any metal in this series will be decomposed by the sulphide of any succeeding metal and the first metal precipitated as sulphide. In complex solutions the secondary sulphides should be deposited in the following order: Argentite, chalcocite, bornite, chalcopyrite, galena, zinc blende, with pyrite at the bottom. In some silver veins an approximation to this exists, resulting in a vertical distribution of the ores in depth. In the Butte copper mines the silver has probably formed argentite, which has altered to native silver, as frequently seen in the upper levels of chalcocite ore bodies. The relative amount of silver is small, and iron, copper, zinc, and arsenic are abundant. The limit of secondary deposition depends on the fracturing and circulation, and this is not uniform, therefore the simplicity of the operation, as outlined above, does not prevail in the underground workings.

FORMATION OF CHALCOCITE.

Of the secondarily formed minerals copper glance is the most important (fig. 25), it being estimated that up to 1906 three-fourths of the copper production of the district came from this mineral; at present it furnishes about one-half. The glance is not necessarily secondary, but in the Butte mines it is believed to be partly so and to have replaced pyrite as a result of the action of copper sulphate upon pyrite. It has been found, however, that glance alters under the action of oxygen to cupric sulphide; and both glance and covellite can easily be produced by the action of cupric sulphate on unaltered primary sulphides. (See p. 76.)

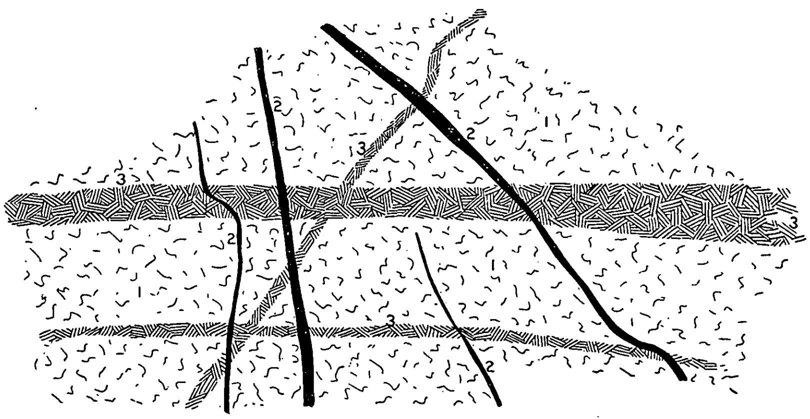


FIGURE 25.—Quartz veinlet (1) shattered and the fissures filled by pyrite (2), and later broken without dislocation, and the fissures filled by chalcocite (glance) (3). Natural scale. Leonard mine, 1,000-foot level.

The following reactions illustrate the change of glance under the influence of oxygenated waters:

$$2Cu_2S + O = 2CuS + Cu_2O$$
$$CuS + 4O = CuSO_4$$
$$CuS + H_2SO_4 = H_2S + CuSO_4$$
$$H_2S + 4O = H_2SO_4.$$

FORMATION OF ENARGITE.

The enargite (sulpharsenate of copper) found in the fault veins is generally primary in the sense that it is indigenous and is not introduced by descending later waters, as is the case with the glance often found cementing fractured enargite. It might be formed secondarily from surface waters if these contained arsenic. But as only traces of the latter metal exist in the waters, and only traces in the pyrite veins of the district, it is impossible to explain the formation of enargite by descending waters whose metallic contents are derived from the weathering of the veins. As surface solutions, however, become more and more basic, and hence reducing and not oxidizing in their action, as they get deeper into the ground, they tend first to deposit glance and deeper down to form enargite. This hypothesis agrees well with chemical facts, but does not agree with the observations made in the district. Thus, for example, the Johnstown (North Connecting) vein of the Mountain View mine shows 6 feet or more of glance ore on the tenth level; higher in the vein, however, enargite appears in greater and greater abundance until on the third level the vein contains practically no glance, its copper being in the form of enargite, which continues up to the oxidized zone. In general, however, the reverse conditions obtain, and greater quantities of enargite may be expected in depth, and have actually been found in the deep levels of the Green Mountain and Anaconda mines.

The general mode of occurrence of enargite throughout the world indicates secondary deposition, for no matter how abundant in the upper levels, immediately beneath the oxidized zone it plays out at a few hundred feet in depth and is replaced by less complex sulphides, mainly pyrite. Such occurrence is noted in Chile, Argentina, Japan, and the Philippines, the other localities where enargite is abundant.

A good example of an old vein enriched by enargite is seen in the Gambetta South vein, where exposed on the 400-foot level of the West Colusa mine. The stopes show a narrow vein of lean, white, dense quartz-pyrite transversed by a strike fault, the mashed granite alongside being impregnated and its cracks filled by solid black enargite, with little or no accompanying quartz or pyrite, and with no apparent alteration of the granite. Between the 400 and 500 foot level the vein shows 2 to 3 feet of solid enargite. A 3-foot streak of glance mixed with crumbly pyrite occurs on the west side. The Gambetta vein itself consists of white quartz with pyrite and nests of enargite, with druses about nuclei. Glance occurs in cracks and films. The amount of enargite present varies from place to place. The vein is cut off by the Piccolo.

Where the east and west veins of the district are faulted by clay seams the location of the rich ores shows clearly whether the solutions come from above, or from below, or from the immediate vein itself. Thus, if they came from above the enrichment would be along the upper side of the clay wall, a condition seen at the Rarus and at the Ramsdell-Parrot. If from below, the enriching solutions would meet the impervious clay wall, would spread out and impregnate the mashed granite alongside of the wall and form ore bodies beneath the fault. The facts observed in the workings along the Blue vein show that the solutions followed the east and west veins downward to the Blue vein and spread out in it. It also appears that the descending solutions spread out over the clay walls of other faults and formed ore bodies. Attention is also called to the difference between the wall rock on the hanging-wall and footwall sides of the east-west veins. The footwall granite shows threads and stringers of glance running off from the vein and down into the rock. The hanging-wall rock does not show such stringers, hence it is inferred that they are due to seepage into the footwall. In a few of the mines the character of the ore shows decided change in passing downward on the same vein. Thus, the Johnstown vein at the Mountain View mine contains glance changing gradually to enargite from the tenth up to the third level, at which last practically no glance remains.

The ore on the 2,000-foot level of the Mountain Con. contained both glance and enargite and what appeared to be sphalerite, although no tests were made. Neither limonite nor copper sulphate was seen. The face was only a week old at the time seen. The vein showed in its eastward extension a very nearly solid mass of quartz and pyrite, or rather of solid pyrite with very little quartz. Wherever the recent white quartz occurs, the vein carries the leached sulphides and is pay ore. In the solid quartz-pyrite vein, however, the values are too low to pay and the ore can not be concentrated, so that in general the pyrite bodies are left unworked. This lack of pay ore in the pyrite, though apparently opposed to the theory of enrichment by descending waters, is in reality evidently due to physical causes—the pyrite vein being solid has not been attacked by waters and its copper leached out and concentrated. Thus, in places where the pyrite vein has been shattered by later movement, but not brecciated, films and stringers of glance will be found in it, generally associated with little threads of quartz, and locally the joint fractures will be coated with an iridescent film of copper glance.

If the rich ores are to be credited to descending waters leaching this great mass of low-grade pyrite the problem is, What becomes of the iron sulphate? Only part of it can be accounted for by the newly formed pyrite, and the concentration must be accounted for quantitatively as well as qualitatively. Thus the pyrite vein, which is perhaps 10 to 40 feet across in the Green Mountain, is so low in copper as to be unworkable, carrying about 2 per cent.

FORMATION OF TETRAHEDRITE.

So far as known, tetrahedrite is rare in the Butte district. It is found in the veins of East Ridge and in the fault veins of the eastern section of Butte, notably at the Gem mine on the northerly or northeasterly border of the copper belt and at the Leonard mine. In other districts it does not generally extend more than 700 feet below the surface, the best-known exception being Cripple Creek, Colo. Its composition makes it quite reasonable to suppose that it is of secondary origin, but thus far no data confirming this opinion have been obtained. In the Gem mine it occurs associated with considerable quantities of fluorite. In the East Gem mine a shoot of tetrahedrite ore is apparently the downward extension of ore in the West Gem mine, where it is unmistakably associated with later fracturing and with an east-west strike fault. This strike fault has so broken up the original vein that it is recognizable only in the rounded quartz and pyrite bowlders which occur in the clay. As no bowlders or balls of tetrahedrite occur, and as this mineral does occur in little veinlets and streaks in the clay, it must be inferred that it is of recent origin. The chalcopyrite with it is shattered and undoubtedly represents the original ore, about which the richer mineral was precipitated, cementing the fragments. A marked feature of all these and the veins of this vicinity is the great amount of zinc which they show near the surface and for 200 or 300 feet down. As depth is gained bunches of galena appear, and this in turn disappears when the tetrahedrite comes in. As these are perhaps on the borders of the copper belt their relation to the silver mines is unsettled; evidence thus far accumulated, however, does not contradict the assumptions, based on the mineral character of the Blue vein and of the different strike faults, that the silver-lead-zinc solutions are more recent than the copper veins, and that they were introduced after a period of fracturing, and that this period of fracturing was probably coincident with the rhyolite eruptions of the district.

MINE TEMPERATURE.

No chemical determination has been made of the mine gases. In general the air in the mines gives no evidence of emanations from the rocks, but in many "dead ends" it is so bad that a candle will not burn, though an acetylene lamp still gives light and a man can live. It is probable, however, that this is due not to carbon dioxide but to the combination of the oxygen of the air with the pyrite, leaving the air unfit for respiration. A loss of 5 per cent of oxygen is regarded as dangerous.[1]

When the mine workings have been on fire the air is bad; even where solid concrete dams have been built to exclude all air from them gas leakages occur and render the vicinity extremely dangerous to many of the men, who differ greatly in their susceptibility to the gases.

The small amount of moisture present in ordinary air is sufficient to take up and carry metallic salts, principally sulphates of zinc, copper, and iron. Walls of dry and long-deserted passages traversed by air currents have become thickly coated with tufts and incrustations of goslarite, chalcanthite, and melanterite. As these efflorescences form on iron, stone, and other solid materials, as well as on the rock walls, they can not be efflorescences due to the moisture of the walls themselves, but must be deposits formed by chilling of the moisture below the dew point.

The deep workings of the Butte mines are all warm, even where ventilation is good, the temperature averaging from 75° to 86° at a depth of 2,000 feet, and being largely independent of the surface temperature. The following observations made in the St. Lawrence mine, under the supervision of H. V. Winchell, have been kindly furnished by him.

Temperatures in the Butte mines.

Level.	Elevation.	Temperature.
Feet.	*Feet.*	*°F.*
200	5,877	45.77
400	5,673	49.55
600	5,471	51.40
800	5,271	69.80
1,000	5,081	62.00
1,600	4,477	74.30

The observations were made with carefully adjusted self-registering thermometers inserted in holes driven in the wall rock and sealed in the hole for 24 hours before reading. The temperature at the 800-foot level is too high, being raised by local gases above the normal.

[1] Köhler, G., Lehrbuch der Bergbaukunde, Leipzig, 1900, p. 674.

CHAPTER IX.—THE VEINS.

INTRODUCTION.

The entire Butte district north of Silverbow Creek, from the low ground near Rocker to the crest of the mountain ridge forming the Continental Divide on the east, is probably traversed by veins. Later rocks, rhyolites, and alluvial sands and gravels cover and conceal these veins over a considerable portion of the district, but in parts of the area the veins are conspicuous features of the landscape. They are not, however, uniformly mineralized, the productive properties being clustered in a comparatively small area.

In considering these lodes the two economically most important features to be treated are their structure and their mineralization. As mineralization follows and is dependent on structure, the structural relations of the veins are as important scientifically as they are from the standpoint of the mine superintendent.

In 1896, when the district was first examined, the broader structural relations of the veins were but partly understood. To-day, however, as a result of the development necessitated by lawsuits, and of the remarkable and detailed work done by the geologic staffs of the mining companies, it is possible to predict almost precisely where veins will be found even in the most intricately faulted blocks. The laws governing the occurrence of workable ore in the veins are, however, as yet but imperfectly known, and the presence of ore bodies in unexplored ground can only be predicted, not assured, from the facts

MAPPING.

On the map (Pl. X, in pocket) the outcrops of the mineral-bearing veins have been platted with great care by the aid of a plane table. This map, which was made by Emmons, Tower, and the writer for the Butte folio,[1] is reprinted with minor corrections. It is, however, deficient in some respects and should be checked by comparison with the maps showing the veins and geologic features developed by mining and reduced to a definite horizontal datum plane (Pls. XIX to XL). Plate XVIII (in pocket) shows the elevations of levels in the Butte mines.

The prominence of an outcrop is by no means necessarily indicative of the economic importance of the vein in depth; many veins that carry large and rich bodies of ore do not reach the surface at all. Where, as is not infrequently the case, the surface is so obscured by débris or buildings that outcrops of well-known veins can not be traced it has been necessary to determine their probable position by projecting upward from the nearest known underground workings. Underground workings, however, as a rule follow only the payable part of the vein, and a vein is often continuous geologically even where it does not carry payable ore. Veins which appear disconnected on the map, but which, from their position and direction, appear to be parts of the same vein, might possibly have been demonstrated to be continuous had the necessary underground drifts been driven or had those that exist been accessible.

It has not been possible, owing to the small scale of the geologic map, to indicate the relative importance of the different veins as ore carriers. Many of the veins represented are not now and may never prove productive. This is especially true of those at a considerable distance from the center of production or on the outer limit of the district.

The map (Pl. X) indicates the position of the outcrops on the present surface and hence fails in some degree to represent the true relationships of the veins. In crossing a hill the line of outcrop is thrown backward and in crossing a valley forward in the direction of the dip, the variation being greatest where the dip is flattest. As the largest veins dip steeply, the

[1] Butte special folio (No. 38), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

distortion produced by inequalities of the surface is generally very slight. At Emmons's suggestion, an attempt has been made to represent the intersection of the veins by horizontal planes. Plates XIX to XL show these intersections, so far as obtainable, on the planes of successive 100-foot contours ranging from 3,600 to 5,600 feet above sea level throughout the area of the copper lodes which have been most extensively and most recently developed by underground working, and about which, therefore, it has been possible to obtain the most complete information. Even here the data are not complete; the maps of some mines were not obtainable; some of the veins have not been developed; and some of the stopes have become inaccessible. The outlines of some few of the ore bodies have therefore been somewhat generalized.

COPPER-VEIN SYSTEMS.

CLASSIFICATION.

The copper veins [1] may be grouped in several well-defined classes which in the main correspond to the principal fissure systems. As shown on the geologic map (Pl. X) and in the series of maps (Pls. XIX to XL) showing the veins projected on the horizontal planes of fixed elevations above sea level, they fall into four recognizable systems; the big mines of the western part of the district, including the Anaconda, Syndicate, and other great producers, derive their main ore supply from large east-and-west lodes; the chief mines of the northern and eastern parts of the district obtain their ores from northwest veins; a number of large and productive mines are situated on northeast veins; some other mines are on veins whose course is N. 65° W.

More in detail the four groups, based on distinctive structural, mineralogical, and physical features, are as follows:

1. The Anaconda (east-west or quartz-pyrite) system, embracing the lode of that name and its displaced portions worked by the Parrot, Original, Gagnon, and Mountain View mines; the Syndicate, including the Mountain Con. and its various spurs; the Colusa-Shannon, Diamond-Bell, Speculator, Modoc, Mat, North Wild Bill, Moonlight, Pennsylvania or South Ledge and its continuation, Penn. No. 3, O'Neill, Enargite, Snohomish, Berkeley, and the veins numbered 4, 14, 17, and 19 of the Rarus mine. The course of the system is practically east and west.

2. The Silverbow or High Ore system, embracing the Silverbow, High Ore, Windlass, Johnstown (North Connecting), and Wild Bill veins, with a course of N. 65° W. This system antedates the Blue Vein system (No. 3) and is characterized by enargite in some of the veins.

3. The Blue Vein or northwest system, including the Blue, Mountain View fault and its extensions, Nos. 7, 10, and 11 of the Pennsylvania mine, Clear Grit, Greyrock, Covellite, Bell or North Greyrock, Jessie, Edith May, and Skyrme veins. The system consists of ore-producing fault veins of a second period of copper-ore formation. It cuts and displaces the veins of the earlier periods (Nos. 1 and 2).

4. The Steward system, including the Steward fault, Caledonia, No. 6 of the Parrot mine, Bell fault, Blue Jay fault and its continuations, Middle fault and No. 16 of the Rarus mine, Tramway, Modoc fault, La Plata vein, and several lesser veins not yet named. The system consists of ore-producing fault veins of a third period of copper-ore formation. The veins have an east to northeast course.

Besides the vein systems there are two fracture systems, not mineralized, but of much economic and scientific importance, namely:

1. The Mountain View system, a series of north-south fissures that are clean cut and persistent, nearly vertical, and contain as their characteristic filling a mass of rounded pebbles from the wall rock, held in a paste of comminuted rock. As the fissures show little or no appreciable faulting they are regarded as the result of shrinkage or contraction or perhaps of settling and adjustment of the fault blocks with very little movement but with considerable grinding of the walls.

2. Rarus fault system, a great fault zone running N. 45° E., accompanied by many sympathetic fractures, which displace all the veins cut by it.

3. Post-Rarus fault fractures.

[1] In the present work, as in the Butte folio (No. 38), the term vein is confined as far as possible to a single mineralized fissure or to the ore body formed along a single fissure, whereas the term lode is applied to an assemblage of ore-bearing fissures so closely spaced that the ore that has formed along and between them may in places be considered to form a single ore body. The principal fissures making up a lode are nearly parallel to each other, but there are also smaller cross fissures connecting them, through which the intermediate rock becomes impregnated with ore until it may constitute vein material. A lode may be only 10 feet wide, or it may be 100 feet or more; and within it are included zones of more or less altered country rock, in places carrying enough values to pay for mining, in other places too barren to pay, in which case they are generally called "horses." An assemblage of veins too widely spaced to form a single lode and yet to a certain extent coordinated into one system is designated a vein system.

The veins of the Anaconda and Silverbow systems are quartz-pyrite veins; those of the Blue and Steward systems are mineralized fault veins. Many of the most productive lodes of the district are compound or composite veins, due to a combination or superposition of the two types in one vein—that is, a reopening of an old vein with deposition of new material. As many of the older veins have been reopened in this way they have the characters of both the quartz-pyrite and fault veins.

The sequence of the vein systems is considered to be as follows: (1) East-west or Anaconda system (oldest); (2) Silverbow system; (3) Blue Vein system; (4) silver veins; (5) Steward system; (6) Mountain View fractures; (7) Rarus fault zone. The enargite veins are of different ages, but are all younger than the Anaconda system.

The four systems embrace practically all the productive veins of the district. It is not certain, however, that all the veins having a similar direction are of the same age. It is known that the district has been an area of movement and fracture ever since the time of the granite intrusion, and has continued so to the present day. The early fractures, though cemented by mineral matter, have been lines of weakness and have been reopened either by direct fracture or during the straining of the rock mass by the faulting of blocks by other crossing fractures.

Grouped according to their mineral content, the veins may be classed as pyrite, quartz-pyrite, chalcocite, enargite, sphalerite, silver-quartz, and fault breccia veins.

ANACONDA (EAST-WEST) SYSTEM.

The members of the east-west or Anaconda system, of which the Anaconda and Syndicate lodes are the best examples, are the most widely-known veins of the district, and for many years in the earlier history of Butte furnished almost the entire copper output.

These veins are of remarkable width and mineralogic uniformity. The larger ones, which have been stoped for thousands of feet along their courses show local variations in richness but no well-formed ore shoots. (See Pl. XI, *A*.) They present abundant evidence of their formation by replacement along shear zones, but their fracturing was not accompanied by displacement, and it is quite probable that their continuity and uniformity of size and character is due to the fact that the vein fissures permitted general circulation throughout the fracture zone, with gradual replacement, unhampered by clay seams, slips, or friction breccia.

The filling is predominantly a dull white or vitreous quartz, carrying abundant pyrite, some sphalerite, and abundant chalcocite, in many places showing rude banding in the arrangement of the sulphides. The ore grades into the wall rock. The lodes are wider in the upper than in the lower levels, as the rock between the constituent veins is replaced by ore in the upper zone. (See Pl. IX, *B*, p. 84.)

The ores are notable for copper glance, which is their most abundant copper mineral, and which, with bornite, enargite, and tetrahedrite, only occurs where the vein has been fractured. The veins lose their secondary glance with depth, even where the fracturing is strong; on this point the Syndicate lode is particularly convincing, for in it good strong streaks of glance are seen to pinch out until finally the glance occurs only as a coating or film on the pyrite. In the large fractured quartz-pyrite veins enargite comes in at 2,000 feet or more below the surface but is not seen at higher levels. It may be due to uprising mineral waters.

The enargite-bearing veins are quite different from the quartz-pyrite veins. Typically they have well-defined walls of granite, but though in many of them a crust of comby quartz intervenes between the enargite and the wall rock, the vein filling is practically devoid of that mineral, the gangue, if any, being altered granite. The enargite runs upward to the oxidized zone, or almost to surface in some veins. It decomposes to a brownish sooty material, and the veins do not show enrichment.

SILVERBOW OR HIGH ORE SYSTEM.

The veins of the Silverbow or High Ore system have a course of about N. 65° W., in places varying to parallelism with the Blue Vein system. Though the veins which name the series are quartz-pyrite veins, in most respects similar to those of the Anaconda system, other members of the series, notably the Johnstown (or North Connecting) and the Windlass veins, differ in character, containing enargite as a primary vein mineral, with little quartz-pyrite ore.

Further exploration may result in the inclusion of the Silverbow and High Ore with the Anaconda veins, despite their wholly different strike. An analogous case is that of the Colusa-Shannon lode, whose course is that of the Steward fault vein system. As already stated in discussing fissure formation (p. 60), the mineralization which formed the Anaconda system acted upon several fissure systems, producing quartz-pyrite veins, but the action was most intense along an east-west direction, making the immense Anaconda and Syndicate lodes.

BLUE AND STEWARD SYSTEMS.

FEATURES IN COMMON.

The fault veins of the Blue and Steward systems differ markedly from those of the Anaconda system. They cut and displace the older veins and have the characters typical of veins filling faults. The fissure is clean cut and is filled by crushed quartz monzonite, aplite, and porphyry, softened and altered, containing more or less disseminated pyrite and quartz, in scarf-like masses, resulting from the crushing of pyrite veinlets. (See Pl. XI, *B*.) The fissure varies in width from a few inches to 20 feet or more, but showing well-defined planes of movement, with striations and slickensides on the walls and bands of tough dark-colored or black clay varying from a fraction of an inch to a foot in thickness.

These fault veins either cut across country or reopen and follow older vein fissures. Characteristically they are fissures filled by friction material, with ore shoots at intervals along their course.

Some of the veins are opened for a mile or more and most of them show ore shoots whose occurrence appears to be entirely independent of any law.

In their characteristic development the ore shoots are lenticular, with a maximum thickness of 25 to 30 feet, tapering to nothing at either end. Beyond the feather edges some of the veins contain lenticules of ore, which may be pure glance, for 100 feet or more; finally these disappear.

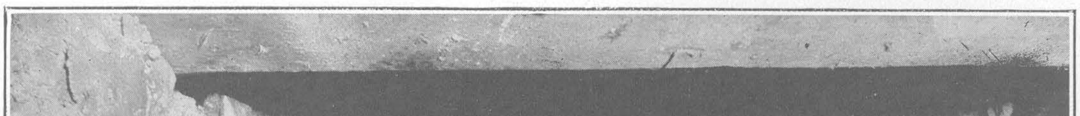
The distance between shoots is variable, but is often hundreds of feet, the vein showing not a trace of ore in this distance, even when the walls are 5 or 10 feet apart. The ore shoot may fill the entire width of the fissure or only part of it. The ore is usually quartz and iron pyrite, with smaller amounts of chalcocite, enargite, bornite, and zinc blende. Covellite and chalcopyrite also occur. The ore body itself shows little or no evidence that it occurs in a fault fissure, the ore entirely replacing the crushed country rock, though usually showing a clay selvage. The shoots vary in size from little lenticules or bunches up to immense bodies over 1,000 feet long, 1,500 feet high, and as much as 30 feet thick.

Transverse fractures across the ore bodies are found in most of the veins. They seem to indicate extensive movement and crushing subsequent to the formation of the ore bodies, with consequent rearrangement of the vein filling, and the removal of many solid blocks of rich ore, to positions against low-grade ore or barren masses of crushed granite. The ore shoots frequently show banding, and where thickest often contain slabs and wedges of waste rock. The ore composing the shoot is not uniform in richness but has local gatherings of richer material, also enrichments due to later deposition on cross fractures. (See fig. 26.)

The fault veins as a whole have been open and free trunk channels for circulating waters, which have altered the crushed rock filling the fissure throughout its entire course, but this alteration has penetrated the wall rock but slightly if at all. In many cases the barren part of the vein is dry and the ore shoot wet, the location of the latter marking the position of a pipe or channel of readiest circulation, determined by the presence of clay walls developed across the vein.

In general the fault veins carry minerals typical of silver veins and contain more silver than the quartz-pyrite ores. The Blue vein, extensively worked in the Little Mina and Nipper

A. FAULT BRECCIA OF ORIGINAL MINE.
First floor over 1,200-foot level east. See page 107.



B. ANACONDA VEIN CUT OFF BY BLUE VEIN.
Neversweat mine, 900-foot level, sixth floor stopes, west end, looking southeast. Note curved plane of fault wall.

mines, and the Clear Grit vein were both formerly mined for silver. The Nipper ore is, in fact, intermediate in character between the silver and copper ores.

The vein filling is usually zincky near the surface, this being the case in the Nipper, Gem, Jessie, and Clear Grit. At a few hundred feet depth the zinc becomes less. The veins contain some pyritic ore, evidently from an older filling that is shattered, but not chalcocitized. The stopes show a cross netting with lenses of ore. The following minerals are found in the fault veins: Sphalerite, tetrahedrite, rhodochrosite, fluorite, galena, pyrite, chalcopyrite, bornite, enargite.

CONTRASTING FEATURES OF BLUE AND STEWARD SYSTEMS.

The foregoing description applies especially to the veins of the Blue Vein system, for most of these are "cross" veins, whereas many of those of the Steward system are strike fault veins along older veins.

The result is a marked difference in the structural features of the two systems in general. The Blue vein and its congeners contain definite shoots of newly formed ore, separated by intervening stretches of barren fault material devoid of even a trace of ore (Pl. XII, *B*) other than what may have been dragged in where they cut and displace older veins. On the other hand, the fault veins of the Steward system are remarkable for their shoots of conglomerate ore, composed of a typical friction breccia of an older vein filling (Pl. XII, *B*), with which newly deposited ore is associated. A few Blue veins, however, follow older quartz-pyrite or enargite veins with a northwest course, and a few veins of the later Steward system are productive away from other veins.

So far as the mineralogic evidence is concerned, no fixed distinction is possible. In a general way the Steward system carries more enargite and has accessory minerals of the silver vein series. However, the Jessie and other veins of the Blue Vein system have been reopened and in part crushed by strike faults, with the introduction of tetrahedrite, rhodochrosite, and other minerals formed during the period of silver-vein formation. The discovery of the rich ore bodies of the Jessie and Edith May veins, belonging to this system, showed that the view held by Winchell was correct, and that these fault veins should be developed, not merely by a crosscut or by drifts upon them 200 or 300 feet apart, but by systematic drifting along them for long distances, on levels comparatively close together. Work of this kind led to the discovery of extensive ore bodies on the Mountain View fault and Skyrme veins.

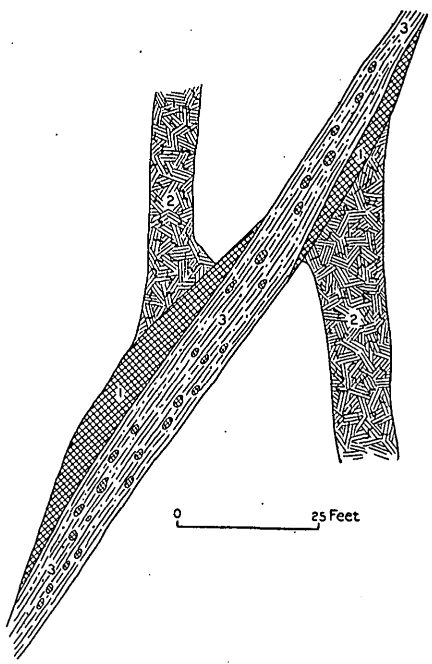


FIGURE 26.—Blue vein cutting off Anaconda lode (2) showing so-called spraying out of ore. (1) New endogenous ore formed along wall of fault at cut-off. (3) Fault matter of Blue vein, containing ore bowlders.

COMPOSITE COPPER VEINS.

The fact that many of the richest bodies of copper ore are of composite character and derive their metallic content in part from each one of the three distinct periods of mineralization necessitates careful study to discriminate the evidence and results of each period. As already stated (p. 107), the earliest or quartz-pyrite veins can be differentiated from the enargite veins; in composite veins original ore matter can be distinguished from that brought in by a later period of deep-seated mineral waters; and all the foregoing ores can be distinguished from the so-called secondary ore formed of transposed and redeposited material of the vein itself.

The rich ore bodies which have made the district famous have been largely of this last-named character. The original ores of the quartz-pyrite veins were generally of too low a grade to work, and most of the glance and enargite ores are of later age.

The term "conglomerate" is locally used in the Original and Gagnon mines to indicate a vein filling consisting of more or less rounded fragments of an older ore and of country rock lying in a paste of clay and ground-up rock and vein matter. The walls are usually defined by seams of tough dark-gray clay, a ground-up mixture of altered rock, and vein filling of variable composition. Where the vein is formed of massive quartz and pyrite, the term "vein filling" is appropriate, even if the vein be due to replacement, but in general the term is ambiguous, as it may be used to designate any material filling the fissure, whether it carries ore or not.

The copper veins are in large part replacements or are masses of crushed and mashed rock impregnated with copper minerals. This complex recurrent faulting, with sympathetic fractures accompanying the greater faults, the crushing of large masses being common, has produced a very complex composite vein. The lesser cross fractures, which cross the great lodes of the camp (notably various portions of the Anaconda and the Syndicate lode) have determined the extent of the impregnation with glance. The great ore bodies of glance have in some places been slightly displaced by such fractures, but more commonly have been simply cracked and the fracture filled by new material; the fissure, running out into the wall rock, is also filled for variable but not great distances from the vein. These lesser fractures are naturally best shown in the deeper levels, where they are extremely important factors in determining the location of bodies of rich secondary ore, for it is here that the process is caught in the act, as it were; higher up its effect is obscured by the greater amount of mineral and by old mine workings. Near the surface few of the fault veins show ore. For the most part they are indistinct breaks or fissures filled by crushed rock and clay and devoid of any mineral matter, not only at the outcrop, but for many hundred feet down.

VEIN FILLING.

TYPES.

The vein filling differs in the different classes of veins. (1) In the oldest mineralized fissures, the pyrite seams, the filling is massive nearly pure pyrite.

(2) In the quartz-pyrite veins the primary filling consists of an intimate mixture of pyrite and quartz, in places rudely banded parallel to the vein walls, but more commonly the pyrite is patchily and irregularly distributed in the quartz. This latter is the normal form of the vein and is due to replacement, in part, of the smaller rock fragments that filled the original fractures, but in greater part to the replacement of the granite between the fractures.

(3) Where a primary quartz-pyrite vein has been opened by a strike fault or, as is often the case, has been cracked and crackled as the ground was adjusted as a result of cross faulting, the effect has been to permit the descent of water down the vein, with accompanying replacement of the pyrite.

Plate XII, *A*, shows the primary quartz-pyrite of the Parrot-Gagnon vein, cut by a strike fault, the Steward vein, in the west face of the 1,600-foot drift of the Gagnon mine.

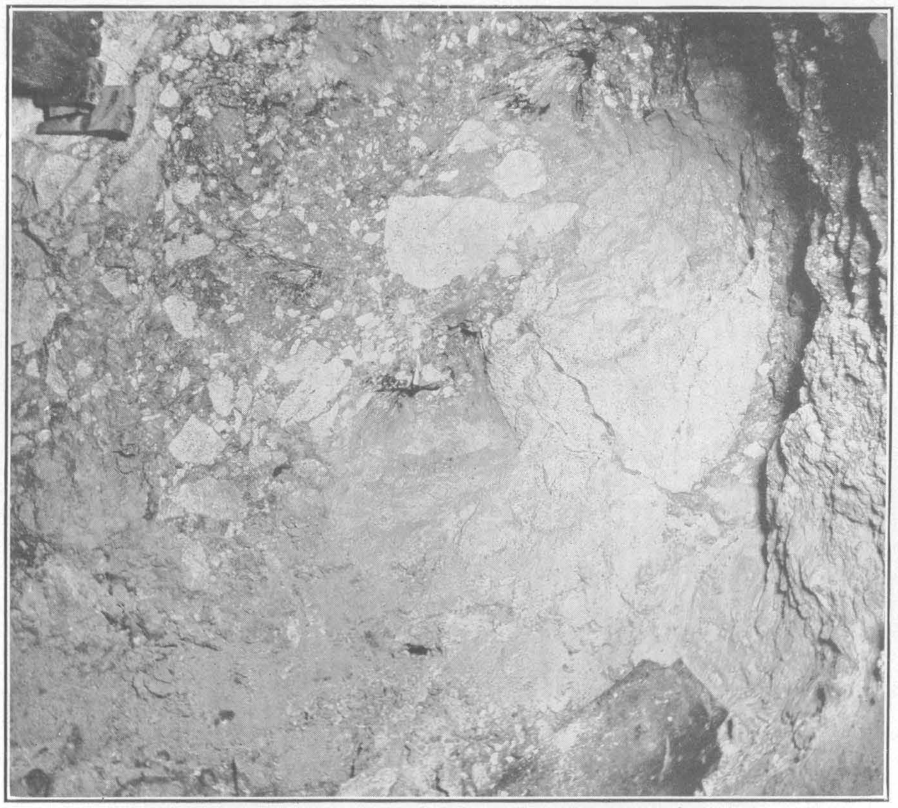
(4) The filling may be a mass of crushed and ground-up rock fragments from the fissure walls, or it may be material introduced or deposited in this fault breccia. Very commonly both are present. Replacement veins are not fissure fillings.

INFLUENCE OF COUNTRY ROCK.

The variations in the veins in the three varieties of rock, the Butte quartz monzonite (either normal or altered), the aplite, and the rhyolite porphyry, are very marked, both in the character of fissuring and in the richness of the vein filling. In the granite the quartz-pyrite veins are wide and generous; in the aplite they maintain their identity and course, but are lean;

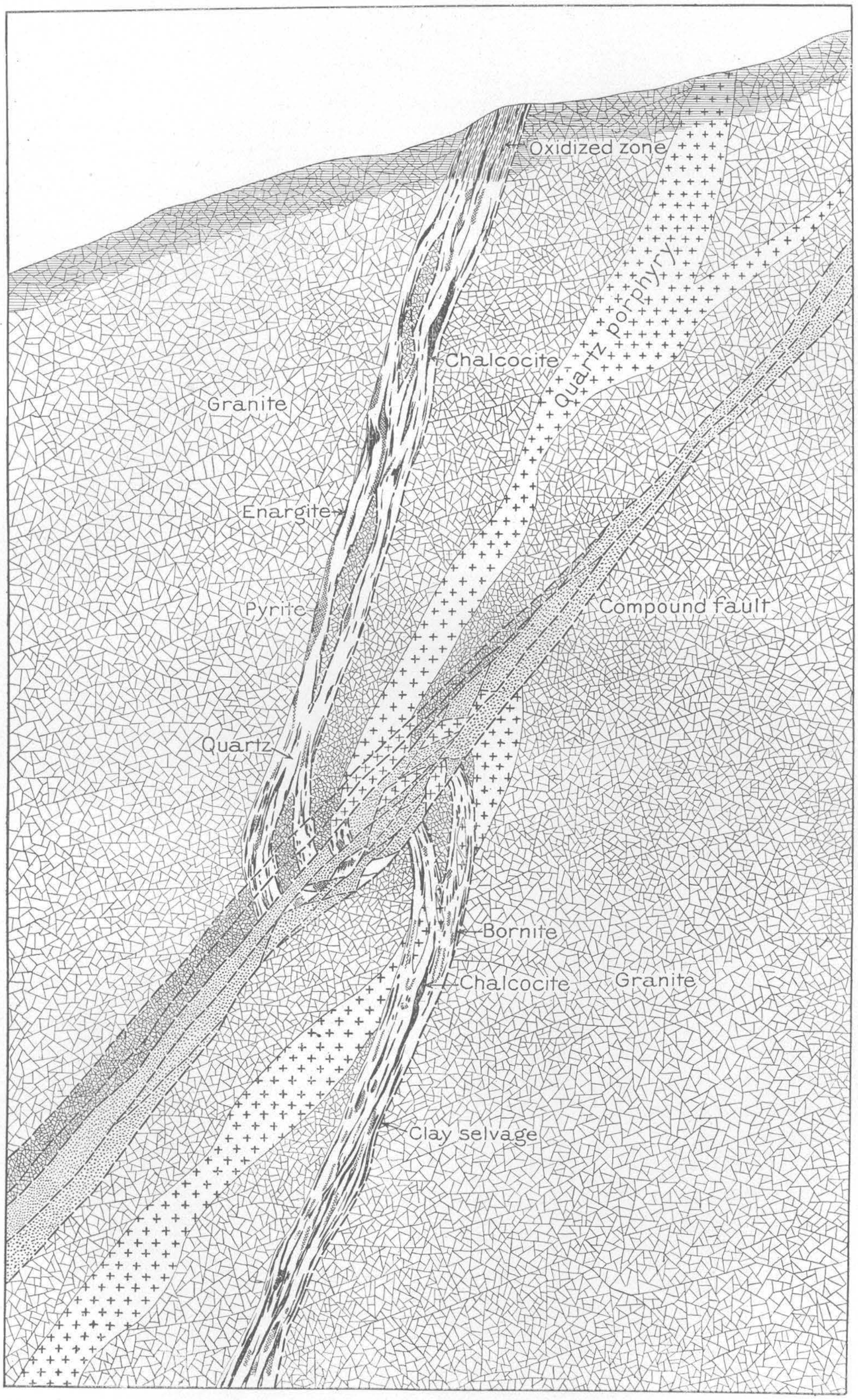
A. GAGNON MINE, WEST FACE 1,600-FOOT DRIFT.

Shows the Parrot-Gagnon vein of Anaconda system, with banded quartz-pyrite ore, cut by the Steward fault vein, filled with ore bowlders and granitic cobbles—a true fault breccia.



B. CONGLOMERATE ORE OF STEWARD FAULT VEIN, GAGNON MINE.

Second floor of stopes above 1,600-foot level, near crosscut to shaft. Shows fragments of earlier ore and of granite torn from old quartz-pyrite vein and rounded by movement along fault vein. See page 109.



IDEAL CROSS SECTION OF ANACONDA VEIN.

Shows relations to porphyry and distribution of ore. (After H. V. Winchell.)

and in the rhyolite porphyry they are narrow and split up and carry relatively leaner or unpayable vein filling; this is believed to be due to the lack of readily replaceable minerals. (See Pl. XIII.)

INTRAVEIN RELATIONS.

The change of vein filling at intersections, offsets, spurs, etc., is very marked and merits full and detailed description, which is given in later chapters. In general it may be said that the occurrence of workable ores is dependent on the fracturing and faulting of a primary lean vein. The earlier veins are pyritic, the later ones carry enargite, and both, when fractured, carry glance ore.

CHANGES IN VEINS WITH DEPTH.

CHANGES IN COMPOSITION.

Each class of veins shows certain changes, due to depth. The quartz-pyrite veins now seen are probably the lower parts of the veins. That the district has suffered much erosion since these earlier veins were formed is beyond dispute, but the amount is not determinable. In the Colusa-Parrot ground the Blue Fault vein has dropped the ground 510 feet on the west side. The ore bodies seen in that mine belong, therefore, to a horizon 510 feet higher than those at a corresponding elevation in the Neversweat, which lies east of the fault. The vein in the Colusa-Parrot ground might be called a "granite" vein down to the 800-foot level, where it gradually passes into a normal quartz-pyrite vein. In the upper levels the ore is an impregnated mineralized granite, in which several veinlets have mineralized granite between—a feature seen in the Leonard-Colusa ground, where, however, the mineralization is not exactly the same. These branches represent a bifurcation of the vein not seen in the Anaconda ledge to the east, as the portion corresponding to this has been removed by erosion. The north branch of the Colusa-Parrot becomes the Parrot ledge going west.

The Pennsylvania or Anaconda South vein shows material changes in character with depth. The upper levels, 200 to 400, show a vein composed of granite netted with rather sparse films of pyrite and a very little quartz. It is what is locally called a granite vein, meaning ore composed of crackled granite with films and specks of glance replacing pyrite. (See fig. 22, p. 95.) Lower down the vein contains an increasing amount of quartz, and below the 400-foot level it becomes a normal quartz-pyrite replacement vein without definite walls, carrying a large amount of pyrite. Glance occurs in fracture planes and as specks in the rock adjacent to the quartz-pyrite vein.

Another and more significant change in the quartz-pyrite veins in depth is their tendency to split up or disappear. Great wide ledges finger out into individual quartz-pyrite veins, and then into less mineralized fissures, and lastly into a mere closely fissured mass of altered granite. This condition represents the first stage of the vein formation.

The Covellite (or Dernier) vein, where cut on the 2,200-foot level of the Diamond mine, shows a remarkable example of the bifurcation of a vein with depth. On the upper levels it is a single well-defined fissure of notable persistence, though cut by cross fissures with a northwest course and slight displacement. On the 2,200-foot level west of the crosscut it is a very lean vein, consisting mainly of a fault breccia composed of mashed granite with walls of more or less solid rock. Eastward the vein splits into branches and is cut square off by cross faults, and does not continue as a recognizable vein, the streak observed being composed of pyrite in a fault of different character. On the 2,100-foot level enargite is first seen. This seems to be in line with observations that enargite is at Butte a mineral formed at great depths, though directly opposed to the known occurrence of the mineral in Chile and Japan.

CHANGES IN STRUCTURE.

In general, broad and thick lodes change downward, passing into a network of small veins, with silicified but unreplaced granite between. This condition probably results from sheeted (or less regularly fissured) granite being attacked by mineral solutions; in the upper part of the lode replacement and mineralization of rock between fissures was complete, but lower down only the rock adjacent to fissures was replaced. This condition is seen to be more and more common as deeper and deeper parts of veins are opened.

The veins are less regular in depth, and the ore bodies irregular, and, though in places large, are not continuous. (See Pl. XXXI.)

The tendency of the veins is to split up with depth. For instance, the Covellite vein of the Diamond west of the 2,200 crosscut is very lean, consisting mainly of a breccia of mashed granite. Eastward it splits into branches and is cut square off by a cross fault and does not show again as a recognizable vein, the streaks found being of pyrite in a fault of different character.

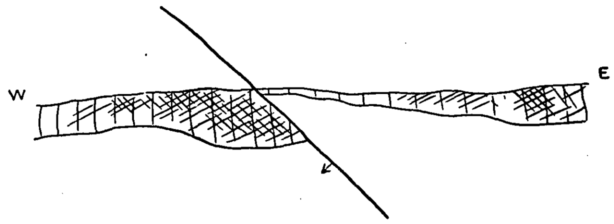


FIGURE 27.—Cut-off and spraying out of Dernier vein by a northwest fault.

In general, the faults and cross slips appear to affect the vein more on the deep levels than above. This apparent difference, however, is believed to be largely due to the action of secondary glance-forming waters, which thoroughly mineralized the shattered ground lying between the fractures on the upper levels, but did not penetrate to nor mineralize the lower fractures, though these are more easily recognizable, nor the intervening granite, even though this was shattered. The effect of cross fractures on ore deposition, even where there is no clay streak to deflect enriching solutions, is well shown in the spraying out of the Dernier vein of the 2,100-foot level of the Mountain Con. mine. (See fig. 27.)

CHAPTER X.—DETAILED DESCRIPTIONS OF THE COPPER LODES.

METHOD OF TREATMENT.

SUBDIVISIONS.

In this chapter an attempt is made to describe the copper lodes in some detail—a description by lodes rather than by individual mines seeming to be the most generally satisfactory method of treatment. As many lodes extend through several mines no method can be devised that will give all the related facts, either of individual lodes or of particular areas, in an altogether satisfactory manner. For this reason a geographic division by belts and clusters has been adopted, with modifications to suit each case. The most important subdivisions adopted are (1) the southern or Anaconda-Parrot belt, which embraces all the contiguous lodes north and south of the lodes from which the name is taken; (2) the Intermediate belt, which lies between the Anaconda-Parrot and Syndicate belts; (3) the Silverbow system; (4) the northern or Syndicate belt, which comprises the mines of the extreme northwest part of the copper district; (5) the Bell-Diamond group, which includes the Greyrock and Speculator mines; (6) the Jessie-Edith May copper-silver veins of the Blue system; (7) the East Butte group, lying along the southeastern borders of the district; (8) the Mountain View-Shannon-Colusa belt to the east; (9) mines north of Meaderville; (10) the Rarus-Pennsylvania group; (11) the Butte Flat group; and (12) the East Ridge group. These names are all sufficiently distinctive to be understood, and it has been found most convenient to discuss the various veins under them, despite the fact that this method brings together veins of different ages and characters.

Each of the larger lodes is separately described, but local details of structure, together with descriptions of the lesser lodes of the mines, if given at all, are more conveniently grouped under the name of the mine. The complex tangle of lodes in the Rarus mine and in the Bell and Diamond mines, and the stockwork of veins in the Leonard are also described under the name of those mines, as it seems neither wise nor feasible to attempt to segregate the veins and describe them under the systems to which they genetically belong.

NOMENCLATURE.

As far as practicable the names already in use at Butte are used in this report. Where several names are applied to a vein, an endeavor has been made to select the best known or most appropriate; where the same name has been given to different veins, it is dropped for all but one of them. A few of the veins have been given personal names for convenience.

Many of the smaller but workable veins are unnamed. In such cases local custom is followed, and they are designated by the number of a drift or raise on the vein, as for example No. 27 raise vein of the Rarus mine. In many cases it has been deemed unwise to give the name of a claim to a vein, as this might imply that it is the discovery vein, or the most important vein of the claim of that name. North and south as prefixes are convenient and are frequently used, but may be misleading if development should disclose other veins to which the adjectives could be more properly applied. Such terms are, therefore, discarded where possible.

CROSS SECTIONS.

In general, the cross-sectional drawings are constructed from data gathered along the actual plane of the section, but lack of data has necessitated in many the use of projections for as far as 100 feet on either side. In making such projections care was taken to avoid the common error of projecting a vein at 90° to the plane of the section, where, as a matter of fact, the strike of the vein would carry it to the plane at a wholly different point, giving a hypothetical section very different from the true one.

Some of the sections have been made directly from mine maps, verified at critical points by underground observation; generally, however, owing to the necessity of determining whether the fault fissures which intersect the east and west veins cross the latter or are deflected and follow them, forming strike fissures, it has been necessary to check up each section by actual inspection of workings from the surface downward.

In constructing the horizontal sections it has been necessary to ascertain whether the mine workings actually followed veins or were laterals in the country rock. Observations, too, have been made as to any changes in the mineralogic character of the ore, and these have been duly recorded for the same vein from one end to the other.

ANACONDA-PARROT BELT.

The Anaconda-Parrot belt stretches nearly due east, with a width of not more than one-fourth mile, from Missoula Gulch almost to Meaderville. It traverses Anaconda Hill, crosses Dublin Gulch, and follows along the high ground back of the compactly built city proper. It contains six great mines, the Gagnon, Original, Parrot (with Colusa-Parrot), Neversweat, Anaconda, St. Lawrence, and Steward, all but the last deriving their main ore supply from the Anaconda lode. (See Pl. XIV.) Other east-west veins and members of the two systems of fault veins also occur in the area of the belt and have not only directly contributed to the output of ore but have also been important factors in the formation of the ore bodies of the older veins of the Anaconda system.

ANACONDA-PARROT LODE.

The Anaconda and Parrot, the most important lodes not only of this belt but of the whole district, are portions of one continuous vein, which has been severed by the Blue Vein fault, and displaced and brought into its present position by movement along the walls of that fault. The Anaconda-Parrot lode has been worked for a horizontal distance of over 7,200 feet, to a depth of 2,400 feet; it has a minable width varying from 5 to 90 feet, averaging 40 feet in the Anaconda workings and 25 feet in the mines west of that property. The western segment, worked in the Parrot, Original, and Gagnon mines, is the Parrot lode; and the eastern segment, mined in the Neversweat, Anaconda, and St. Lawrence claims, is the Anaconda lode proper. Farther east, beyond the Mountain View fault, the Anaconda lode is continued in the South ledge of the Mountain View mine.

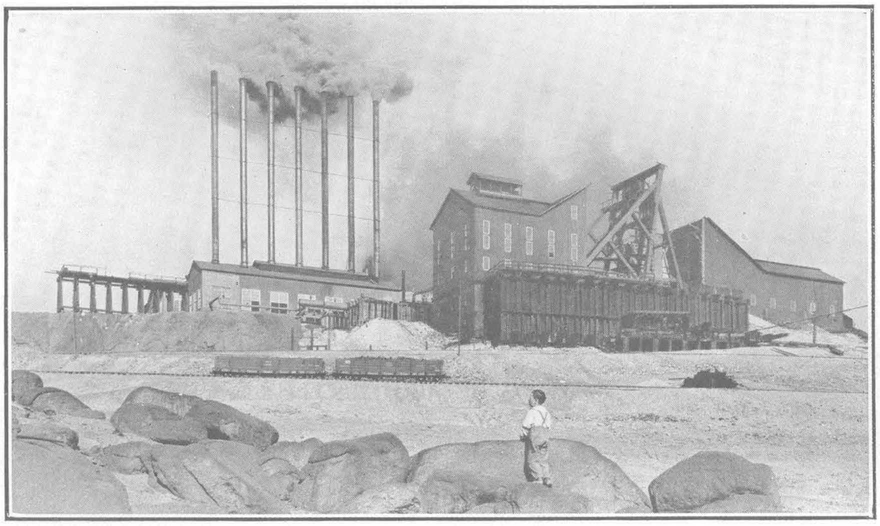
ANACONDA LODE.

In the Anaconda mine proper, comprising the Neversweat, Anaconda, and St. Lawrence mines, four large veins are worked. Of these, the Anaconda vein is by far the most important. Next south of it is the Moonlight (Middle ledge), still farther south the Pennsylvania (South ledge), and still farther south the O'Neill—the last probably the Pennsylvania vein beneath the Rarus fault (p. 228). North of the Anaconda lode is the Hogan vein (p. 122), known and worked only in deeper levels. The relation of this vein to the Anaconda is shown in the cross section (fig. 28). The general east-west course of the lode is the mean of two directions—N. 80° W. and N. 80° E.—which prevail in different parts.

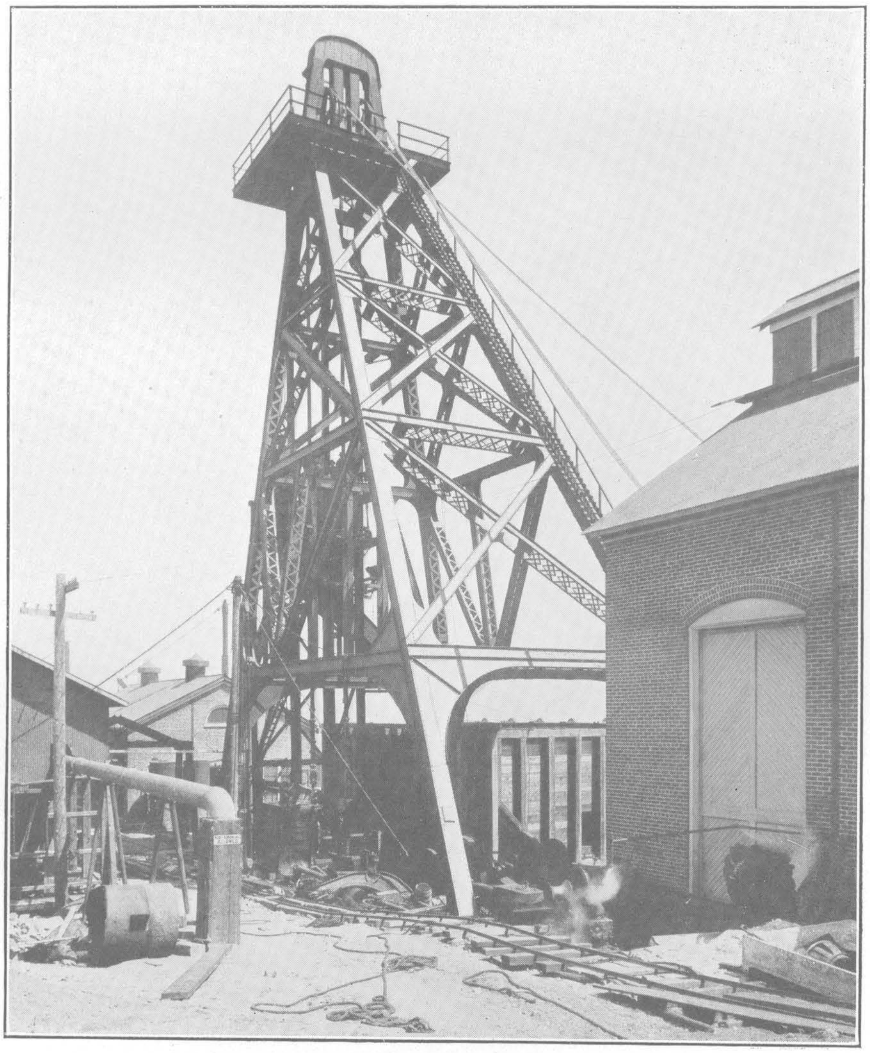
ANACONDA VEIN.

ORES.

The Anaconda vein has been enormously productive from the 200-foot level downward. It is a typical replacement vein, composed of quartz and pyrite with streaks and masses of chalcocite. The entire vein is as a rule workable, but it also contains large masses of rich chalcocite ore, constituting true bonanzas. The chalcocite replaces the primary ore and fills fissures and cavities in it. It is recognizably secondary in most places, though it is found from the upper limit of the sulphide ore to the deepest level (2,400 feet) of the mines. Chalcocite is associated with secondary fracturing and faulting and not only occurs in the vein but also extends in places



A. NEVERSWEAT MINE FROM SOUTHEAST.



B. SHAFT OF ANACONDA MINE.

as stringers and veinlets into the hanging-wall rock. The ore ranges from 15 to 100 feet in width.

The primary vein filling is a very dense and massive mixture of quartz and pyrite, with more or less accessory sphalerite in places. The quartz is finely crystalline, shows neither marked banding nor crustification, and is a characteristic replacement product. Most of the pyrite shows lack of arrangement, but on a broad scale plating or rude banding parallel to the vein walls can be distinguished. The vein filling is so massive and solid that it stands well without timber. The altered granite lying between the veins is in some places impregnated

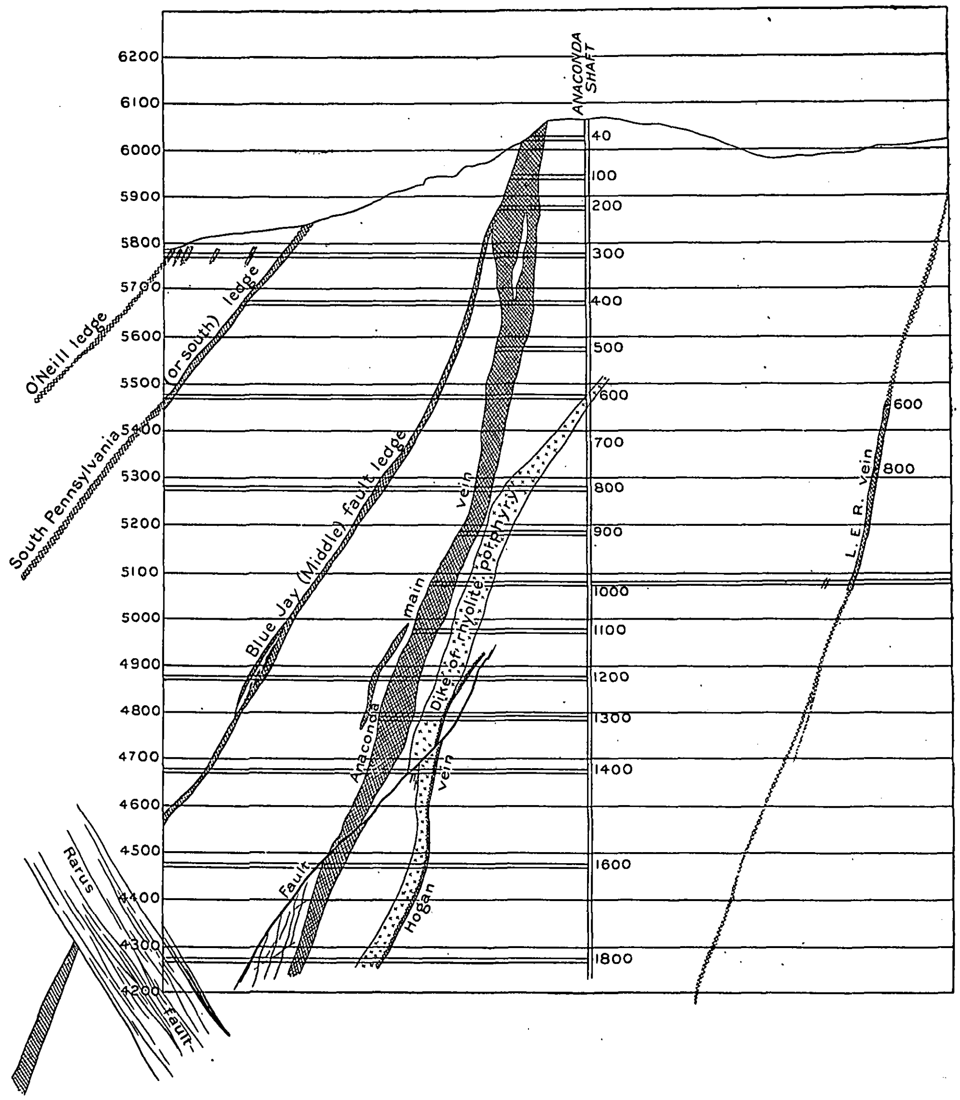


FIGURE 28.—Vertical north-south cross section through Anaconda shaft. Figures on left are feet above sea level; those in center are levels of Anaconda mine.

with enough copper to be workable. The plating of granite, the gradual replacement of that rock observed on a broad scale in the underground workings, and the detailed replacement seen in thin sections of the rock studied under the microscope, all show that the lode results from the gradual replacement of the country rock along a line of fissuring or sheeting.

WALL ROCK.

The unfractured primary vein filling seldom shows any traces of the original sheeting planes of the granite, but consists of a thick and solid mass of quartz and pyrite that lacks symmetrical banding or comb structure. Definition is in many places lacking, not merely between the ore and the altered granite horse that separates the two streaks of the Anaconda vein, but also between the ore and the wall rock proper. In general, however, the vein shows fairly distinct boundaries, especially on the footwall side, where a slip or gouge has resulted from later fracturing. The wall rock is impregnated with secondary quartz, thoroughly sericitized and dotted with pyrite, but this alteration, intense near the vein, fades gradually out away from the walls.

The prevailing rock cut by the vein is the Butte quartz monzonite. The more siliceous aplite is abundant on the 300-foot level of the Neversweat mine, but elsewhere is neither more nor less abundant than on the surface.

In its eastern half the Anaconda shows a general parallelism to a dike of the rhyolite porphyry, which for a considerable distance forms its footwall. The Anaconda, however, crosses the dike in the St. Lawrence and Mountain View mines, and, as shown in the vertical cross section (fig. 28), in general lies south of the dike and at a varying distance from it.

Where the Anaconda cuts the rhyolite porphyry and also where it traverses aplite it generally consists of lean or unworkable ore. On the other hand, the uncongenial character of these two rocks, preventing replacement and ore deposition, has made them retain the original characteristic fissuring, and has revealed the fact that the veins are replacements in parallel and netted fractures. (See fig. 29.)

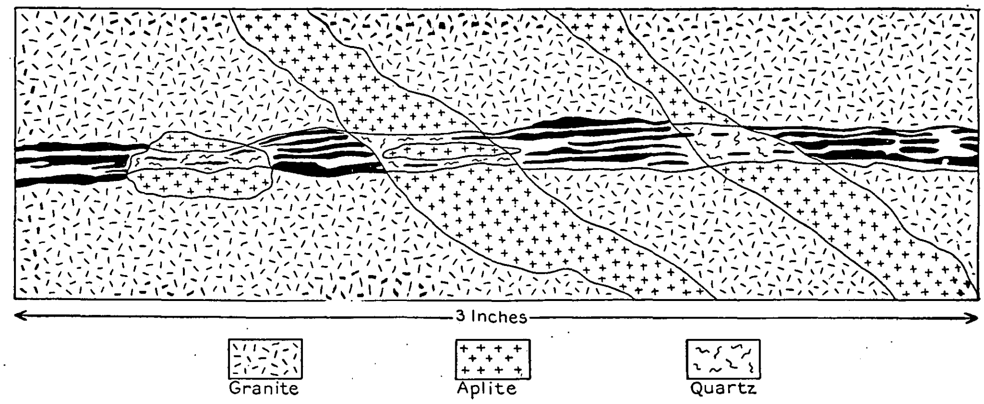


FIGURE 29.—Diagram showing change in character and richness of vein in crossing rhyolite porphyry and aplite.

Where the Anaconda crosses the porphyry dike the latter shows no displacement. This is also true where it crosses aplite. These facts prove that the vein fissuring was without any appreciable faulting or displacement, and confirm the theory that the Anaconda is a result of a replacement of fissured rock and not the filling of an open fracture.

SPLITTING OF THE VEIN.

In the upper levels the Anaconda is one big vein, with a few horses of granite, but in depth its structure is dual, consisting of two nearly parallel veins 25 to 50 feet apart (fig. 30). From the surface down to the 700-foot level local splits occur, showing the tendency of the lode to divide downward. In the Anaconda mine the hanging-wall portion separates at a depth of 700 feet, and thereafter continues (see fig. 31) as two ledges, known as the "hanging-wall" and the "footwall," and are very persistent throughout the Anaconda mines. Westward on the Parrot lode the south or hanging-wall ledge diverges, both in strike and dip, forming the south or Virginius ledge of the Parrot mine. (See p. 132.) Farther west in the Parrot and Original mines a footwall fault vein appears and in the Gagnon the dual character is resumed.

The lode has a general dip of 72° to 80° S., but as the walls roll, the dip varies to the extent of 10° or so. In the Neversweat mine its upper 200 feet is nearly vertical.

The two ledges composing the Anaconda are alike in character, but the north or footwall ledge is the thicker and more persistent. This ledge varies considerably in width, but in the

Anaconda mine maintains an average thickness of 25 feet to the 2,400-foot level (the lowest depth attained in 1907), whereas the hanging-wall ledge is thin and unrecognizable below 1,800 feet.

SUMMARY.

The Anaconda vein, which is typical of the series, is an east-west lode, formed of a hard, compact mixture of pyrite and quartz, lacking crusts but having rude banding. This quartz differs from that formed in cavities and shows all the characters of replacement material. The vein has been in part sheeted and is crossed by numerous northwest fractures, three of which are mineralized and of considerable size. The vein is also fractured by east-northeast faults (N. 70° E.). Both classes of faults have shattered the vein and permitted extensive secondary enrichment, making the rich ore bodies of glance for which the mine is famous.

The vein is in large part double, consisting of two streaks, united in the upper levels (though horses occur here), but distinct below, the interval widening. The rock between is netted with fractures and is pyritized but not crushed. The north branch of the vein has an average width of 40 feet in the St. Lawrence and Anaconda ground and of 25 feet in the ground westward. It is developed to a depth of 2,400 feet and a length of 2,700 feet. It was once continuous with the Parrot and the Mountain View lodes, which are displaced parts of the same vein, but is now cut off from them by the Blue vein fault, and again by the Mountain View fault. Farther to the east it is again cut by the Rarus fault, beyond which it has not been positively identified, the suggested correlation with the Windlass lacking substantiation.

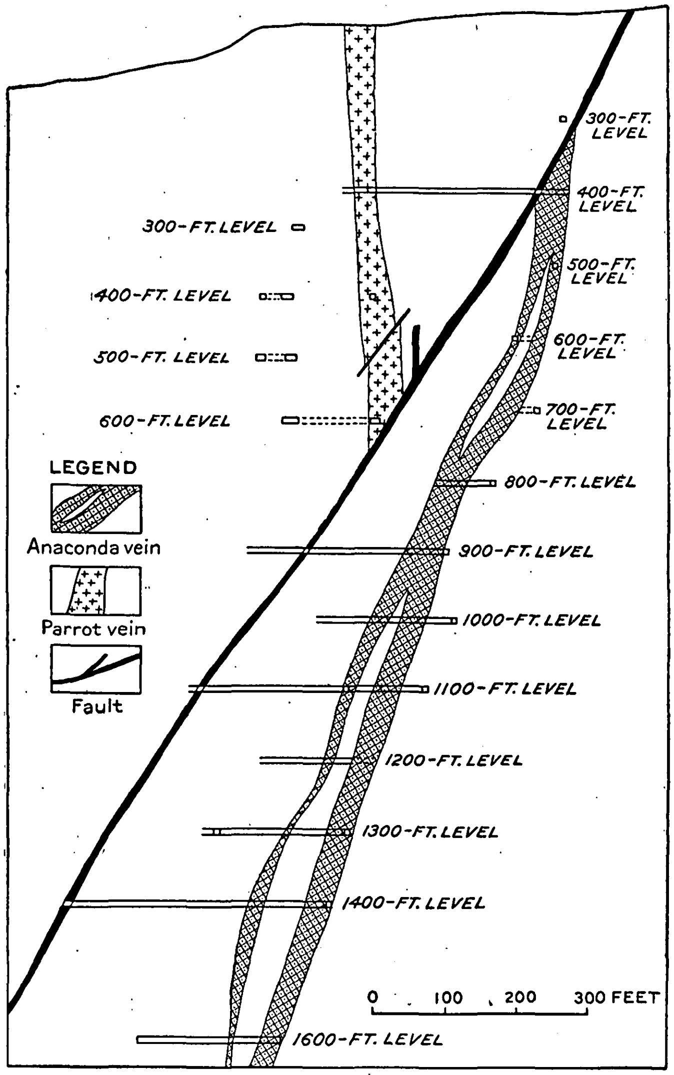


FIGURE 30.—North-south section through Anaconda and Parrot veins and Blue vein fault.

PENNSYLVANIA VEIN.

The most important lode of the belt next to the Anaconda is the Pennsylvania. This large and important member of the Anaconda system, which has long been the chief ore producer of the Pennsylvania mine, has also been extensively worked in the Anaconda mines (fig. 32), where it is called the South ledge. As the identity of the South ledge and Pennsylvania veins is well established, it seems best to use the latter name. It has been continuously developed from the Blue vein eastward through the Anaconda, St. Lawrence, and Pennsylvania mines a distance of 2,600 feet. In the Pennsylvania mine it is known as the Pennsylvania No. 2 vein eastward to the Rarus fault and as No. 3 vein east of that fault. It is not positively identified west of the Blue vein, but is probably continued eastward beyond the Mountain View fault in the Enargite vein.

The vein has a course nearly or quite parallel to the Anaconda, and, like that lode, shows mineralization alternately along N. 80° E. and N. 80° W. fracture planes. It has a thickness of 6 to 20 feet, averaging 8 feet in the Pennsylvania and 12 feet in the Anaconda properties. The dip averages 65° in the Anaconda, but varies both horizontally and vertically, being 80° in the lower levels of the Pennsylvania mine. The character of the upper vein is well seen in the fourth, fifth, and sixth levels of the Anaconda mine, where it has been extensively worked. In these levels the vein is double, and has the same granite gangue seen in the Parrot lode, as exposed in the uppermost levels of the Colusa-Parrot mine. The vein filling consists of altered granite netted by quartz and pyrite films, with more or less complete replacement of the pyrite by chalcocite.

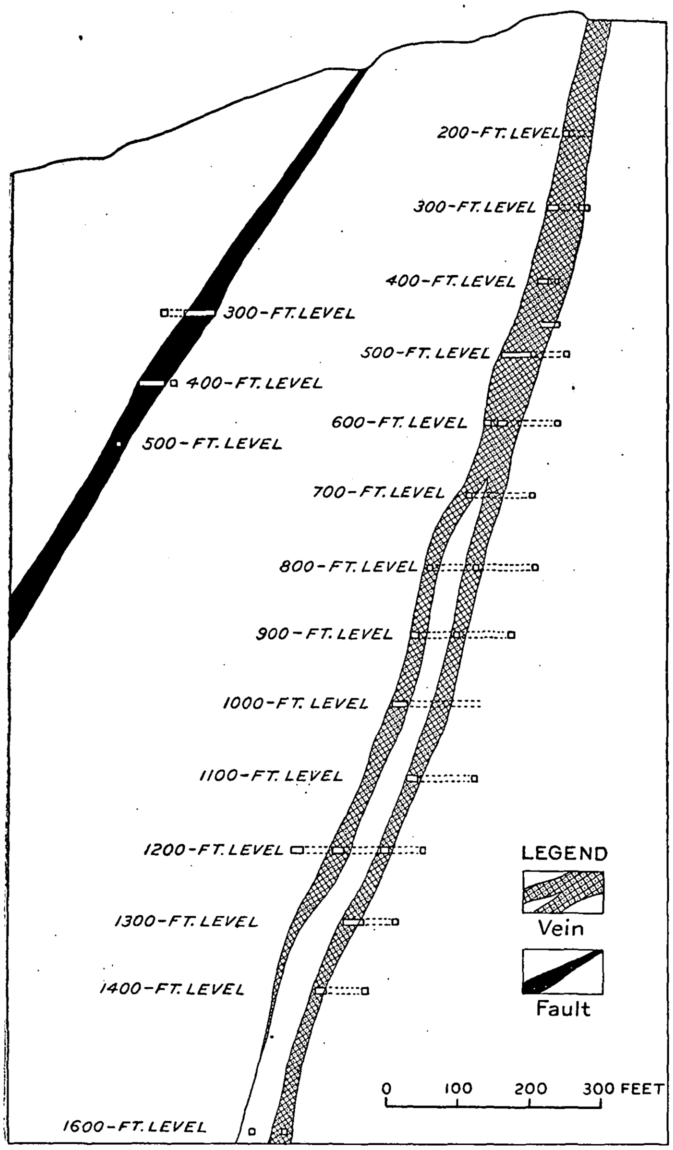


FIGURE 31.—Section through Anaconda lode, showing splitting of vein.

In these workings the ledge has evidently been shattered during the downward movement of the block by faulting, and the crackled vein matter, being readily permeable to descending waters, has been enriched by the deposit of chalcocite in the fractures. With increasing depth more and more quartz appears until the vein has a normal quartz-pyrite filling. The oxide ore extends downward to the fourth level of the Anaconda workings with soft and friable sulphides between this and the solid sulphide ore. Lower down chalcocite is found in films and specks in the included rock and replacing the pyrite.

In the Pennsylvania mine the vein has been productive from the surface downward. In the upper levels it has been cut and deflected by the Rarus fault, but, as described in the account of that fault, the vein has not suffered abrupt and great displacement, but is broken by distributed faulting, with numerous slight shifts which have not interfered with development along the vein. In this mine the general eastward course of the vein which prevails in the upper levels alters to N. 70° E. at a depth of 900 feet beneath the surface, the dip steepening to 80° in the 1,000-foot level and below. This is also the dip in the faulted part of the vein called Pennsylvania No. 3.

The width of the vein in the Pennsylvania workings varies from 6 feet to 16 feet. In the deeper levels there is commonly a clay or breccia streak a few inches to a foot thick on the hanging wall, with about 3 feet of first-class ore between this and the crushed granite footwall. In part it follows the quartz porphyry contact.

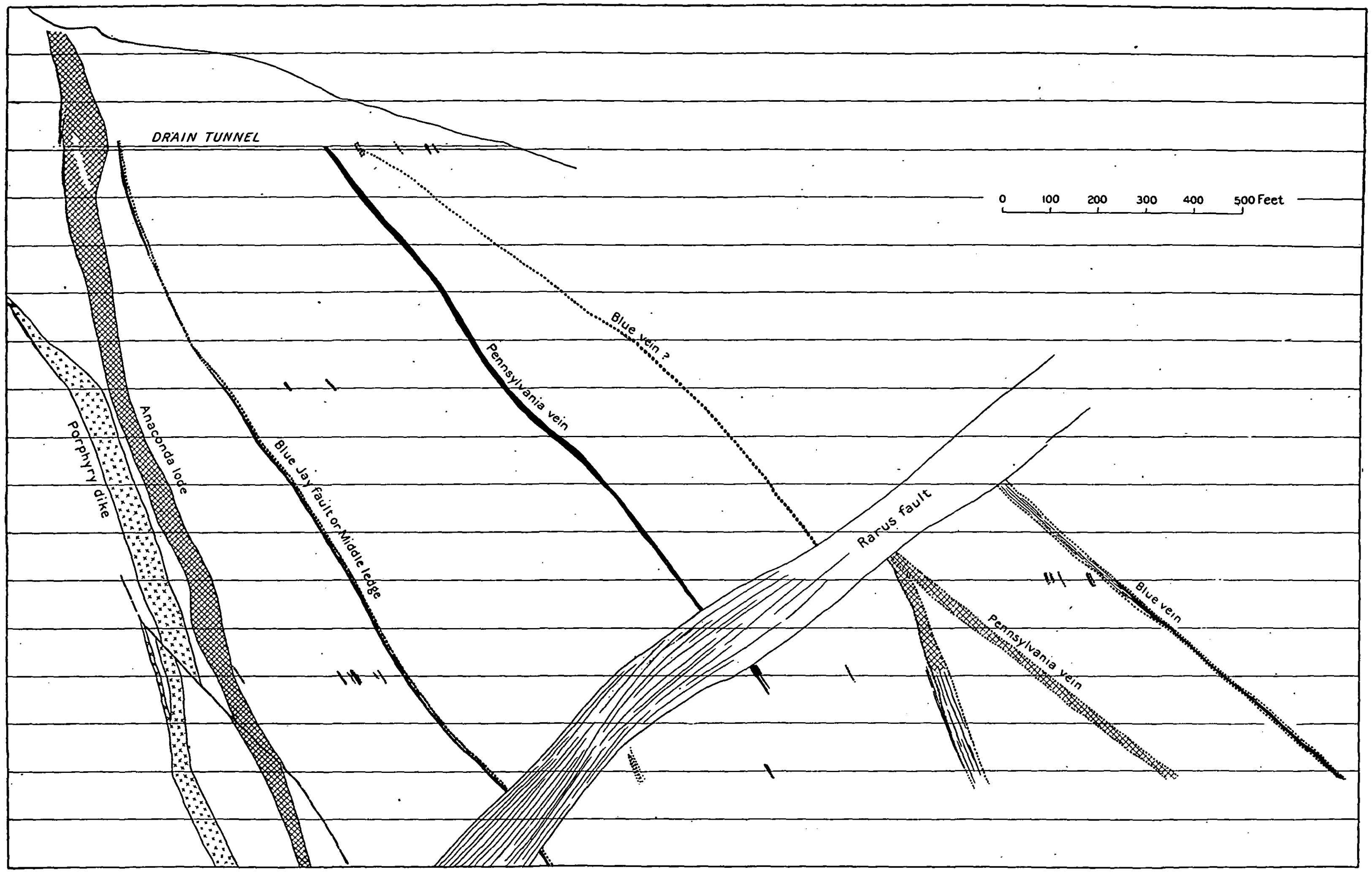


FIGURE 32.—Cross section through Anaconda shaft on line through long south crosscuts.

Mineralogically the Pennsylvania vein shows the same general composition and variations seen in the Anaconda. In the uppermost level of the Pennsylvania mine it has an average thickness of 8 feet and is inclosed by walls of softened altered granite. In the 200-foot level of the mine the vein showed a streak of enargite 6 inches to a foot thick, due to secondary mineralization along postvein faulting.

The vein appears to join the Silverbow vein for a short distance, separating again westward. On the projection of the veins of the district on the 5,600-foot plane the vein is traced from the Pennsylvania workings westward through the St. Lawrence, Anaconda, and Ramsdell-Parrot mines.

Down to the 1,000-foot level the Pennsylvania vein carries more or less glance and enargite, but lower down it becomes leaner and has less secondary quartz or pyrite, though evidences of crushing and strike fault movements are plainer than above.

On the 1,000-foot level of the Pennsylvania mine the vein is 7 to 10 feet thick, and shows an upper or hanging-wall streak of mashed granite and clay above a 3-foot band of solid but lean pyrite and quartz devoid of secondary minerals. The center of the vein is a 3-foot band of broken quartz carrying streaks of glance and secondary milky quartz holding a little pyrite and some clay. An enargite streak 6 to 10 inches thick separates the last band from the foot-wall layer 3.2 feet thick, carrying clay with friction breccia and pebbles, and running parallel to the clay streaks and slips in the ore body proper. The vein carries 2 to 3 feet of first-class or smelting ore in the 1,000-foot stope. Where it crosses the porphyry dike, as for example on the 900-foot level, it is lean.

Numerous southeast slips run out from the hanging wall of the vein and many of them carry glance for a few feet from the wall. Even when not recognizable in the mines these slips show an offset of the vein, as indicated on the level maps. The vein walls are smooth but rolling, showing varying dips of 60° to 80°. Clay slips are common, but are not uniformly present except near cross faults.

In the deeper levels the vein consists of a mixture of quartz and pyrite, the latter in many places predominating, but showing drusy streaks of white recently formed quartz. This white quartz also cements together the crushed vein where it is fractured by fault seams. This secondary quartz often carries chalcocite, but the amount varies from place to place and is sometimes nil.

At 1,200 to 1,400 feet below the surface the vein is very irony, hard, and lean; it still shows its composite character, having the original solid quartz-pyrite vein along the hanging wall with crackled and in places crushed ore in the center, and showing many clay cross slips and rounded masses of white quartz carrying druses of quartz and pyrite. The recementation of the crushed older vein by new quartz and ore is not complete. The ore is dry and shows no glance above a heavy clay slip, above which the streaks dip north into the vein. The vein varies from 8 to 16 feet in thickness in these lower levels of this mine.

The Pennsylvania vein is correlated with the O'Neill ledge, but there is some doubt as to the identity of these two. (See p. 122.)

MOONLIGHT VEIN.

The Moonlight is the first large vein south of the Anaconda lode and has a course parallel to it. It is worked in the Blue Jay, Bellona, and Moonlight mines, being developed to a depth of 1,300 feet and for a length of about 2,000 feet. It is an east-west quartz-pyrite lode, cut and displaced by the Blue Vein fault, the eastern part forming the Middle ledge of the Anaconda mine east of that fault. It is also intersected and enriched by the Blue Jay fault vein of the Steward system (fig. 33). The Moonlight vein belongs to the Anaconda system, and shows the usual characters of the older quartz-pyrite lodes. Its dip averages 68° S. The vein filling consists of hard and generally solid quartz and pyrite, 5 to 50 feet wide, with ill-defined walls, the ore fading into the hanging-wall rock except where strike faults have formed clay selvages. The vein is not uniformly mineralized, the richer ore occurring in shoots; the largest of these, worked in the Bellona mine continuously from the oxidized zone down to a depth of 1,300 feet, shows 50 feet of stoping ore. The ore shoots consist of shattered primary ore, enriched by intersecting northwest fault veins, the intersection determining the location of the shoots. These richer ores contain enargite, sphalerite, and chalcocite, the first named in irregular streaks and masses embedded in a clay matrix, or in altered granite, while the glance is later and forms a cement binding fragments of rock and earlier ore together or filling fractures. In the stopes, fragments 5 feet across are common.

On the 750-foot level of the Moonlight mine the Bricker ore body is 50 feet or more wide, narrowing westward to the Blue Jay fault vein. The ore shoot is defined by soft fault matter on the hanging wall, with soft, decomposed, blocky granite on the outside of it for 115 feet. This is incased in black granite netted with joints, along which the rock is altered and is soft and slacks readily. The foot-wall of the ore body is irregular, showing a 5-foot band of 3 per cent ore between the wall and the vein proper. The vein beyond the Bricker ore body is now proved eastward on the 750-foot level to the shaft, the ore pinching and passing into the wall of the level near the raise to the 600-foot level, the drift following a mere clay seam. North of the vein the granite is normal. On the 500, 750, 1,000, and 1,100 foot levels of the Moonlight mine the lode has been worked for over 1,000 feet horizontally. The vein in these workings shows the usual netted fissuring of the east and west veins.

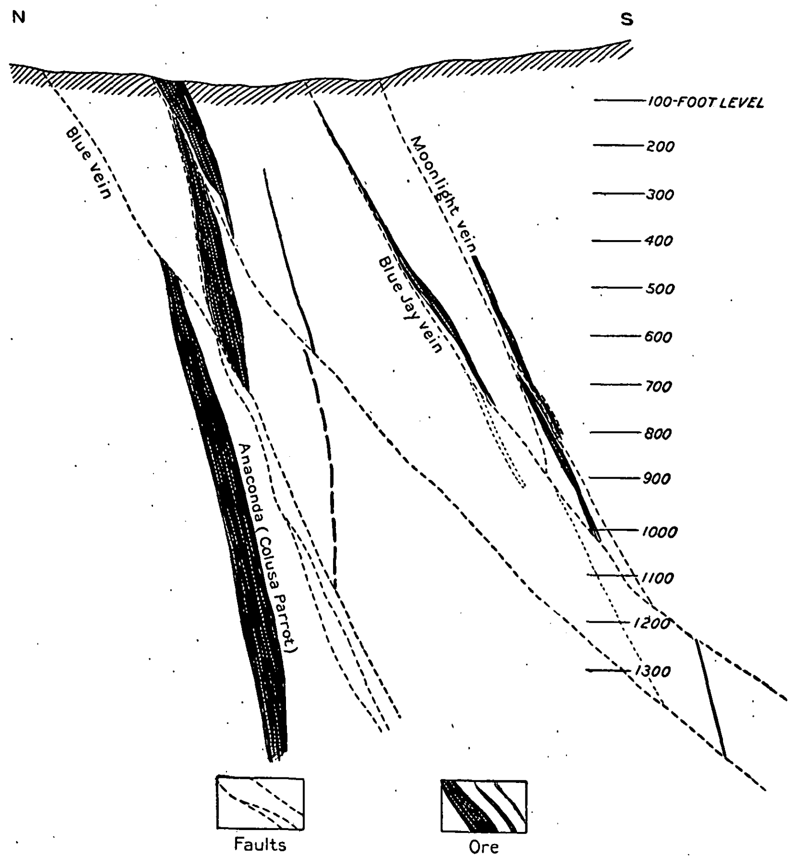


FIGURE 33.—North-south cross section through Colusa-Parrot vein, showing relations of Blue Jay fault and Moonlight vein.

A north and south section through the Bellona shaft shows the vein to lie wholly above both the Blue and the Blue Jay fault veins, and it appears probable that the east-west quartz-pyrite vein east of the Blue vein is the extension of the Moonlight, displaced by the Blue and subsequently broken along its strike by the Blue Jay fault vein. As the ore shoots result from the cutting of the vein by faults, a knowledge of their occurrence is of prime importance.

The Blue Jay fault cuts off the vein both downward on its dip and westward, so that the vein is seen west of the fault in the Blue Jay mine workings. It becomes zincky and lean westward. The eastern displaced portion of the vein, seen east of the Blue vein, is so shattered by the Blue Jay that a composite vein is formed, and the vein is not known beyond the point where the Blue Jay leaves it. The structural features of interest are those also common to the Middle ledge. It is to be noted that the vein has been first faulted by the Blue vein, and then along its strike by the Blue Jay, which after leaving the Moonlight crosses the Blue and becomes a strike fault on the eastern part of the vein.

The 1,000 and 1,100 foot levels of the Moonlight mine show the vein of this name extensively worked both in drifts and stopes. On the 1,000-foot level the vein lies on the south side of the Blue Jay fault, but between the 1,000 and the 1,100 foot levels the Blue Jay passes through the Moonlight with almost no shifting of the ledge, so that on the lower level the vein lies on the northwest side of the Blue Jay fault and follows along a displaced easterly section of the Moonlight, which probably fades out eastward, as it does not show in the mine workings. That it corresponds to the Middle ledge of the Anaconda mine is plain if one matches the opposed ends of the vein on each side of the Blue vein, allowing for approximately the same displacement observed between the Anaconda ledge and Parrot.

HOGAN VEIN.

The Hogan (or Hogans Alley) vein is a quartz-pyrite contact vein, belonging to the Anaconda system, that is cut on the deep levels of the Anaconda properties. Its outcrop has not been recognized. The vein is best developed on the 1,200 to 1,600 foot levels of the Anaconda, where it occurs underneath the porphyry dike that lies either on or near the foot wall of the Anaconda ledge. The Hogan vein thus lies between porphyry and granite, being overlain by the former, but departing from the contact and running off into the granite as it is followed upward. The vein is from 5 to 15 feet wide and shows an average of 8 feet of stoping ore, but is not everywhere workable. It carries much water, and its ore contains both crystalline and sooty glance. (See fig. 37, p. 126.)

The vein is well developed on the fifteenth level of the Anaconda mine, where it lies on the foot wall of a 30-foot dike of the rhyolite porphyry. The course is S. 80° W. magnetic, and the dip 65° S. The vein shows a thickness of 3 to 4 feet of pyrite and quartz ore carrying perhaps 3 per cent copper. On the 1,800-foot level this vein is too lean to warrant working. The lode is cut off to the west by a northwest fault fissure 4 feet wide, running N. 40° W. and dipping 75° S.

O'NEILL LEDGE.

The O'Neill ledge is a faulted block of the Pennsylvania vein beneath the Rarus fault. (See fig. 32.) The lode shows in the south crosscut from the Anaconda mine, and is worked in the Belmont, but, being cut off by a northwest fault, its continuation west of the Anaconda crosscut is unknown. The lode is 15 to 20 feet wide, consisting of shattered quartz-pyrite ore, with well-defined walls marked by clay seams. The dip is southerly and rather flat. The vein is continuously developed east of the Rarus fault on the Pennsylvania 1,000-foot, Anaconda (South) 1,400-foot, and the Belmont 900-foot levels. In the Belmont mine it has been opened up on the eighth and ninth levels, and the identity of the ledge worked on these levels with the O'Neill ledge drifted on in the Anaconda 1,200-foot (which would be equivalent to the Belmont 700-foot if such existed) seems beyond question. But as the Blue vein passes through this ground it is possible that the correlation with the Pennsylvania vein is incorrect.

MINERALIZATION.

The enormous copper production of the Anaconda lode is due to the great quantities of copper glance which it contains. The upper levels held masses of nearly solid chalcocite 25 or more feet wide, several hundred feet in both length and depth. Besides these masses of solid glance, the intervening granite was netted by veinlets and impregnated with scattered grains of copper glance, forming the concentrating ore which furnished the bulk of the production. Chalcocite is most abundant where the vein has been shattered or faulted, and the larger ore bodies of rich ore show a marked dependence upon the presence of cross fissures. Plate XIII (p. 110, after H. V. Winchell), which represents an ideal cross section of the lode, shows the relation of the lode to the quartz porphyry dike and to fault fissures.

In general it may be said that chalcocite is less abundant with increasing depth and that the thick bodies of solid chalcocite found throughout the vein from 500 to 1,200 feet in depth gradually narrow downward and end in threads or films of glance penetrating the primary vein filling. The presence of this mineral appears to be wholly dependent on the depth of the fracturing and the readiness with which waters penetrated downward. Where the primary quartz-pyrite vein filling is solid and unbroken it carries little or no glance and is usually too lean to work. In the upper levels the large masses of chalcocite formerly mined resulted from a complete replacement of the primary pyrite ore by reaction between descending waters carrying copper sulphate and the primary pyrite or other sulphides. Glance is most often, however, found in areas of crushed and faulted material, where it largely results from the filling of open spaces, as shown by the occurrence of large included crystals of quartz in the chalcocite (fig. 34).

The outcrop of the Anaconda is not conspicuous and throughout most of its course must be searched for, as it is broken down and its quartz greatly resembles the silicified granite of the adjacent rocks. For 20 to 150 feet below the surface it consists of quartz, generally shattered and stained a rusty brown by limonite, but rather massive, and lacking either the porous structure or the great amount of limonite usually characteristic of the gossan of quartz-pyrite veins. At a depth varying from 20 to 100 feet this quartz, which is devoid of copper but carries a residual silver content, gives way to a mass of black friable material consisting of pyrite and copper glance. This layer of so-called "sooty sulphides," which ranges from 2 to 6 feet thick in the Parrot mine to the west, is thin or absent altogether along the Anaconda lode proper. It is underlain by solid glance and pyrite ore, the upper surface of the glance showing the effects of the oxidizing waters.

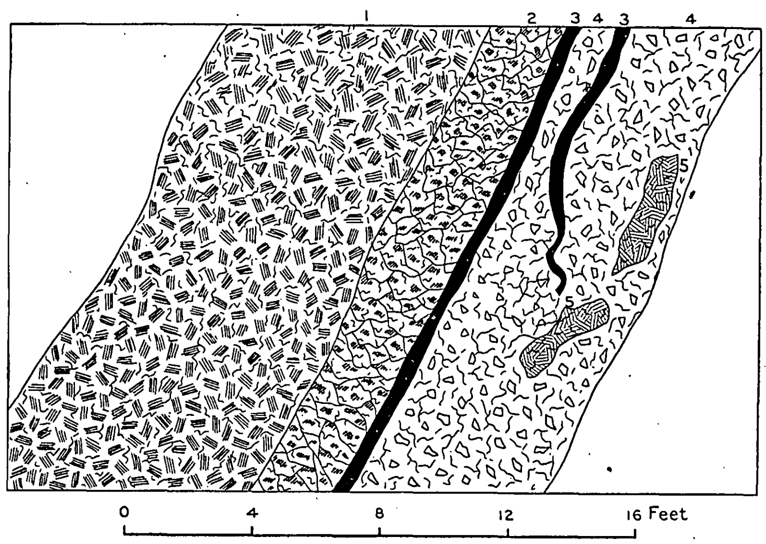


FIGURE 34.—Anaconda lode, third floor west on the 1,600-foot level of Neversweat mine. 1 Solid quartz hanging-wall band, 8 feet; 2, crushed white quartz peppered with pyrite, 2 feet; 3, clean glance, 4 inches; 4, brecciated white quartz, 6 feet, inclosing fragments (5) of quartz-pyrite ore.

As already indicated, the cross fractures, which are later than the primary lode filling, are most important, as they govern the occurrence of the high-grade ore. These fractures vary from mere joints, only recognizable by films of glance in freshly exposed surfaces, to well-marked "spur veins" carrying glance ores. Where ore-bearing these cross fractures have evidently derived their copper from the same source as the secondary ores of the lode, and their copper content fades out as the distance from the lode increases.

The two main faults of the district, the Blue Vein and the Mountain View, have produced great displacements, and are, for convenience, used as limits defining the sections of the lode. All the numerous minor cross fractures whose general course is northwest cause slight displacements, but are not shown on the maps, as they are far too numerous to plot on the scale used.

Besides the copper glance, enargite and bornite appear in the lode. The enargite is found only in connection with faulting and is the result of mineralization later than the vein. Bornite appears to be both primary and secondary, but as it is inclosed by the enargite it is known to be the older. Much bornite is found in the Parrot mine and in the workings westward, but it occurs in comparatively small amount in the Anaconda properties and in the Mountain View mine.

In the lower levels of the mines which work this lode cross fracturing has resulted in a shattering of the granite, due to an adjustment of the displaced blocks, and this shattered granite has been enriched by the deposition of copper glance, so that considerable masses of ore outside of the vein proper have been mined at various points.

Figure 35 shows the rock traversed by a series of slips and seams, running from N. 20° to N. 30° W., and dipping southwest at varying steep angles. The granite is thoroughly sericitized and bleached. Besides the fault slips shown, a network of joints runs at every angle and in every direction. These joints are filled by glance and pyrite and the intervening rock is impregnated.

In general the vein filling in the vicinity of fault fissures has been found to contain rich ore in the deeper levels, but to be poor at such places in the upper parts of the lode.

In the Colusa-Parrot mine (Parrot lode) the upper portion is unlike the normal quartz-pyrite vein below. It consists of narrow quartz-pyrite veins, with the intervening granite impregnated with grains of pyrite replaced or coated by glance. As it is known that the displacement of the Blue vein caused a downthrow (of the Colusa-Parrot) of at least 510 feet the Parrot workings represent the highest portion of the Anaconda lode preserved at the present time. (See fig. 36.) It is not known how much erosion this portion of the lode has suffered; but inasmuch as the adjacent Neversweat workings east of the fault show enriched ore at much greater depths than those of the Parrot it is assumed that this enrichment is due to a concentration within a zone 2,000 feet deep of the copper leached from a former vertical extent of the lode above the present surface much greater than that which contributed to the enrichment of the Parrot ground.

In the Anaconda lode, as well as in other lodes throughout the district, the workable ore sprays out above the cross faults, showing that the deposition of glance has been by descending waters. Owing to the greater abundance of glance in the upper levels, this feature is not so marked as it is in levels 1,000 feet or more beneath the surface.

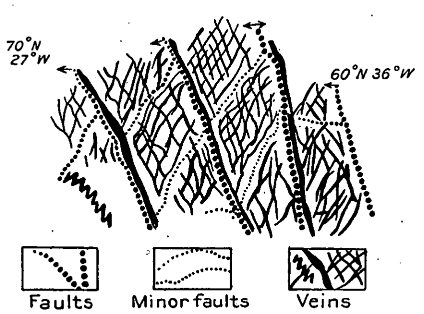


FIGURE 35.—Altered and mineralized granite alongside of Anaconda lode (south) on third floor above the 500-foot level of the St. Lawrence mine.

Besides the northwest fissures, whose effects have been noted above, fissures having a general course of N. 60° to 70° E. intersect the lode at a comparatively small angle. These intersecting fault veins have been extremely important factors in the production of large ore bodies; but inasmuch as they have brought about a separate mineralization, and as the earlier ore found in them is broken and comes from the primary veins, their discussion is postponed.

The footwall of the vein is commonly marked by breccia and clay, forming a porous layer that is everywhere a source of water. The abundance of water is regarded as a favorable sign, as where the ledge is dry and tight it is generally too low grade to be workable. This clay slip separates the altered rock from the normal biotite granite to the north. The Blue Jay fault or Middle ledge, where cut on the 1,800-foot Anaconda level, admitted water which gushed to a height of several feet, but gradually subsided in the course of a few weeks.

The rock between the two ledges of the Anaconda vein is always more or less jointed, though seldom crushed. It is pyritized and shows extreme alteration along the joints.

Although normally devoid of banding, the vein, where crushed or crackled, shows new quartz and secondary ore minerals arranged in bands and vugs.

The general character of the Anaconda is well shown in the 2,000-foot level of the Neversweat (east), where the vein is 40 to 50 feet wide, and is generally solid (and lean); if cracks occur they carry recently deposited pinkish quartz; where the vein is vuggy, glance appears. Enargite also appears at this depth, occurring mainly in patches and in veinlets, but also in streaks in the granite walls.

The cross fractures that cut through the Anaconda lode are not shown on all the vein maps. All of them were not recognizable on all the levels when the notes were made and no attempt was made to project them. Their distribution is evidently important, determining the existence of rich ore bodies, but the vein is so large that they are easily overlooked in working. Such fractures and "spurs" were seen in many freshly opened stopes, but they are hard to recognize in the levels; even a 3-foot shift in the wall of a vein 60 feet wide could scarcely be noticed. The Anaconda vein in the Neversweat mine west of the main crosscut is cut by a dozen strong clay slips running N. 35° to 65° W. and dipping 60° to 80° SW. In places these slips can be seen to cross the vein, but more generally they can not be recognized except on perfectly clean faces.

The map (Pl. XXXVI) showing the vein structure on the 5,700-foot plane (300-foot level Anaconda and 100-foot level St. Lawrence) shows the full development of the Anaconda vein. The vein passes through a dike of the rhyolite porphyry at the eastern end, and is lean, carrying pyrite, but no glance, in this rock. The oxidized "free-milling" ore extends down to this level in some places.

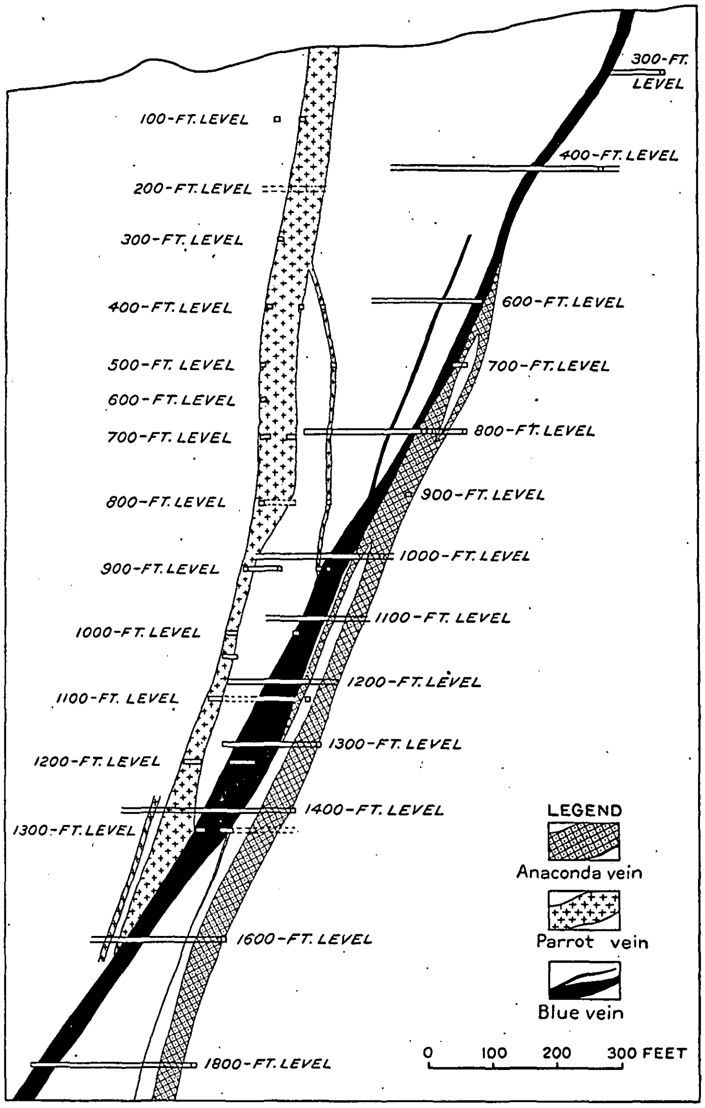


FIGURE 36.—Section through Neversweat and Colusa-Parrot mines.

FAULTING.

The most interesting structural feature of the eastern part of the Anaconda lode is its cutting and dislocation by three cross faults, known as the Blue Jay (Middle or No. 16), the Mountain View, and the (later) Rarus. The two last named intersect on the 1,400 and 1,500 foot levels of the St. Lawrence mine. At the east end of this mine the Rarus fault splits up into four or five strong fissures, with crushed and altered granite between, and this crushed and altered ground contains flat ore bodies which have yielded large amounts of rich enargite ore quite different from that found elsewhere in the mine. These ore bodies have an inclination of about 30°, are not over 15 or 20 feet thick, and appear to be displaced and enriched portions of the main vein. The strong fault fissures of the Rarus are very apparent, cutting off the ore abruptly on the west; beyond them the Anaconda lode is solid, but is a lean mixture of quartz and pyrite. Between the fissures the ore is a crushed granite, filled with streaks and fault slips running in every direction and thoroughly impregnated with pyrite and enargite. The interfault matter, where composed of rhyolite porphyry, is lean and is not enriched, unlike the broken ground in the granite area proper. The diagram (fig. 58, p. 153) represents conditions on the 1,400-foot level of the St. Lawrence mine, where the ore body worked on the 1,300-foot level has been followed downward and has been extensively developed. On the underlying 1,500-foot level the intersection of the Mountain View fault vein is well shown. The vein, which is 3 sets wide, is cut by north and south fractures passing through the solid quartz. The vein has apparently been twisted, as shown by the fractures observable on fresh surfaces. The vein quartz is mostly white and very lean, but in places carries pyrite, with specks of glance. Between the faults, marked by strong clay seams and gouge, the ore consists of mashed granite impregnated with pyrite and enargite.

The Hogan vein is seen east of the Rarus fault in the south crosscut from the 1,500-foot level (fig. 37), but it is lean and not workable.

The 1,400-foot level (St. Lawrence) shows the typical structural features of the main lode. It here has a general east-west course, and lies parallel to a quartz porphyry dike, which is about 30 to 50 feet back in the footwall. This dike shows very plainly that northwest faults lying between the Blue and Mountain View faults have broken and thrown both the dike and lode, and have been channels for enriching waters. A fault of the Steward system crosses the ledge, but gives slight displacement. East of the St. Lawrence shaft the lode is lean and, on account of the still persisting mine fire, has not been stoped. The lode is thrown eastward by the Mountain View fault, a northeast fissure filled with hardened clay and friction pebbles. The oxidized quartz has been mined for converter linings and to recover its silver content on the 150-foot (5,872 feet) and 200-foot (5,821 feet) levels of No. 2 St. Lawrence shaft.

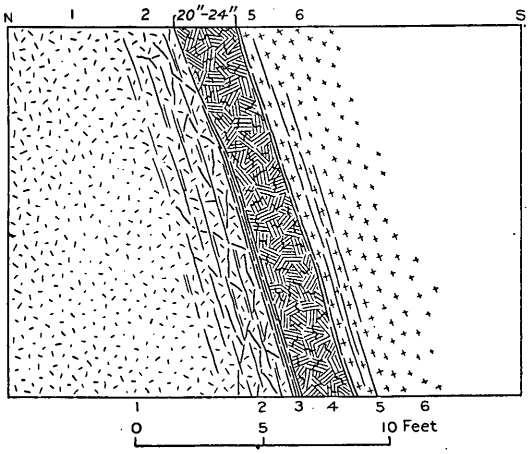


FIGURE 37.—Section of Hogan vein. 1, Quartz monzonite; 2, crushed quartz monzonite with clay streaks; 3, clay; 4, quartz-pyrite vein; 5, porphyry with clay streaks; 6, porphyry.

The Rarus fault cuts across the Anaconda ledge in the workings of the St. Lawrence mine, showing well on the 1,800-foot and 2,000-foot levels. On the 2,000-foot level, south of the Rarus fault, the Anaconda workings show drifts on three veins of the Anaconda lode. The main one is a fault vein, worked through to the St. Lawrence; it is flat (dipping 35° S.) and is lean at the west end, showing but 12 inches of quartz, running $2\frac{1}{2}$ per cent copper and $3\frac{1}{2}$ ounces per ton of silver. The second vein is 6 feet wide and carries 1 to 3 per cent copper, with 1.8 ounces of silver per ton. The third vein is also 5 to 6 feet thick, with ore of the same general tenor.

On the Anaconda 2,200-foot level the vein has a strike of N. 65° E. and a dip of 65° S.; it carries 3 feet of quartz containing 5 to 6 per cent copper and 2 ounces per ton of silver. The vein is cut and displaced eastward by a northwest fault and by several northeast slips, and the rich ore occurs along these fractures. The main ledge, where cut by the St. Lawrence main crosscut, is 30 feet wide, and farther west where crossed by the fault slips is 45 feet wide and runs 7 to 11 per cent copper.

The southwestern extension of the Rarus fault is disclosed in the twentieth level of the Anaconda, showing in the south crosscut. The interfault material holds large blocks of ore and porphyry turned partly around. The Rarus fault is 300 feet wide at this place.

PARROT LODE.

THE LODE AS A WHOLE.

DEVELOPMENT AND GENERAL CHARACTER.

The Parrot was the first copper vein discovered and the first one worked in the Butte district. It has been traced almost continuously from Missoula Gulch eastward to the Blue fault vein, near the Anaconda mine, a distance of 3,750 feet, all of which has been actually developed by underground workings. The deepest levels driven on the lode are 1,800 to 2,200 feet beneath the surface, corresponding to an absolute elevation of 3,400 to 3,800 feet above the sea. So far as shown by present mine development the lode forms the southern limit of the productive copper belt west of the Blue Jay mine.

The general course of the Parrot lode is nearly east and west, with divergence of about 5° S. at the west end. The vein dips south, generally at 75° to 85°. (See fig. 38.)

The outcrop is readily traceable and in early days is said to have been marked by an abundance of green carbonate and silicate of copper and by an entire absence of vegetation. At present it is seen as a distinct band, differing in color and character of débris from the adjacent granite, though rising but slightly if at all above the general level of the weathered rock.

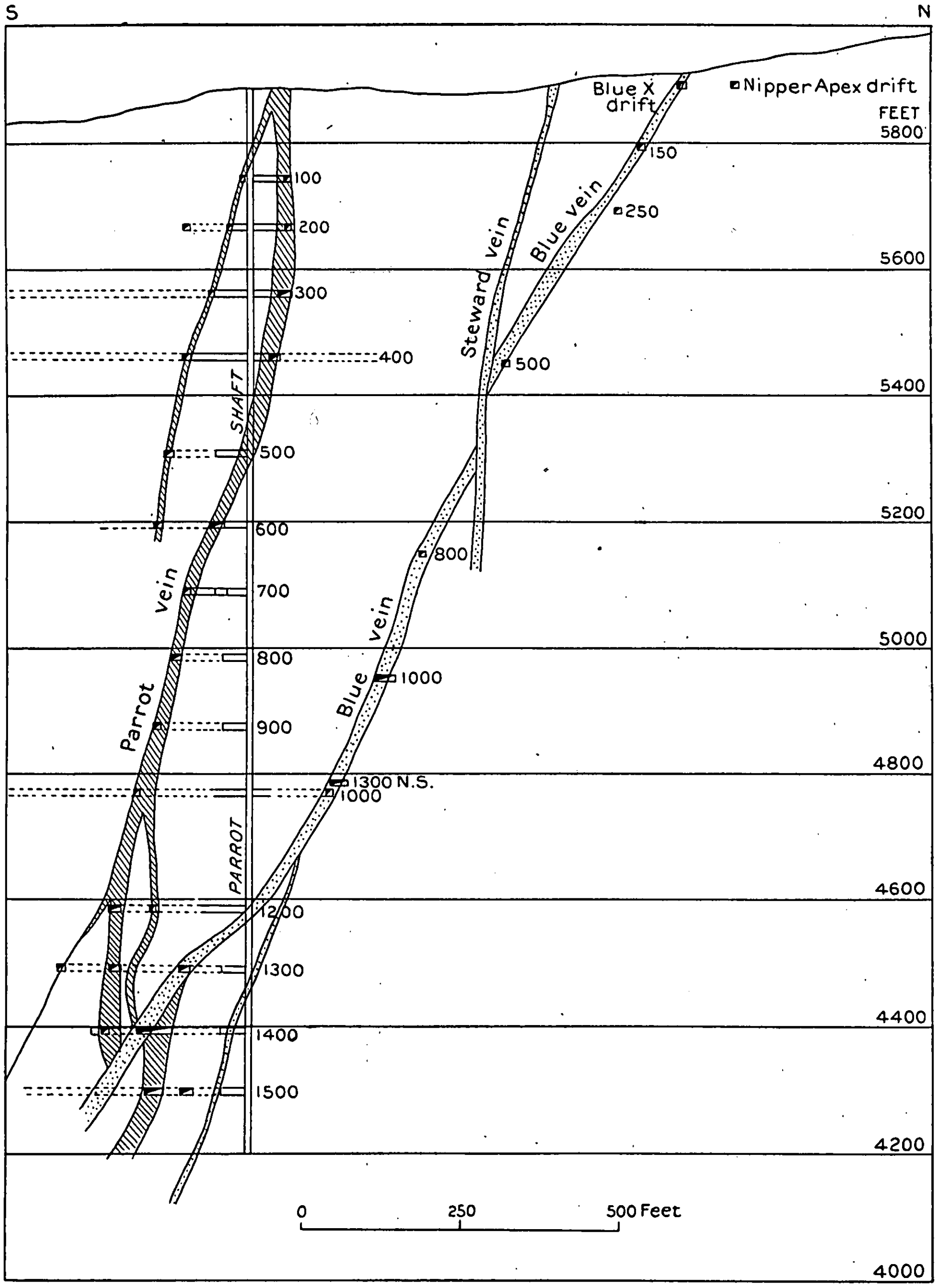


FIGURE 38.—North-south section through Parrot shaft.

The Parrot lode shows the same general characters as the Anaconda, but differs in minor features. As already stated, the vein consists of quartz and pyrite, cracked by secondary fractures and enriched by secondary mineralization. It bears bornite and carries enargite in increasing amounts toward the west, glance becoming of secondary importance. Its structural features also change, and its silver ratio increases westward toward the silver belt.

SPLITTING OF THE VEIN.

At the east end the Parrot lode shows the two ledges which compose the Anaconda lode; the hanging-wall ledge diverges from the main vein both downward and westward (see fig. 39) and west of the Parrot shaft can not be regarded as part of the lode; it is known as the South Parrot or Virginius vein.

Toward the western end of the Parrot mine another vein is observed on the footwall side. This, known as the Original fault vein, is nearly parallel to the main Parrot vein, both vertically

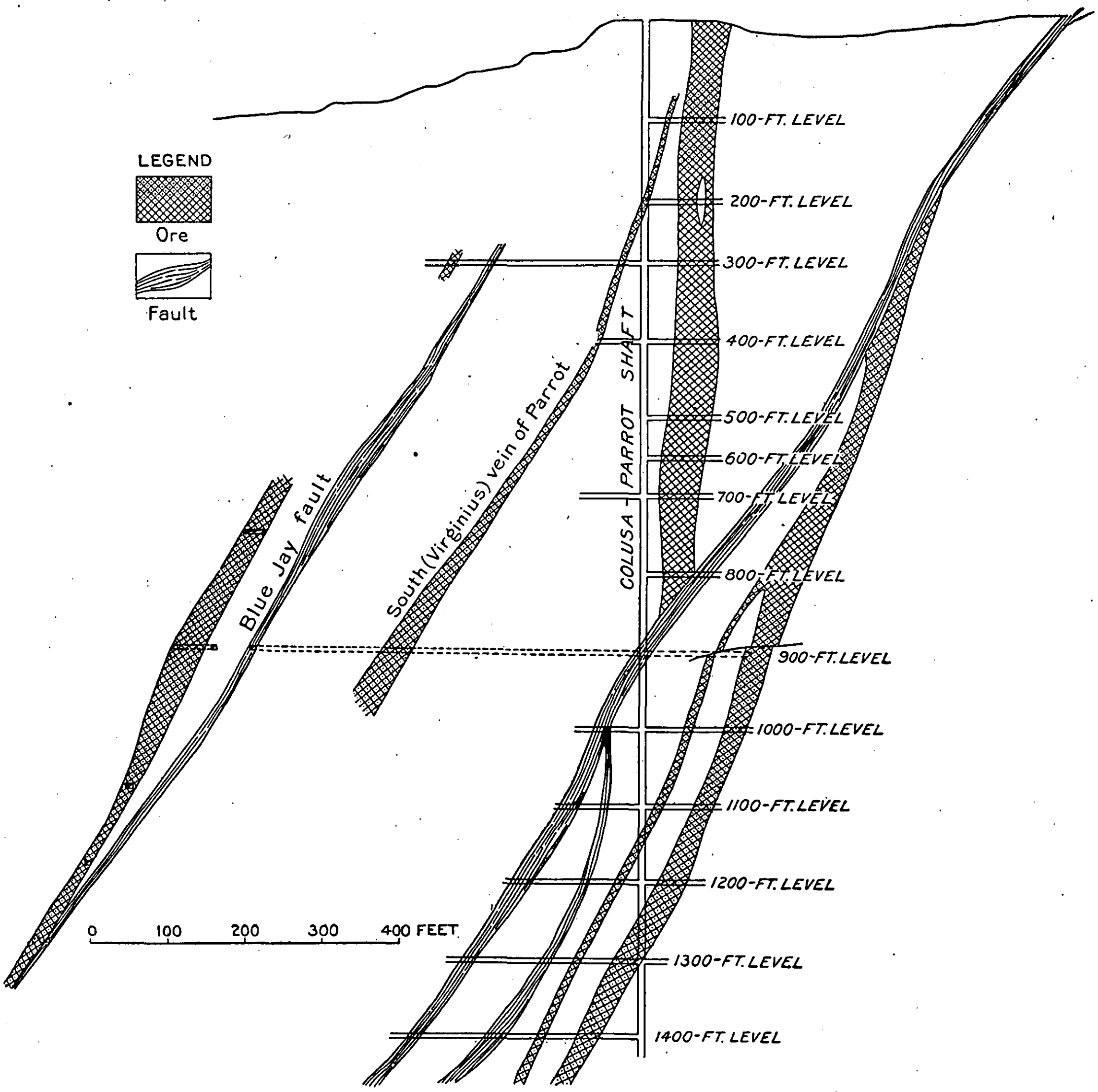


FIGURE 39.—Cross section through Colusa-Parrot shaft.

and along its course, from No. 6 shaft westward to the Gagnon, being recognizable to depths of 500 feet or more, but being lost when the entire lode is crushed and broken by the intersection of the Steward fault vein.

The Parrot vein maintains its identity intact, despite numerous cross fissures and veins, from the Colusa-Parrot mine to the Gagnon. This is true, however, only in the upper levels, for in the lower levels (fig. 40) west of the Parrot mine the lode is cut and crushed by faults, the largest of which follows along the strike and forms a composite vein. The Parrot vein proper is regular in course and dip from the surface downward to a depth of 800 to 900 feet; below this it shows fracturing and many minor displacements, with corresponding irregularity in mineralization. The general course is east-west, the drifts running either N. 80° W. or N. 80° E. and the stopes showing the course of the vein to be first along one and then along the other of these directions.

In the Original mine the Parrot maintains its character as a solid quartz-pyrite vein, cracked by slight faulting, with seams and films of glance filling the cracks.

Near the surface the Parrot lode consists of the footwall vein (No. 6 vein) and the Parrot vein proper. The latter is itself double from No. 6 shaft westward. The Parrot No. 6 vein consists of two ledges, each 2 feet thick, of hard, lean, quartz-pyrite ore, carrying less than 1 per cent copper, with 6 to 7 ounces of silver; the veins are separated by 25 feet of altered granite. In the 200 and 300 foot levels of the Original mine these veins are thicker, the southern one being 3 to 5 feet and the main ledge from 10 to 15 feet wide. The intervening granite is 12 to 25 feet thick. The veins show banding, the streaks dipping 65° to 70° S. with the vein. The ore is solid, but lean, there being no secondary fracturing and enrichment.

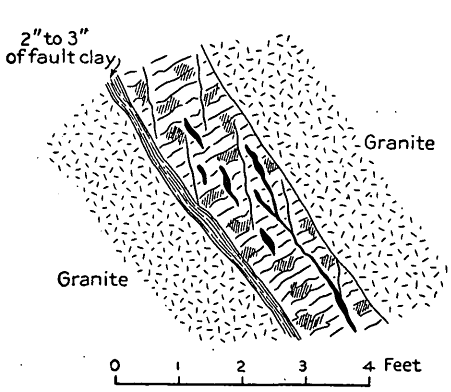


FIGURE 40.—Section of south ledge, 1,400-foot level of Parrot mine.

Farther east, near the Parrot shaft, the lode is single down to a depth of 1,000 feet, splitting below this into two veins separated by 50 feet of altered granite. On the Parrot 1,200-foot level the footwall vein is the lesser, varying from 5 to 12 feet across. It is a very hard pyritic quartz vein with a thick clay and breccia seam on the footwall and a foot or more of nearly pure bornite lying between the clay and the quartz-pyrite vein (fig. 41). The main ledge or hanging-wall vein is 8 to 25 feet thick, but rolls and pinches, both vertically and horizontally. It is cut by N. 10° to 40° E. fractures with a dip of 80° to 90° W.; in some places these fractures are so close together as to brecciate the vein. They vary from mere cracks to clay seams 2 feet thick and delimit the rich ore on the hanging-wall side. In some places streaks of glance run out along the cross fissures for several feet from the lode.

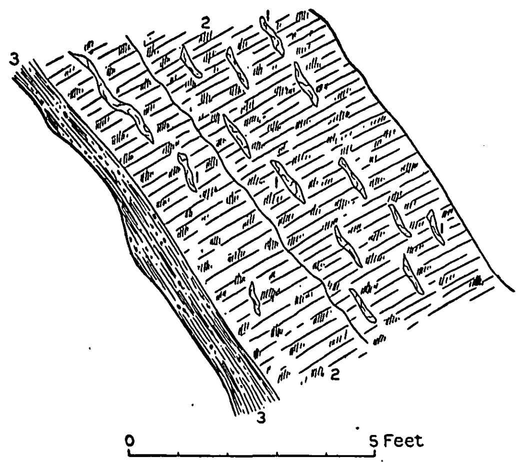


FIGURE 41.—Ore bands, Parrot lode, 1,400-foot level. 1, Quartz; 2, pyrite; 3, soft sand.

The Parrot vein is continuously worked from the Blue vein westward through the Parrot and Original mines to the extreme limits of the Gagnon (on the 200-foot level of the latter property, corresponding to an elevation of 5,600 feet). This continuity does not obtain in the deeper levels, for, below the 800-foot level, the Parrot vein, as developed in the mine of that name, has a flattish southward dip, and the main ore supply of the deep levels, 1,100-foot to 1,800-foot, of the Original and Gagnon mines comes from a compound or composite vein formed by the union of this and the Steward fault vein. It appears probable that a spur of the Parrot vein runs into and forms this vein. The Parrot vein is certainly continuous through the entire length of the Parrot mine on the 700-foot level westward into the Steward and Original workings.

FRACTURES.

The Parrot lode is not so wide as the Anaconda, averaging perhaps 20 feet. Cross fractures are often strongly developed in the upper levels, particularly near what is known as No. 6 shaft, but more commonly the northwest cross fractures are scarcely recognizable in the levels from 500 to 1,000 feet, whereas from the 1,000 to the 2,000 foot levels they are marked, delimiting the rich ore and causing much trouble in mining.

From east to west there is a gradual change in mineralization shown in the larger amount of bornite, in the increasing abundance of enargite where faulting has occurred, and in the increased proportion of silver carried in the ore.

The Clear Grit vein, a prominent northwest fracture parallel to the Blue vein, crosses the Parrot lode without much displacement of the latter, and many of the lesser fault fractures shift the vein from a few inches to several yards.

Westward the Parrot lode is intersected by the Steward fault vein, with which it forms the great composite lode that has yielded richly in the deep levels of the Original and Gagnon mines. In these mines the lode above the intersection is lean, or where pay ore is found it is limited to small ore shoots, but below the intersection large ore bodies, rich in enargite, are encountered.

At its east end, on the lower levels of the Colusa-Parrot claims, the lode closely resembles, in its structure and characteristics, the faulted end of the Anaconda ledge lying east of the Blue vein. The lode, however, to a depth of 700 to 800 feet, consists of mineralized and altered granite rather than of quartz-pyrite veins. The significance of this has already been mentioned in discussing the faulting of the district (pp. 58, 125), the inference being that the Parrot represents the faulted downthrown block in which the upper granite part of the vein has been preserved while erosion has removed it from the Anaconda to the east. This means a time interval since the Blue vein was formed sufficient for the differential erosion of 510 feet of vein and rock from the surface of Anaconda Hill.

PARROT MINE.

ORES.

In the Parrot mine the rich bornite ore which is so abundant in the upper levels gradually decreases in amount with increasing depth, until at 1,000 feet the ore is relatively lean. This character prevails westward until the big Steward fault is encountered in the Original mine. There is little doubt that in the Parrot mine the lode does not carry rich ore to as great depth as the Anaconda; the physical, as well as the mineralogic, character of the ore indicate incomplete replacement in the deeper levels, as compared with those above.

FRACTURES.

The character and influence of the lesser cross fissures is difficult to estimate. Westward they certainly appear to continually shift the vein to the north and to have a marked influence on the richness of the vein, as shown by comparison of the ore mined on the upper and lower sides of the cross fault. Most of these faults have so slight displacement that it is difficult to find them in the level workings, but they can not be found at all in the old stopes of the upper levels as these are all filled and closed up; those at the deeper levels are therefore more apt to appear on the mine map than are those nearer the surface. Figure 41 shows the fracturing on the 1,400-foot level.

The west stopes of the 1,300-foot level of the Parrot mine show a vein having an 18-inch foot-wall streak of crushed granite and clay, which at times passes into breccia. This adjoins 4 feet of quartz and pyrite formed as a replacement along a network of fractures in a shattered granite, the rock showing no recognizable sheeting or plating. The hanging-wall portion shows 2 feet of shattered quartz and granite. This portion of the vein shows very plainly that it is cut by cross fractures, which cut off the ore and destroy the continuity of the ore shoots. In general they strike 90° to the vein, and dip 80° E. This may indicate a greater number of such cross fractures in the lower workings than in the levels above 1,000 feet, but the excess is believed to be only apparent and probably due to the fact that in the upper workings no fresh faces are observable. However, there is a strong probability that the mineralizing process is not complete in the lower levels and that the workings are approaching a zone of leaner ore (or rather of ore streaks separated by barren places) and that for this reason the deflection of the enriching currents by the cross fractures is much more evident in the lower than in the upper levels.

The second floor of the 1,300-foot stope shows 15 feet of good ore, which consists mostly of pyrite, with enargite and bornite, the latter occurring in spots and along vugs. The bornite here seems partly primary and partly secondary; attention should be called to the elongated vesicles, which indicate gas inclusions, found both in the bornite and glance of these lower levels. The hanging-wall side of the solid ore has been crackled and shows 2 inches to 6 inches of crushed quartz on the wall, with 6 inches to 10 inches of quartz-pyrite ore and one-sixteenth inch of glance.

The character of the lode in the deeper levels of the Parrot mine is well shown in the 1,400-foot level. The main ledge consists of somewhat crackled quartz, with a chalky texture, owing to the fact that the mine waters have been drawn off by the deeper Neversweat openings. The quartz contains much pyrite with threads and small scattered particles of bornite. In general the main ledge at this level is a solid quartz-pyrite vein, in which enrichments occur where the ledge is shattered. Considerable red quartz appears and is considered to be the result of the precipitation of glance by reaction with carbonates. The south drift shows dark altered granite with disseminated pyrite, netted by films and streaks of quartz carrying pyrite, and by veinlets of pure white milky quartz. The pay streak is 18 inches to 20 inches wide and shows disseminated bornite in the quartz-pyrite vein, in which the pyrite occurs in irregularly defined patches. The vein has a workable width of 15 feet.

Away from the immediate fissures of the Blue vein the vein is very solid. Moreover, the lode shows much secondary quartz and glance, especially in the south streak of the main ledge on the 1,400-foot level, where ore and quartz make against the footwall gouge and where frosty quartz is forming against the clay selvage. The footwall streak is composed in part of curly quartz, with interlocked sulphides, and the main ore streak is a banded but solid mass of pyrite and sphalerite, traversed by flat fissures and joints having a dip of 20° N. and a strike parallel to the vein. These fissures often show thin sheets of ore along the joint planes.

In the Parrot ledge rich sulphides extend westward to cross fractures, which appear to stop the mineralization. The vein keeps on without disturbance but is lean; ore shoots at the intersection, which are of considerable size and of fair value, were stoped on the upper levels. The same fissures probably extend downward but they are not recognizable; their intersection is not marked by ore in the deeper levels nor do they apparently interrupt or displace the Parrot vein.

FAULTING.

The Parrot is cut by numerous fault veins of different systems and different ages. The principal northwest faults are the Blue and Clear Grit; the Washoe is of less importance, and minor fractures are very numerous.

As already stated (p. 129), it is impossible positively to correlate the Parrot ledge developed continuously throughout the Parrot mine with the east and west composite vein (Gold vein) found below the 900-foot level of the Original mine, for the latter appears to lie north of and parallel to the Parrot, at a distance of about 100 feet, extending westward until cut by the Steward fault vein.

The Pennsylvania (South) vein is not definitely recognizable west of the Blue vein. It may correspond to the Zinc vein of the Original mine, which is a fault vein itself, and has a course nearly parallel to that of the Steward fault vein.

The character of the Parrot lode near the surface indicates the correctness of the conclusions derived from a study of the Blue vein faulting (p. 136), that the Parrot mine still preserves the upper part of the vein. The character of the lode in the 50, 150, and 200 foot levels of the Original mine and in the Benham workings indicates a wholly different phase from that observed below, and shows that the top of the vein is near.

Both in the Parrot and Gagnon mines small faults, which differ materially from any of the fault veins previously mentioned, may be observed. One of these cuts off all the veins exposed on the 1,700-foot level of the Gagnon. Its course is N. 65° E. and its dip 65° N., the fault showing 1 to 3 inches of clay, with quartz and pyrite associated with it on the footwall side.

On the 1,800-foot level the vein is also cut by a N. 35° W. vein, dipping 65° W. The main drift on this level of the Gagnon is on the Steward fault vein, which has here left the Gagnon ledge (Parrot), going off into the footwall. The vein shows rhodochrosite in the center, associated with a streak of crushed granite, with lenses of ore, and is inclosed between two well-defined walls. The main ledge on this 1,800-foot level is also crushed, consisting of fragmentary ore with an 8-foot band of lean ore and an 8-foot band of high-grade ore; it gradually recovers its values as it approaches another cross fracture.

Throughout the Parrot workings the vein shows many peculiarities of structure which govern the richness and character of the mineralization. Generally, the lesser fissures crossing the vein have not only had a structural influence on it, but have materially altered its original filling, producing enrichments and apparent depletions of the copper contents. The influence of these cross fissures bears no relation to the amount of faulting, but seems to depend rather on the amount of the descending waters and the influence which the clay fissure exerts in deflecting them. A similar fissure on the 1,600-foot level of the Anaconda mine passed through the porphyry and displaced it and yet does not show at all in the Anaconda vein, the mineralization being thorough enough to obscure and heal up. Another example is seen in the Neversweat 400-foot level, where a northwest fault lying east of the shaft cuts off the ore of a south stringer of the vein but does not show in the Anaconda vein proper. This same peculiarity is very strikingly shown in the Virginius shaft and in the No. 6 shaft of the Parrot lode (fig. 42) in both of which the workings show a deflection of mineralization along the cross fissure and the formation of ore

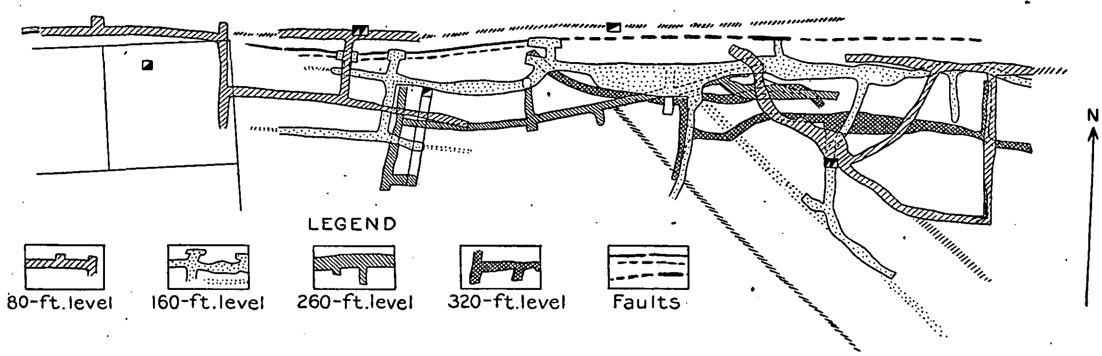


FIGURE 42.—Plans of 80, 160, 260, and 320 foot levels, Parrot No. 6 mine.

consisting of fragments of quartz, pyrite, and bornite, inclosed in a cementing material of well-altered granite. A third vein on this level, lying to the south, shows 2 feet of sphalerite on the foot wall of a fault vein composed of clay, quartz, and pyrite with mineralized granite, the vein getting less bowldery to the west. In drifting westward on the vein several perplexing cut-offs were encountered, but fortunately the shifting is not extensive. On the 1,500-foot level one such cut-off is due to two fault fissures, one having a course of N. 55° W. and a dip of 60° SW., and the other running north and south, vertical, and terminating the ore, the stopes between these two faults being filled by crushed granite and clay. (See Pl. IX, *B*, p. 84.)

SOUTH PARROT OR VIRGINIUS VEIN.

The South Parrot vein, whose relation to the Parrot has already been alluded to (p. 128), is well developed on the Parrot 100, 200, 300, 400, 500, and 600-foot levels, and in the 300-foot drift of the Virginius mine. It has been drifted on for 1,200 feet, from the walls of the Blue vein westward to the Virginius shaft and on the Virginius workings for 250 feet farther. These workings show that the South Parrot diverges to the south from the course of the Parrot ledge as it goes west, and as its dip is flatter than that of the Parrot it rapidly separates from it, both westward and downward. Like the Parrot it is cut and shifted by newer northeast faults. It is cut in the south crosscut of the Original, but is worthless westward and in the deeper levels of the Parrot mine.

ORIGINAL MINE.

GENERAL DESCRIPTION.

The Original mine lies west of the Parrot, between it and the Gagnon. It is in the heart of the city, north of the courthouse and but a short distance west of Main Street. The mine is owned by Hon. W. A. Clark[1] and is worked in conjunction with the Steward. The Original claim is only 200 feet wide and 1,000 feet long.

The Parrot lode passes through the Original claim, but proved disappointing in the upper levels, as the pay ore occurred only in shoots neither very rich nor large. For 600 feet the ore extracted hardly paid expenses, though in recent years these old levels were reopened and furnished considerable amounts of low-grade ore. Below 700 feet the drifts on the Parrot ledge showed good ore (fig. 43), cut off westward by the Steward, a northeast fault vein, which at greater depths held great bodies of high-grade ore.

VEINS.

From the surface down to 900 feet the Parrot vein was the chief producer; below that level the Steward fault vein furnished most of the ore, as it does in the deeper levels of the Gagnon on the west and the Steward mine on the northeast. Besides these two veins the Original includes an east-west vein (the Rialto), a presumably dislocated section of the Bailey or Old Steward, running parallel to the Parrot and north of it, and several lesser veins—the northwest Pyrite vein, the Zinc vein, the No. 6 fault vein and others. All of these, cut in the deeper levels, have contributed small amounts of ore and, by their intersection, have permitted the formation of the great ore bodies of the mine, where the ground was most extensively crushed and opened.

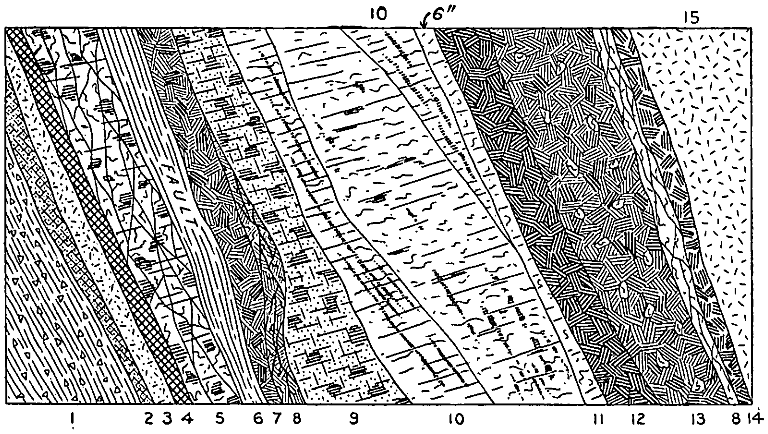


FIGURE 43.—Section across Original ore body. 1, Fault breccia; 2, ore; 3, altered granite; 4, first-class ore; 5, crushed quartz and bornite; 6, fault clay; 7, solid pyrite and bornite; 8, crushed quartz and pyrite; 9, solid enargite ore with bornite; 10, banded white quartz and bornite; 11, white quartz, 6 inches; 12, solid bornite; 13, solid pyrite with bornite and quartz blotches; 14, bornite; 15, granite.

Parrot vein.—In the Original mine the Parrot vein yields but a small part in the ore supply of the mine, and is, indeed, of minor importance. It is worked westward to the intersection by the Steward fault vein down to the 900-foot level and is developed for 200 feet lower, but its ore is lean and zincky. The main ore supply of the mine comes from the Steward fault and from the east-west Rialto vein.

The Parrot vein is commonly distinguished by considerable bornite. On the 1,200-foot level of the mine the vein is 15 to 20 feet wide, consisting of solid quartz, banded in alternating dark and light streaks, with lines and patches of pyrite, though in smaller amount than is usual in this vein. Threads and streaks of bornite occur in the ore, and also patches of enargite, though the latter mineral is more characteristic of the fault veins. The walls are commonly marked by postmineral clay slips, but where these are absent the ore grades rapidly into pyritized silicified granite.

Rialto vein.—The Rialto, which is about 100 feet north of the Parrot lode and which runs parallel to it, is a solid vein of quartz and pyrite, with films and nests of bornite and of enargite, and is the source of the ore bowlders of the ore body found in the fault vein. It is from 15 to 20 feet thick on the 1,200-foot level, with clay slips on each wall, incasing unbroken quartz banded with enargite and pyrite containing vugs lined with enargite. In part the quartz is milky;

[1] It was purchased in 1910 by the Anaconda Co.

in part it is dark and banded with pyrite; but in general it has very little pyrite. Threads and streaks of bornite and patches of enargite occur through it. Recent cracks in the ore are rust colored, showing a replacement of pyrite, without access of oxygen-bearing waters. The vein carries 10 feet of rich enargite ore, and is marked by fluorite on the footwall side. This vein has been fractured and the enargite crushed, clay seams crossing the enargite ore. Fluorite appears to be more recent than the enargite and of the same age as the galena sometimes seen in the footwall fault breccia. The Rialto is considered a quartz-pyrite vein later than the Anaconda system, but of eccentric character.

Steward vein.—That the Steward is a fault vein cutting off the older veins and carrying drag ore torn from them, is particularly well shown on the 1,100-foot level of the Original mine. The east-west Rialto vein here splits into two branches. The south branch shows 6 to 10 feet of lean banded quartz-pyrite ore with granite streaks near the footwall, carrying bornite and enargite in films and patches, even where not crushed. The south split is 5 to 10 feet wide, mostly low grade and zincky, but where crossed by minor fractures, enriched and workable. It has hard walls of but little altered granite.

Sixteen feet below the 1,000-foot level the Steward ledge, here 15 feet wide, is separated from the east-west quartz-pyrite vein by 8 to 10 feet of pyritized granite. The latter, however, shows 2 to 3 feet of fault matter on the hanging wall, showing that the faulting opened a fracture along the vein wall. So far as known this did not affect the Parrot vein on this level.

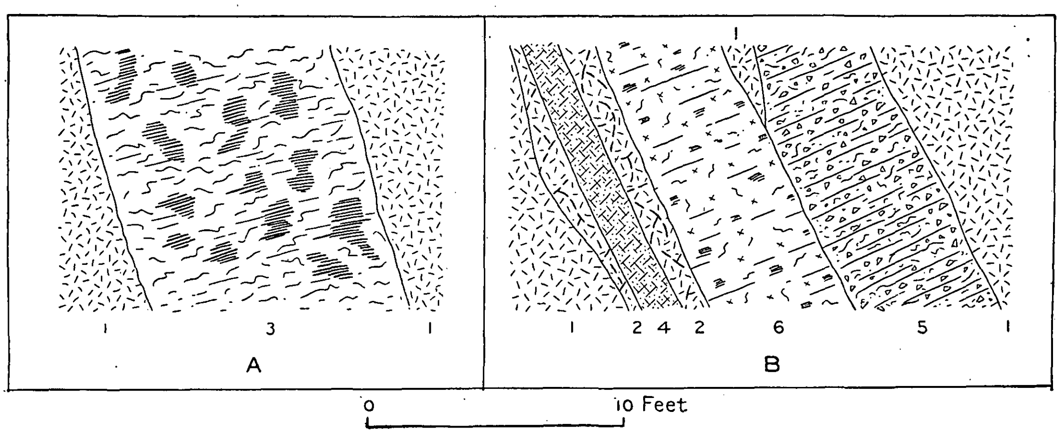


FIGURE 44.—Sections on 900-foot level of Gagnon mine: A, West face; B, 375 feet west of raise. 1, Quartz monzonite; 2, crushed quartz monzonite; 3, banded bornite ore in white quartz; 4, enargite; 5, quartz breccia; 6, quartz porphyry.

Pyrite vein.—The Pyrite vein is a northwest fault, which has been drifted on from the 300, 400, and 500 foot levels of the Original mine; below 500 feet it passes into the Gagnon. It is a cross vein having a course of N. 45° W. and a dip of 63° S. It carries but little ore, shatters but does not displace the primary veins, and is probably itself displaced by the Steward fault vein. Like the Clear Grit it is due to fracturing and is probably coincident in age with the Steward and No. 6 veins.

Zinc vein.—The Zinc vein, a N. 70° E. vein, with 75° to 80° dip, is developed by drifts and stopes on the 700 and 800 foot levels, with a raise on the vein between the two drifts. It is a banded quartz-pyrite vein, carrying an unusual amount of zinc and a low percentage of copper, partly a replacement of sphalerite by glance. It is probably the same vein on which the south 1,000-foot drifts on the Gagnon are driven. The vein shows fault clays along the footwall.

Two other veins running N. 70° to 75° W., with steep southerly dip, are cut by the south crosscuts of the 800-foot level. They are narrow quartz-pyrite veins carrying much sphalerite.

Y vein.—The Y vein, developed on the 700 to 1,000-foot levels of the Original, is a N. 60° W. fault vein, dipping 80° W., that has shattered but has not shifted the other veins.

GAGNON MINE.

The veins worked in the Gagnon mine include the western end of the Parrot lode and two intersecting fault veins. The fault vein lying to the north is the Steward (or Conglomerate) vein; the one to the south is the Caledonia or No. 6. Both these veins intersect the Parrot, the Caledonia cutting through the lode and continuing downward as an independent ledge, and the Steward vein approaching the main lode and following it westward both on strike and dip (fig. 44).

PARROT LODE.

The Parrot lode shows in the Gagnon workings the usual structure observed in other parts of its course. It has two ore streaks, consisting of quartz and pyrite, which in this mine are usually zincky, the proportion of sphalerite being very much larger in the Gagnon ground than it is in any other portion of the lode. The zinc content apparently gradually decreases both eastward and downward along the ledge, the ores in the Original ground being less zincky than in the Gagnon, and the upper levels containing more zinc than the lower ones; the apparent decrease with depth, however, is thought to be chiefly due to the fact that the ore taken out from the depths of 600 to 2,000 feet is from a composite vein and not from the primary quartz-pyrite ledge. Where the Parrot vein is solid and unbroken it is 40 to 50 feet wide, but it is generally separated by 10 to 20 feet of altered granite showing quartz-pyrite veinlets from an underlying footwall vein 10 feet wide. Compared with the same ledge eastward it has maintained both its size and regularity to an unusual degree, but has changed in the character of its vein filling, this having become extremely zincky. The bulk of the lode filling, when unfractured, consists of milky white quartz carrying an abundance of pyrite and showing rude banding in places. The lode presents the usual structural features of two parallel veins, which approach and diverge along the strike, and are separated by horses of more or less mineralized granite (fig. 45).

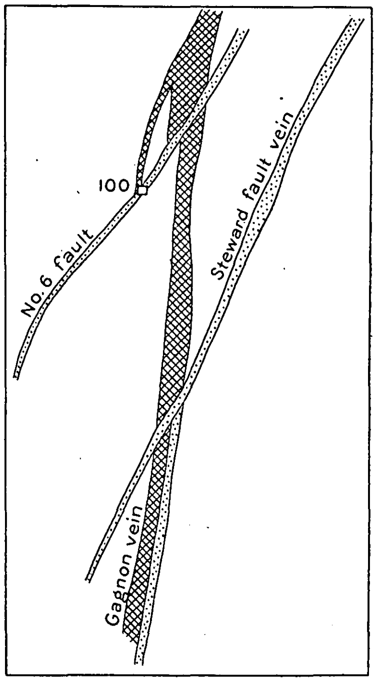


FIGURE 45.—Section through Gagnon shaft.

The Gagnon mine yields ores which are notably higher in silver than those of any other copper mine of the district. The ore is not only zincky, but it contains minerals characteristic of both copper and silver lodes. This is because it comes both from the fault veins and from the Parrot ledge; the ores of each vein have their proper character. As the main ore supply comes from the composite veins and as the great ore stopes are at the intersections of the Steward fault vein with the Parrot, it is easy to understand why the ores differ from those of other mines. The main drifts and stopes are all on the big Steward vein, either alone or where it is merged with the Parrot; but in the western workings the hanging wall or south vein of the Parrot lode is followed by the drifts, which shows that it has regained its individuality. (See fig. 46.)

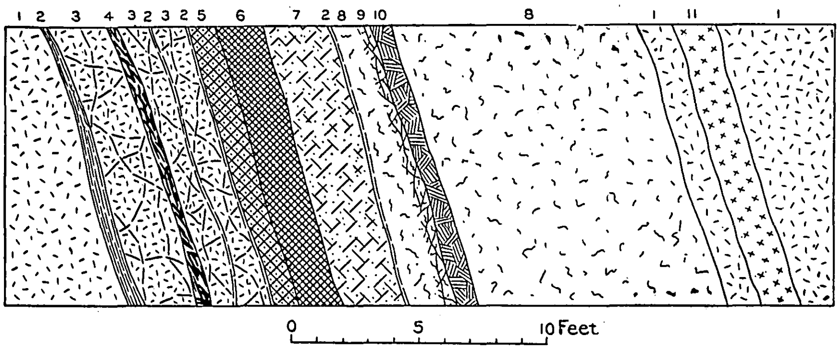


FIGURE 46.—West face, 1,400-foot level, Gagnon mine. 1, Quartz monzonite; 2, clay; 3, crushed quartz monzonite; 4, glance; 5, ore; 6, first-class ore; 7, enargite; 8, quartz; 9, crushed quartz; 10, pyrite; 11, porphyry.

The Parrot lode proper shows the two veins observed elsewhere, but the footwall ledge is relatively unimportant in the upper levels; in the lower levels the veins merge near the shaft but separate westward, having 10 feet of altered granite between them. In the extreme western workings the identity of the hanging-wall ledge is lost, owing to faulting.

STEWARD VEIN.

In the lower levels of the Gagnon mine the ore comes chiefly from the Conglomerate vein formed by the intersection of the western end of the Parrot vein with the Steward fault vein. On the 1,800-foot level a drift has been driven on this fault vein where it has branched off and left the main lode, going off into the footwall. The Steward fault vein here shows a central streak of rhodochrosite in the crushed granite of the lode filling. Lenses of enargite occur all through the vein; the main ledge, or Parrot vein, which on this level is somewhat crushed and in places well brecciated, carries 8 feet of lean ore, alongside of 8 feet of rich fault ore made up of fragments of quartz, broken pyrite, and bornite, lying in a cement of granite and clay. In places a 2-foot streak of sphalerite shows on the footwall, and streaks of clay, pyrite, quartz, and mineralized granite occur. In general, it may be said that the vein contains fewer bowlders toward the west. On the level above—the 1,600-foot—the same vein is well defined, having clean-cut walls, clay selvages, and a filling of highly altered and mineralized granite, with streaks of copper glance.

The granite alongside the veins is sheeted by many parallel fractures, following in a general way the course of the veins, and many of these fractures contain blende or quartz. In the mine workings it has been observed that this sheeted granite is frequently decomposed and altered, forming decomposition bowlders in which nucleal masses of fresh granite are surrounded by crusts or shells of altered material. Plate VI, *A*, which shows the first west crosscut on the 800-foot level of the Gagnon mine, illustrates this. This altered material has contributed largely to the formation of the fault clays which are so common in the fault veins.

CROSS FAULTS.

The veins cut in the Gagnon are intersected by numerous cross faults, mostly with a northwest course, and slight displacement. One observable on the 300-foot level, about 300 feet west of the shaft, has a northwest course and a dip of 60° SW., and displaces the main ledge 8 feet to the north. The N. 70° E. system, to which the big faults belong, also shows in minor fractures with throws of 6 to 8 feet.

SUMMARY.

The Gagnon is the most westerly of all the copper mines; its ores are high in silver and zinc and have been supposed to represent a transition between the silver and copper types. They are, however, due to crushing and faulting, followed by impregnation of copper ores by silver-bearing solutions. The mine shows three distinct veins, which, where intersections occur, form large shoots. The composite Steward-Parrot lode consists of a mass of crushed granite and ore, in which fragments rounded by attrition are conspicuous.

BLUE VEIN SYSTEM IN THE ANACONDA-PARROT BELT.

IMPORTANCE.

Veins of the Blue Vein system were worked for many years in the Greyrock and Bell mines and the Blue vein itself was extensively developed in the Little Mina and Nipper mines before the true character and relations of the veins were understood. It was not until 1898, when the Colusa-Parrot case was prepared for trial, that new development work in the disputed territory revealed the relation of the Blue and Anaconda veins.

The discovery that the Blue vein represented a fault cutting off and dislocating the Anaconda led to the recognition of other cross faults and displacements, solving many of the most perplexing problems of vein structure, and led at once to an intelligent planning out of new development work in many of the mines. With the discovery of the rich ore shoots of the Jessie and Edith May mines the importance and value of the Blue Vein system became generally appreciated. The importance of these discoveries rested not alone on the fact that the veins themselves constituted a great addition to the wealth and production of Butte and considerably extended the limits of the productive area, but also in the demonstration of the fact that fault veins carried lenses of high-grade ore, worthy of careful systematic development. It may be truly said that the recognition of these conditions has prolonged the life and prosperity of Butte by many years.

The general character of the Blue Vein system has already been described (p. 108), but individually the veins present many interesting features worthy of detailed description. The southerly members of the Blue Vein system and the three great cross faults of the district and their lesser companions are described below; those of the northern and northeastern part of the copper area, including the veins of the North Butte Co.'s property and of the High Ore, Bell, Diamond, Greyrock, and Corra mines, are treated separately in connection with the Bell-Diamond area (p. 171).

BLUE VEIN.

JUDICIAL INVESTIGATION.

In the search for evidence in the Colusa-Parrot lawsuit the relation of the Blue vein to the Parrot and Anaconda veins was the subject of detailed study by a number of famous mining experts. It is doubtful if any other mining suit ever brought together such an array of eminent engineers and geologists as those who took part as expert witnesses in this case; Clarence King, R. W. Raymond, W. S. Keyes, Louis Janin, N. S. Shaler, and D. W. Brunton were but a few of those engaged in the work. Under the direction of H. V. Winchell for the Anaconda and of F. L. Sizer for the opposing side, thousands of feet of crosscutting and drifting were driven for the purpose of establishing the relation of the veins and fault slips.

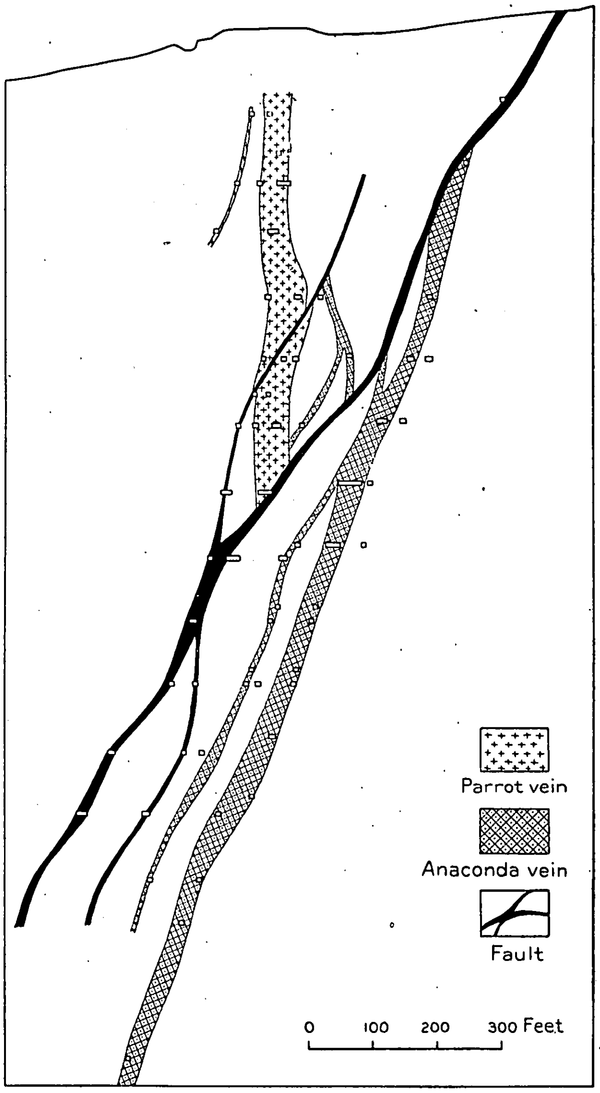


FIGURE 47.—Section showing cut-off of Anaconda and Parrot veins by the Blue vein fault.

The suit was nominally an action brought by the Colusa-Parrot Co. against the Anaconda Co. for trespass, a suit based on the so-called "law of the apex," the first-named company alleging a union of the Anaconda and Colusa-Parrot veins in depth and an ownership below the union by reason of priority of location and patent of the claim. The Anaconda reply held (1) that both the strike and the dip of the Colusa-Parrot and Anaconda veins being parallel, they could not unite in depth, especially as the Anaconda became steeper in the 1,600-foot and deeper levels; and (2) that the Blue vein, a diagonal cross vein, cut off the Anaconda on the west and the Parrot vein on the east, thus preventing any such union even if the dips could bring it about. (See fig. 47.)

Though the legal question involved was one of apex rights, the real issue was whether or not the Parrot and Anaconda veins are cut off and terminated by the Blue vein. The decision by the court held that the evidence established such a cut-off; that the Anaconda and Parrot veins were once one, but that this vein had been cut and the ends displaced by the Blue fault vein. This decision gave the Anaconda Co. the right to follow the vein beneath the subfault apex, and limited downward working on the Parrot (by the Colusa-Parrot Co.) by the walls of the Blue fault vein.

Underground development since this suit fully confirms the decision and shows conclusively that the Blue vein not only cuts and displaces the great Anaconda lode, but also the neighboring east and west lodes from the south side of the Syndicate ledge on the north to the vicinity of the Glengarry mine to the southwest. It shows, further, that besides faulting and displacing the east and west veins and containing drag ore broken off from these earlier fissures, the Blue vein holds endogenous ore deposited within the fissure, and forming ore bodies differing in mineral character and occurrence from those of the earlier veins.

DEVELOPMENT AND GENERAL CHARACTER.

The Blue vein is justly regarded as the most important fault vein of the district. Its outcrop has been carefully developed by pits and trenches from the streets of Centerville to the vicinity of the Moonlight shaft. Underground it has been continuously developed from the Little Mina on the northwest, through the Nipper, across the Anaconda belt far to the southeast of the Neversweat mine, and if it be correctly identified in the extreme southerly workings of the Anaconda properties it has a total known length of over 1½ miles. It has been explored from the surface downward for 1,600 feet and is cut in isolated places to depths 600 feet greater.

In the Little Mina mine the Blue vein contains a large ore body which has been worked continuously from the 150-foot to the 1,000-foot levels. In the Nipper mine it has yielded large amounts of ore, and in the 1,000-foot level of the Parrot mine it contains a large ore shoot. To the southeast the vein is found in deep workings from the Anaconda shaft, and it is probably present in the vicinity of the Glengarry mine, though owing to its intersection and displacement by the Rarus fault and to the extremely broken character of the adjacent ground, it can not be positively identified.

Through its entire course the Blue vein maintains a very constant strike of N. 40° to 50° W. and a dip of 64° S. It splits in the Little Mina property into two streaks, both carrying ore, as well shown on the 800-foot level of that mine. In crossing the great Anaconda lode the fracture is accompanied by displacement. The breaking of this great lode must have caused considerable disturbance in the neighboring granite, and the workings show that the force was sufficient to actually bend the lode before rupture occurred. Quartz outcrops on the Little Mina claim show a well-defined quartz vein running the entire length of the claim parallel to the outcrop of the Blue vein. This quartz outcrop is not developed in depth, so that its relationship is not positively known, but it is believed to represent a fault fracture similar to the Blue.

The width of the Blue vein varies greatly from point to point. It is naturally widest where the rocks fracture most readily, the bounding walls in some such places being as much as 50 feet apart. On the other hand, in its northwest extension it is narrow in places; where cut and displaced by the Steward vein it has a width of only 5 or 6 feet. In the vicinity of the Neversweat mine its width is 50 feet on the 900 to 1,300 foot levels and its least width 20 to 25 feet.

INTERSECTION WITH ANACONDA LODE.

The Blue vein was systematically explored where it cuts the Anaconda lode, and as this development extends from the surface to the 1,800-foot level, full details of the cut-off are known. The cross sections shown in figures 30, 31, 36, 38, 39, and 47, constructed from the detailed measurements made of stopes, raises, and levels during the litigation, show the proved relationship at this point.

A notable feature in connection with the Blue vein, which is also observed in the other fault veins, is the impoverishment of the Anaconda lode at and near the actual contact. Where the east and west lodes are cut off abruptly and the ore is solid or but little shattered, an undiminished copper content would naturally be expected up to the actual point of cut-off. As a matter of fact a decrease in values near the fault vein is in many places observed, as if descending solutions penetrating the east and west veins had leached out the copper from the portion of the vein near the fault and had carried the material into the fault fissure to be redeposited as fresh ore. That this hypothesis can not account for the ore shoots in the fault veins is, however, apparent when the mineral character of the ore is considered. The Anaconda lode is essentially a glance vein, enargite first appearing at the 2,200-foot level and then only in connection with strike faulting. Moreover, galena is scarce, being present only in minute amounts in and near broken or faulted parts of the Anaconda ledge. Chalcopyrite is practically never found in the latter, and sphalerite occurs intergrown with pyrite. On the other hand, in the ore found in the Blue lode galena is locally abundant, chalcopyrite is present in large amounts, enargite is abundant, and sphalerite occurs in crystalline aggregates. These facts and the presence of well-defined ore bodies lying against clay walls seem to prove conclusively that the ore has not been derived directly or indirectly from east and west veins, but is due to uprising solutions introduced as a result of the Blue vein fault.

Southeast of the Anaconda ledge the Blue vein narrows and in places is only a foot or two in width. The vein cuts the Moonlight, another east and west vein in the Ramsdell-Parrot ground, and the stope sheets show a progressive rising of the cut-off to the east, conforming to the dip of the Blue vein. It is true in a general way that the east-west veins show impoverishment at the general contact with the faults, but it is also true that the largest ore bodies and richest ore found in these east-west veins occur where they are crossed either by the Blue vein or by other parallel fault fissures. This is believed to be due to the open character of the ground, resulting from the fault, by which down-seeping waters find ready access to the ground and deposit their burden of copper. Barite and calcite are minerals characteristic of the Blue, Steward, and other fault veins of the district, but barite is lacking entirely in the east-west veins.

The displacement of the Anaconda vein varies from 500 to 520 feet vertical, as shown by matching the curves of the broken-off ends of the Anaconda and Colusa-Parrot veins. This matching can, of course, be best done by projecting the veins on the plane of the fault, and this gives a very close adjustment. This is not entirely satisfactory since the Colusa-Parrot down to the 800-foot level is a granite vein (not a quartz vein) until that level is reached, and below the 900 it is quite like the Anaconda—that is, is quartzy and contains 52 per cent SiO_2 by volume. Thus a matching of 510 feet would bring a wide quartzose vein against a narrow granite vein. One may therefore suppose a very much greater throw. Moreover, the glance character of the Anaconda vein does not extend to the cut-off on the 1,300 foot level, but fades out. On the other hand the original unfaulted Anaconda is essentially a trunk vein. In the Neversweat ground it branches westward, and in the Colusa-Parrot, as the branches diverge, the intervening space instead of being quartz is a mineralized granite, changing gradually to barren granite farther west. It is true that the South Parrot (or Virginius) vein diverges in depth and is not seen in the Colusa-Parrot workings below the 400 level, but it is cut on the Parrot down to the 600-foot level and at the 1,000-foot level south, where it is 150 feet south of the Parrot vein. The South Parrot vein is also seen in the Dave Bricker crosscut to the Moonlight, where it is 30 feet wide and very irony. The other forks diverge and remain so westward all the way to the Original mine. It may therefore be inferred that the Blue vein cut the Anaconda vein just where the trunk vein bifurcates; hence the Colusa-Parrot does show granite between veins and the Anaconda does not show it, except as big horse between the foot and hanging wall ore bodies. The northern vein becomes the main Parrot going west, and the others diverge and thin out.

Recent development has shown that in the upper levels the Parrot vein does not extend in a perfectly straight line eastward to the fault, but bends north. This evidence modifies conclusions as to the amount of throw, which were based on a correlation of the faulted ends of the vein, and some observers question whether the fault is not a thrust instead of a normal fault.

In some places the cut-off of the Anaconda vein by the Blue vein is accompanied by the presence of ore bodies lying along the wall of the Blue vein and apparently due to descending solutions coming from the Anaconda vein and ponded back by the clay walls of the Blue vein. In one case ore bodies approximately 6 to 8 feet thick and 50 to 100 feet long were formed on each wall of the Blue vein. This has been called a spraying out of the vein at the cut-off, but as it is clearly due to a later enrichment, it is not properly to be attributed to the fault itself.

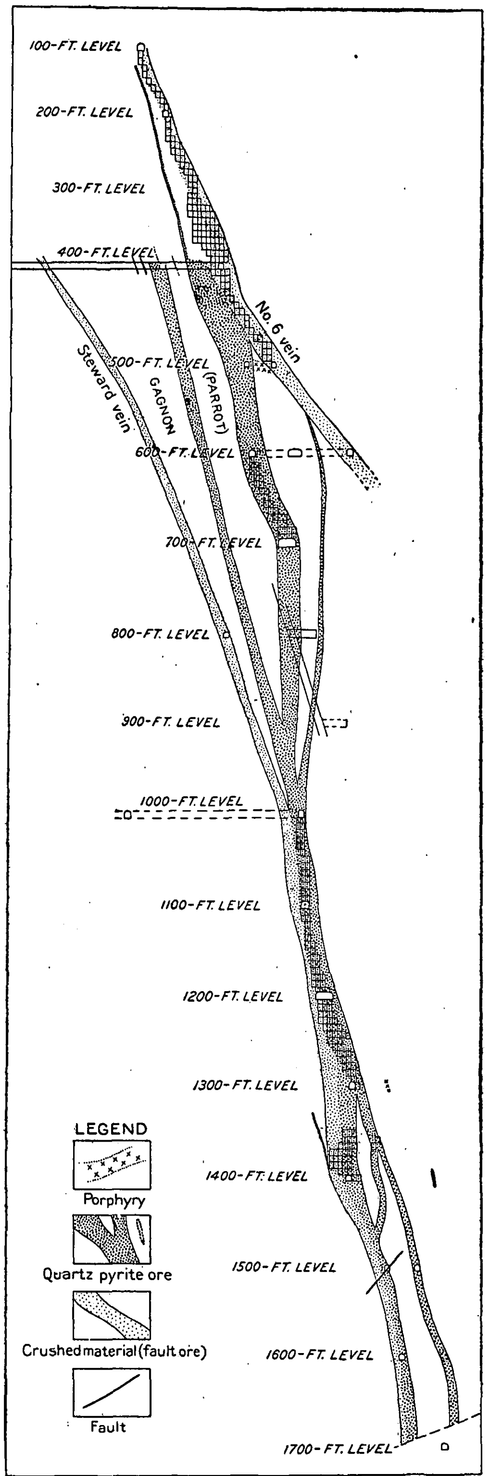


FIGURE 48.—North-south section through Parrot, Steward, Gagnon, and No. 6 veins, 75 feet west of Gagnon shaft.

The Nipper mine has been developed mainly on the Blue vein, the workings on the lode connecting northwest with those of the Little Mina and southeast with those of the Neversweat. Two other prominent fissures, which also show in the Syndicate ledge, trend N. 70° E. and N. 70° W. and dip 65° to 70° S.; they are barren or nearly so. The mine is traversed by a rather regular dike of rhyolite porphyry 15 feet wide, the rock being dense, hard white porphyry, sheeted parallel to the planes seen in the granite.

INTERSECTION WITH STEWARD VEIN.

That the Blue vein is cut and displaced by the Steward fault vein is well shown on the 1,000-foot level north crosscut from the Parrot vein, where the displacement is 116 feet. The Blue vein is here a mass of fault breccia and clay, with a streak of solid and banded pyrite and quartz. The Steward vein at this point is from 5 to 10 feet wide. The vein is wet, the water forming limonite where it enters the drift, and the vein consists mainly of fault breccia, the ore streak having given out at this point. The eastward extension of the Steward vein has not been drifted upon, but is cut in the Nipper workings, where, however, its true relations were not recognized when the Nipper was studied, and can not now be studied, as the latter mine has been under water for some years past as the result of litigation. That the Blue vein is actually cut off and displaced is established beyond doubt by these workings, and it is drifted on 250 feet or more north of the Steward vein. (See figs. 48 and 49.)

ORES.

The endogenous ore of the Blue vein consists of pyrite, glance, sphalerite, chalcopyrite, and enargite in quartz, with accessory galena and hübnerite. The silver content is large. The new ore occurs as streaks (seldom persistent for more than a few yards) of quartz with enargite, bornite, glance, and zinc sulphide. In the 600-foot Neversweat workings the new ore of the Blue vein is very zincky and contains much galena, with newly formed pyrite, the ore containing high silver values. Where most abundant it formed wedges a few inches to 2 feet thick and 8 to 10 feet long, limited by clay slips. This ore was solid and uncrushed and was continuous from the 800 to the 900 foot levels. In general, however, the new ore has been crushed and brecciated by the settling and adjustment of the whole district that is still going on (p. 50).

The ore in the Little Mina mine shows many vugs lined with pyrite crusted by quartz and chalcopyrite; these in turn are covered with needles of comb quartz, with flat-lying crystals of dogtooth spar an inch or more in length, parasitic upon earlier minerals but thus inclosing copper glance. Many specimens from these vugs show a final coating of the quartz with galena and chalcopyrite. The vein was formerly considered a silver lode, and was worked as such to a depth of 600 feet, where a good shoot of copper ore was found and worked out down to a depth of 800 feet. The ore from this shoot consists of dark-colored quartz with copper sulphides and sphalerite. Bunches of chalcopyrite are common and with dogtooth spar (calcite), are parasitic on it. Galena is common.

In April, 1900, the stopes in the Little Mina mine yielded ore carrying 40 per cent lead and 275 ounces of silver per ton. This came from the stopes below the 600-foot level, below the raise on the Blue vein. The Anaconda vein shows more zinc but has no lead nor manganese.

The vein is well exposed at the point where it cuts off the Anaconda vein four sets (28 feet) below the 600-foot level of the Neversweat mine. At this place it shows the smooth wall of the Anaconda lode cut off by the Blue vein, whose new ore carries galena and other minerals that are extremely scarce in the Anaconda. The ore body is itself cut by clay slips, which are not mineralized. The walls of the Blue vein consist of very fresh granite on the north, while the

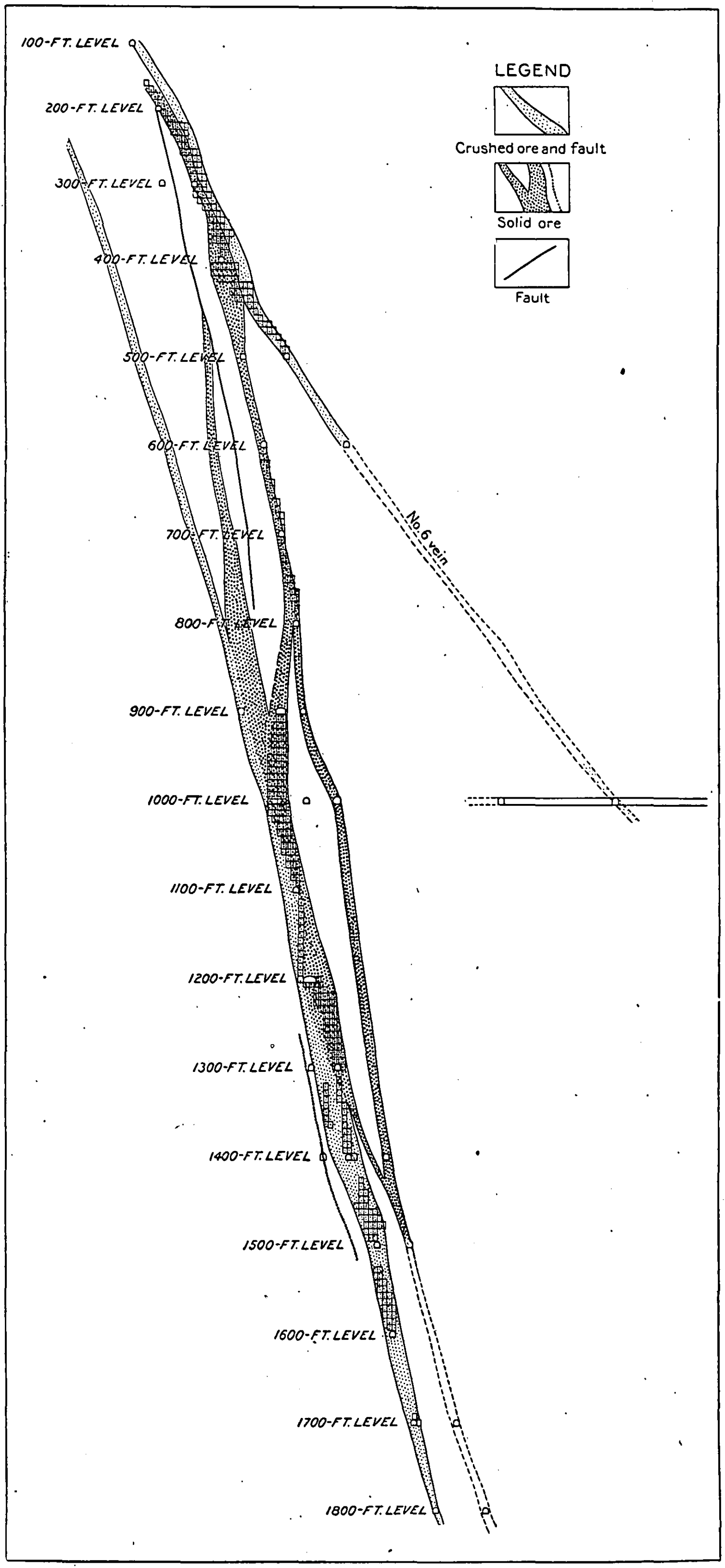


FIGURE 49.—North-south section 210 feet west of Gagnon shaft.

rock on the south shows fractures with a rusty stain, though the granite is not crushed or mashed. The quartz streak of the Blue vein is only 2 inches wide at this place and dips 30° S. The country adjacent to the Blue vein has been mined in many places where parallel sympathetic fractures come in, and in such cases it is hard to distinguish between the Blue vein proper and the entire lode.

MOUNTAIN VIEW FAULT VEIN.

DEVELOPMENT AND GENERAL CHARACTER.

The Mountain View fault vein is one of the largest and most persistent fault veins of the Blue vein system in the entire district, being cut in the Parnell mine and being almost continuously traceable from the Mountain View workings south, through its displacement by the Rarus fault and through the Pennsylvania ground, to the vicinity of the Silverbow mine. It has been positively identified on both sides of the Rarus fault, being known as the Orange vein in the testimony given during the Rarus case.

The Mountain View fault vein varies in width from a few feet to 20 or 30 feet or more. Its outcrop is scarcely recognizable and is usually but a few feet wide, but it is extensively developed underground, the average strike being N. 40° W. and the dip 70° to 80° SW. To a depth of 500 or 600 feet it generally carries only fault material and no pay ore. In deeper levels it carries isolated shoots of ore, and in the ground beneath the Rarus fault it has ore bodies of considerable value. On the 500-foot level of the Mountain View, where it is developed by drifting for 600 feet, it varies in width from 3 to 4 feet and has a filling of fault breccia and clay, with 2 feet of barren pyrite on the hanging-wall side. The extreme northwest development of the vein is on this level (5,289 feet elevation).

The Mountain View fault cuts sharply through quartz monzonite, aplite, and porphyry, and clean across all preexisting veins; on the Anaconda lode it shows a horizontal displacement of about 300 feet. It is therefore comparable with the Blue vein in its size and extent. Throughout its course the vein is marked by fault clays or selvages, which vary from a few inches to 1½ feet in width. The granite walls are in many places striated and in some places polished, the striæ indicating diagonal movement. A tendency toward splits or branch fractures appears in the hanging-wall side. In the deep levels the vein carries good ore, an average of 7 feet, with a 15-inch band of nearly pure bornite, being observed on the 1,200-foot level.

Though parallel to the North Connecting vein this fracture differs materially from that lode. So far as known it contains no traces of an earlier vein filling but is a fault fissure traversing country rock, whereas the North Connecting vein is a much older fissure filled by quartz and pyrite—a replacement vein later enriched by enargite.

INTERSECTION WITH OTHER VEINS.

The Mountain View fault vein appears to be cut and displaced by the Blue Jay fault vein, a feature analogous to the displacement of the Blue vein by the Steward fault vein. In the Mountain View mine the vein has been extensively developed on the 200-foot level, where it shows 6 to 18 feet of clay with hard granite walls and well-marked slickensides. To the southwest the granite alongside is crushed; to the northeast it is hard. The foot-wall streak is a solid band 3 to 5 feet wide of hard quartz-pyrite ore, with a southerly dip of 77° S. On the level below the character is similar, but the clay and fault matter is 5 feet thick. On the fifth (500-foot) level the vein is 7 feet wide and shows a foot-wall band 2 feet thick of crushed granite and clay containing pebbles 2 to 4 inches in diameter, then a 15-inch band of solid pyrite and bornite ore with crushed granite and ore above it. The cut-off ends of the veins seen along the fault resemble spur veins. Farther east the vein narrows to 5 feet with 2 feet of pyritic ore in the foot wall and a course of N. 40° W.

South of the Anaconda the Mountain View fault vein is known as the Orange vein. It cuts and displaces at least two east-west veins, whose segments are known as the Iron and Cross veins to the west and as the Cross and the Powder veins to the east.

The Mountain View fault vein is itself cut and displaced by the Rarus fault, but reappears to the east in three branches, Nos. 7, 11, and 10 of the Pennsylvania mine, the last named being the main fissure. At this point it has cut and displaced the Pennsylvania vein (now called No. 3), the part east of it forming the Enargite vein.

Westward the Mountain View fault probably extends into the complex of veins of the Bell and Diamond workings. In the Parnell mine a fault vein whose course and dip correlate it with the Mountain View fault is cut on the 500-foot level.

In the High Ore mine the deeper levels along the veins show a decreasing amount of water, and up to the end of 1906 the lowest limit of this water had not been reached. In the Speculator mine, on the other hand, the deeper levels on the fault veins of this series show a perfectly dry vein; further, the Rarus fault, where cut on the 2,200-foot level of the High Ore mine, was dry and dusty, indicating that this, the most recent faulting of the district, which produced great fractures whose open porous character has favored descending waters, has not yet been saturated by descending solutions at this depth.

Although the Mountain View fault is one of the largest and strongest fault veins of the district, it has not been well explored, and there is reason to believe that at depths below 1,000 feet it is worthy of careful prospecting. Its relation to the veins on either side is well shown by a glass model constructed by the Anaconda Co.; the fault is seen to be nearly vertical and to displace the Anaconda lode, whose eastern segment forms the Mountain View South or main Anaconda vein. To the south the fault is convex to the east.

ORES.

The Mountain View fault vein itself is not well mineralized west of the Rarus, or at least carries but small bunches of ore. In the Mountain View mine it is a well-defined fault fissure with clear-cut walls, a filling of friction breccia, clay, and crushed or mashed granite, and some drag ore. No great bodies of either drag or endogenous ore were seen in the workings.

In the Pennsylvania mine the vein is cut on the fifth, sixth, and ninth levels. It has also been extensively stoped in the Rarus mine, where it shows 1 to 3 feet of good ore, generally a solid mass of hard quartz and pyrite with 2 to 10 feet of clay and fault matter on both sides of ore, though most abundant on the footwall side. The dip is 75° S.

Where the crushed matter is replaced by quartz, pyrite, and enargite, as it is in vein No. 10 of the Pennsylvania, the vein does not resemble a fault vein. On the 1,000-foot level of the Pennsylvania mine the middle branch is but slightly mineralized, the northern one not at all. The turning about of the faulted blocks of the Enargite vein shows a strong horizontal southeast shift of the hanging wall of all three forks, though the ends of No. 3 or the Enargite vein are not twisted at all.

The Mountain View fault vein, between the walls of the Rarus fault, shows a large ore body of crushed and crackled pyrite and enargite. The ore contains numerous vugs along fracture planes. Considerable glance occurs in persistent streaks in the enargite; it is solid and not shattered and is therefore regarded as of more recent formation. In its structure it shows incipient cleavage or sheeting, indicating very slight movement since deposition. The enargite does not form persistent streaks, but occurs in bunches and lenses, accompanied by small masses of white quartz. Inclusions of altered granite occur in the vein, and these are usually crackled and permeated by seams and films of enargite. This portion of the vein also shows the same peculiar breccia seams shown in the Mountain View system. The material consists of well-rounded pebbles, with a cement of arkose, generally rather dry, filling sharply cut fissures, whose walls are solid and lack the mashed granite characteristic of many other veins. These fractures are later than the veins, and they contain neither pyrite nor ore except where they cross existing veins and have brecciated them. The nearest approach to this character is seen in the Tramway vein, which is essentially a glance vein and shows a brecciated structure similar to that of these fractures. A peculiarity of the breccia of the Mountain View seams is the unevenness of the fractures and the fact that they jump from one joint plane to another. They give no evidence of any measurable movement.

CLEAR GRIT VEIN.

The Clear Grit is the third important northwest fault vein of the district. It outcrops about 700 feet southwest of the Blue vein and is parallel to the latter, the course averaging N. 51° W. and the dip 58° to 65° SW. The importance of the vein lies both in its mineral contents and in its dislocation of east and west veins. It is developed both in the Clear Grit shaft and the workings from it, and in the underground workings of the Steward and Original mines.

In the Clear Grit shaft the vein, which was worked for its silver ores in the early days, is developed by drifts of 100 to 200 feet at depths of 100, 200, 300, and 400 feet, the collar of the shaft being 5,970 feet above sea level. Throughout this part of its development the vein shows lenses of solid ore composed of quartz, pyrite, and sphalerite, with high values in silver. It varies from 5 to 12 feet in thickness and has a clay gouge which varies from a few inches in the northwest workings to a thickness of 3 or 4 feet at the southeast end of the mine drifts. The vein is well developed both in the workings from the Clear Grit shaft and in those of the Steward mine.

On the 700-foot level of the Steward mine the Clear Grit vein cuts off, and seemingly faults the Steward ore body, producing a throw of 60 feet south along the hanging wall. It intersects the much-broken ground of the 800-foot level of the Steward and possibly appears in the 500 and 600 foot levels of the Parrot mine, as indicated by exposures noted in the stopes. In this southern extension of its course it appears to shift the Parrot vein, but the displacement is slight and scarcely recognizable in the mine levels.

The evidence in the Steward mine shows that the Clear Grit vein cuts and displaces the north branch or north vein of the Steward mine, which is regarded as the old vein, but is itself cut off by the Steward fault vein. These relations are well shown on the 1,100-foot level of the Steward vein. In the earlier workings of the Clear Grit vein a shaft was sunk to a depth of 500 feet and two veins were developed, one generally known as the Silver vein and the other the Copper vein; they come together in depth. The copper ore consisted of bornite in a dark-grayish, extremely fine grained quartz resembling that of the Parnell mine. In recent years these old workings have been reopened and the vein thoroughly explored, its continuity being proved as far as its intersection with the Steward vein.

The Clear Grit vein is characterized by distinct fault breccia of granite, drag ore, and older vein matter, together with streaks of newly deposited endogenous ore, the latter occurring in well-defined bands and as layers along clay slips in the fault matter. The mineral character of this endogenous ore differs from that of the earlier vein fillings, resembling that of the Blue vein and containing galena, an abundance of sphalerite in bunches, bornite, chalcopyrite, calcite, and some copper glance. The ore carries high values in silver, and in depth intersects a silver vein cut in the upper workings of the mine.

On the 500 and 600 foot levels of the Clear Grit mine the vein is extensively developed, the drifts being several hundred feet in length. These workings show a vein containing from 3 to 5 feet of solid quartz, carrying pyrite and sphalerite, and separated from the granite by clay walls. The granite is nearly fresh, and shows very little, if any, effect from the vein-forming waters. To the east this solid vein changes to a fault fissure filled by breccia and clay, the quartz streak thinning to 2 feet. On the 600-foot level (5,413 feet elevation), 240 feet to the northwest of the shaft, the vein is thrust about 25 feet south by a northeast cross fissure. Beyond this cross fissure the vein consists only of fault matter and shows no quartz.

In the West Steward mine the vein is extensively developed from the 700 to the 1,300 foot levels. Its most remarkable feature here is the square cut-off of the Steward ore body by the Clear Grit. The relationship of the Steward, Original, Parrot, and Clear Grit veins is all well shown on the 1,100-foot levels of the Original (4,816 feet), Steward (4,819 feet), and Old Steward (4,821 feet), in which the Clear Grit vein is seen to cut off the east and west Rialto vein (figs. 54 and 55, pp. 149 and 150) and to be itself faulted by the Steward fault vein as it leaves the east-west vein developed in the Original mine. The workings in the Original mine do not develop the Virginius or South Parrot vein, which lies off to the south and whose westward extension is a worthless zincky vein which is not drifted upon.

OTHER NORTHWEST FAULT VEINS.

Several other northwest fractures lie parallel to the Blue vein. One of these is 400 feet southwest of the Blue vein, approximately midway between the Clear Grit and the Blue. This vein is cut in the East Steward workings at the 160 and 300 foot levels. It has a northwest course and has yielded some ore, but the ore shoots play out in depth.

Another northwest vein lies 325 feet southwest of the Clear Grit. This ledge is cut in the Virginius workings, an old shaft lying near the Washoe and Parrot, and is also seen in the workings of the No. 6 Original shaft on the 160-foot level, where its intersection with an east-west vein makes the large ore body stoped out in that property.

These parallel sympathetic fractures and many others which show in the stopes along the course of the Parrot ledge displace the veins slightly, but are not important features in the mining operations. They do not show on the surface, and have not been traced far enough to determine whether or not they are persistent in length. They are regarded as due to settling of the fault blocks, and not to direct fissuring. The apparently contradictory evidence of the relative age of the Clear Grit and Blue veins and the Steward and other northeast faults, supplied by displacement of the Blue by the Steward, of the Clear Grit by the Steward, and of the latter by northeast fissures (on the 600-foot level), is best explained by rupture with simultaneous displacement in two directions.

THE STEWARD VEIN SYSTEM OF THE ANACONDA BELT.

GENERAL CHARACTER.

The Steward vein system consists of fault veins, the result of the latest period of fracturing and primary copper-ore formation. It has a general course of N. 65° to 70° E., but many of its veins are deflected by the quartz-pyrite veins of the Anaconda system, forming strike faults and following these older veins for considerable distances both in strike and depth. They also break and dislocate the veins of the Blue Vein system, and are themselves fractured and shifted by small northwest fissures and by the Rarus fault.

The principal members of the system are the Steward and No. 6 veins, opened and mined in the Gagnon, Original, Steward, and Parrot mines; the Blue Jay fault vein and its eastern continuation, the Middle vein, called No. 16 beyond the Rarus fault, and the Bell fault vein of the Greyrock-Diamond Bell group of mines. The Bell fault vein is described in connection with the Bell-Diamond area (p. 171).

The veins, which represent a third and important period of copper-ore formation, furnish the main ore supply of the westernmost mines of the Anaconda belt. The ores are relatively high in silver, are characterized by enargite, and contain fluorite and rhodonite, minerals typical of silver veins and not found in the ores of the Anaconda lode. Secondary enrichment, or glance formation, by descending waters is a minor feature. As in the Blue Vein system the ores occur in shoots, separated by barren stretches of fault matter, and the veins show swells and pinches with striated and irregularly warped walls. The dip is always to the south, and varies from 50° to 80°.

That the veins are younger than those of the Blue Vein system is shown by the dislocation of the Blue vein by the Steward, and by the shifting of the various northwest fault veins of the Bell-Diamond and Greyrock mines by the Bell (Middle) fault. One vein of the system is, however, dislocated by the Rarus fault.

The ore shoots show fracturing, with cross seams, clay streaks and other evidences of movement, but the fractures, in large part at least, are confined to the vein itself, and are probably due to adjustments during or immediately succeeding the period of ore deposition. As the largest ore shoots occur mainly where the fissures follow veins of the Anaconda system, the veins now worked are composite; they have both old and new ore and are correspondingly modified in character. Although the Steward fault vein, from which the system is named, is

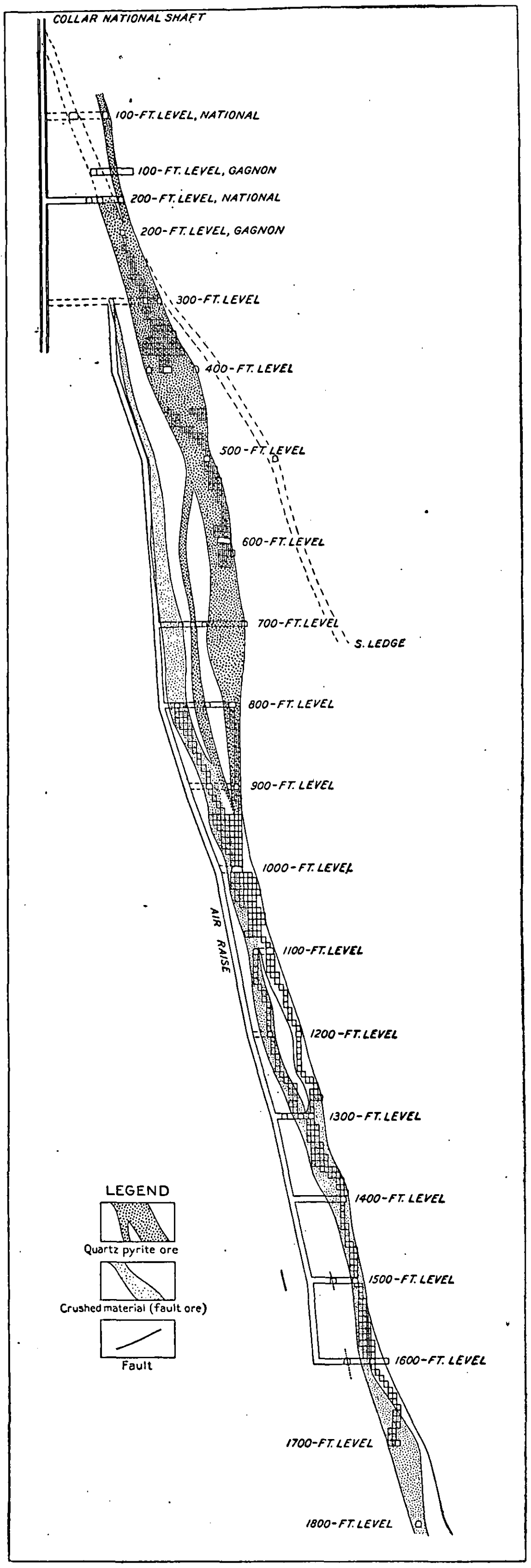


FIGURE 50.—North-south section 510 feet west of Gagnon shaft.

the largest and most productive vein of the group, the No. 16 vein of the Rarus mine shows the best examples of displacement and of ore deposition that is clearly later and endogenous; in the Bell fault ore deposition has not thus far been demonstrated.

In the western part of the copper area three veins of this system occur; the most northerly is the Steward (often called the Conglomerate) vein; 235 feet south of it is the No. 6 fault vein, which has been identified throughout the extent of the Gagnon, Original, and Parrot mines; farther south is the Blue Jay fault vein.

The Steward is worked continuously from the west end of the Gagnon mine eastward through the Original and Steward mines, supplying the great ore bodies of these mines.

In the Steward mine the Steward vein shifts the northern displaced portion of the Blue Vein 110 feet west, but in the Gagnon it is itself cut by numerous flat-dipping northeast fissures, whose course of N. 43° to 51° E. corresponds with the Rarus fault, though they have an opposed dip of 54° to 70° SW. In the Bell and Diamond mines the Bell fault cuts and displaces the Covellite, Skyrme, and other northwest veins; and in the middle and eastern parts of the Anaconda belt, the long and wide fracture called the Blue Jay or Middle fault has been an important factor in the formation of the ore bodies.

The slight angle which many of the veins make with those of the Anaconda system, and the fact that in many places they join the latter, makes their discrimination difficult.

STEWARD FAULT VEIN.

The Steward lode is developed from the west end of the Gagnon mine eastward almost to the Nipper property, a distance of 5,100 feet on its strike, to a depth of 1,100 to 2,000 feet in the Steward, Gagnon, and Original mines.

On the 1,500-foot levels of both the Steward and Original mines, the Steward vein has a broad and continuous ore body some 20 to 30 feet wide, that has been worked the entire length of the Original mine, a distance of over 1,400 feet, and through the length of the Gagnon mine a distance of 2,700 feet. In the latter property it consists mostly of a breccia carrying fragments and bowlders of earlier ore, but in the Steward and Original workings much of the ore is solid and was undoubtedly formed in place.

STEWARD MINE.

The Steward mine is situated in the western part of the district, the claim of that name being north of the Original and Parrot mines and extending east from the main working shaft near Woolman and Main streets (across from the Gagnon and Original shaft houses) almost to the Nipper mine. The mine is an old one, formerly worked from an inclined shaft near the Nipper, but the large ore bodies which have been found in the lower levels were later discovered as a result of exploration work following the sinking of the West Steward, now the main working shaft of the mine, which has a depth of 1,800 feet (fig. 50).

VEINS.

The older workings at tne eastern end of the property have developed a lean quartz-pyrite vein (here called the Bailey) that has a general northwest course and is probably a member of the Silverbow group of the Anaconda system. (See p. 156.) The Bailey vein was explored 150 to 200 feet west of the shaft to a depth of 250 feet. A second incline shaft was then started; it encountered another older vein between 300 and 400 feet, and followed it down to the 800-foot level at a vertical depth of 750 feet (5,158 feet above sea level). On the 400-foot level (5,537 feet) the Steward fault vein intersects and cuts off the Bailey vein.

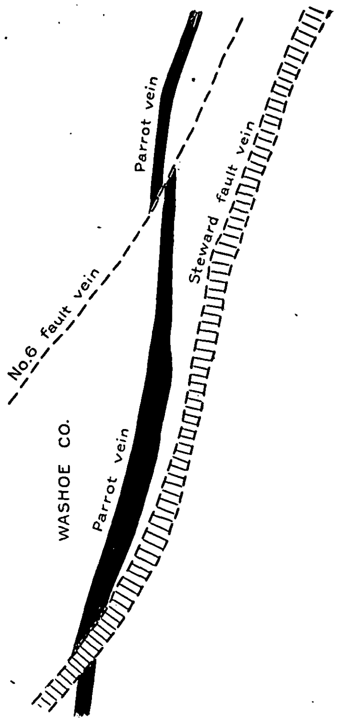


FIGURE 51.—Faulting of Parrot vein by Steward and No. 6 veins.

Below this another vein, here called the Acquisition, was encountered and a large ore body stoped out on the 600, 700, and 800 foot levels. This vein, in which all the criteria of a fault fissure are now seen, is a former member of the Anaconda system, an old quartz-pyrite vein, reopened and crushed by the Steward strike fault. Parts of the old vein filling still remain in places and the ore is in large part fragmentary, composed of balls and angular fragments of the old quartz-pyrite ore, mixed with newly deposited sulphides. The Acquisition is developed from the 600 to the 1,000 foot levels, but the Steward departs from it, and its ore is cut off to the west by a cross fault, the Clear Grit. The Steward fault vein was followed westward, and a new vertical shaft (the West Steward) sunk to develop it. In this shaft the Steward fault vein was found to be wide, strong, and generally ore bearing and to pass into and intersect the ore bodies of the Gagnon and Original mines in depth. (See figs. 51 and 52.)

The Acquisition vein runs N. 85° E. and dips 70° S. On the 700-foot level of the Steward mine it is dry and composed of solid unbroken quartz and pyrite, with irregular streaks and bunches of good ore, in which bornite in specks and spots has enriched the lean primary vein filling. Its width is about 15 feet. The richness of the ore varies somewhat from point to point through the stopes, and the vein itself is in places well banded by streaks of nearly solid pyrite a foot or more thick. In general the footwall streaks or bands are vuggy and show bunches of bornite 2 to 6 inches thick. Much of the quartz is milky, as if recently deposited, and now drying out. Where cut by the Steward fault the composite vein has a rolling and irregular hanging wall of hard normal granite that shows slickenside surfaces. The footwall is straighter and has a more uniform dip, which averages 70°, and is marked by striæ and slickensides dipping 20° E. The vein narrows eastward in the mine workings from 20 feet to 5 feet, showing at the end some 2 feet of fault breccia and clay of the Steward fault. The most persistent feature of the vein is the abundance of zinc, generally in streaks, 1 to 4 inches thick, containing some associated galena and cementing fragments of altered granite for 6 to 18 inches from the footwall. This zinc and galena ore is endogenous and is not crushed like the older ore.

In the vicinity of the East Steward shaft the composite Acquisition vein is nearly vertical from the 700-foot to the 1,000-foot level, but westward it has a pronounced southerly dip. Much of the fault material is barren, and varies from a breccia or conglomerate, formed of granite and ore, to an arkose sandstone. The primary vein is solid on the east drifts of the 900-foot level and comprises slabs of ore on the east 700 and 800 foot drifts. These conditions result from the faulting and displacement of the Acquisition vein by the Clear Grit (see fig. 53) in the same manner that the Blue Vein has cut the Anaconda. The Steward vein has cut and shifted both the Clear Grit and the displaced part of the Rialto. (See fig. 54.) On the 800, 900, and 1,000 foot levels the situation is complicated by the presence of a subsidiary northward-dipping fork of the Steward, and by a parallel sympathetic fracture to the south, so that the conditions approximate, if they do not exactly correspond to, those shown in figure 55.

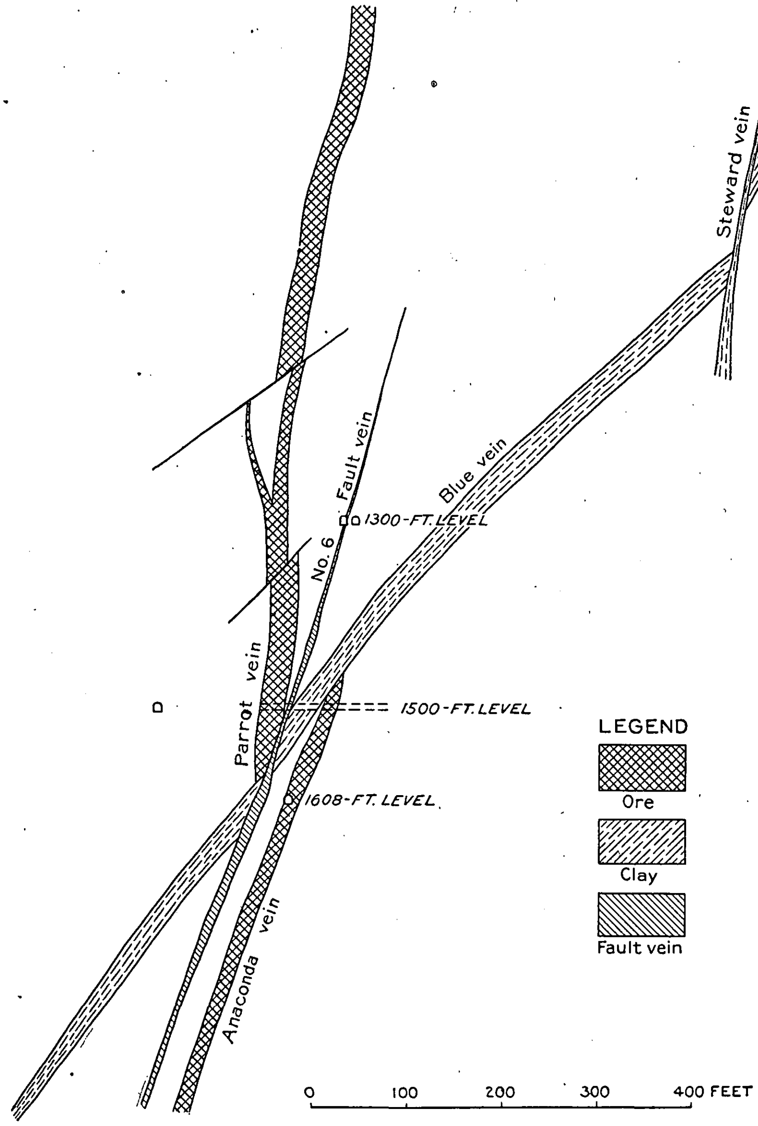


FIGURE 52.—North-south section of veins 250 feet west of Parrot shaft.

In the East Steward mine the vein has a general course of N. 70° E. and a dip of 60° S. Where it follows the older veins the course is N. 85° E. and the dip 85° S. It varies greatly in thickness both vertically and horizontally, its average width being about 2 feet and its maximum about 50 feet. In the Steward mine the vein's most peculiar feature is the presence, between the 700 and 900 foot levels, of an arkose or sandstone, where the strike fault has produced open fissures filled by material washed down from above and deposited in approximately horizontal layers, the material forming a friable sand rock. This material consists partly of quartz fragments but mainly of crushed granite. In the 800-foot level this arkose gradually gives place to a fine breccia or conglomerate.

ORES.

In general it may be said that the ore shoots now mined consist of the filling of the older quartz-pyrite vein, shattered and displaced by the Steward strike fault and carrying sulphides deposited not from above but by the mineralizing waters introduced along the strike fault. In places the old vein is but slightly broken, and the stopes show an average width of 7 feet of massive quartz-pyrite vein filling, with an abundance of zinc blende, the fault showing only as a black clay seam running through the center. Where, however, the fault has crushed and brecciated the older vein filling the stopes show 8 to 10 feet of ore, consisting of clay carrying ore balls, crushed rock, with some secondary chalcopyrite, and bornite. Bornite increases and enargite appears in quantity at 900 feet in depth and below.

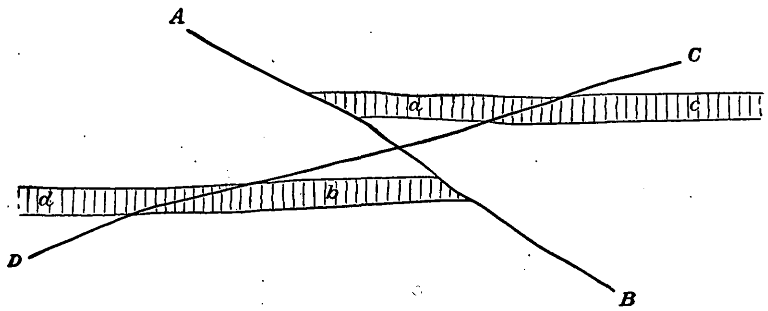


FIGURE 53.—Displacement of Rialto vein by Clear Grit fault. *a–c*, *b–d*, Segments of Rialto vein; *A–B*, Clear Grit fault; *D–C*, Steward vein fracture before faulting.

VARIATIONS IN THE STEWARD VEIN.

Where the Clear Grit vein meets the Steward the relations of the two veins are distinguished with difficulty, owing to the abundance of soft, clayey material, and the fact that the material falls so easily that close timbering is necessary. At this intersection fractures in the ore body

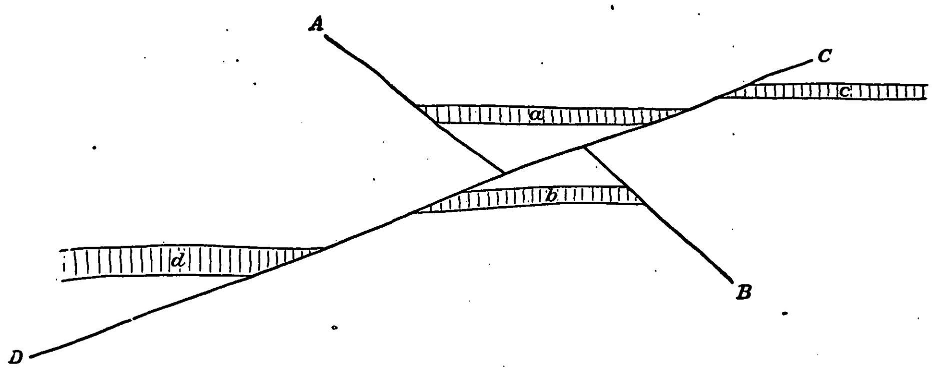


FIGURE 54.—Displacement of Rialto and Clear Grit fault vein by Steward vein. *a–c*, *b–d*, Segments of Rialto vein; *A–B*, broken Clear Grit vein; *D–C*, Steward vein.

show bunches of crackled calcite and glance, with pale cream-yellow barite. Galena is found in the vein in scattered spots and streaks 1 to 4 inches thick. Zinc blende also occurs, both

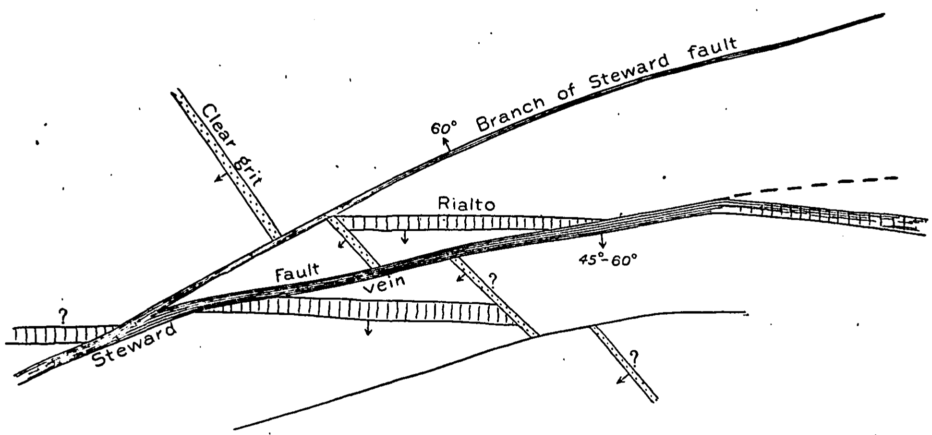


FIGURE 55.—Displacement in Steward mine; 800, 900, and 1,000 foot levels.

mineralized and cementing fragments of altered granite, so that the material is evidently endogenous and is not crushed like the older ore.

Eastward toward the Nipper mine the Steward vein is progressively lower in grade. In general, the values in the upper levels come from such portions of the older vein as have been torn off and lie within the fault filling. Near the shaft the vein is nearly vertical from the 700-foot level to the 1,000-foot level, but westward it has a strong south dip.

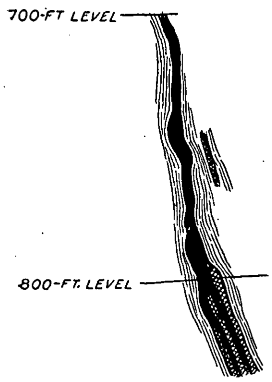


FIGURE 56.—Ore body from 700 and 800 foot levels, Steward mine.

The cross section of the vein varies greatly in detail from point to point. Aside from the primary ore of the older vein it holds bunches and streaks of later bornite and enargite, with masses of altered granite (shot through by a network of films of glance, which make it a good concentrating ore), fading out in the hanging wall into barren granite; these are evidently due to descending solutions.

The diagram (fig. 56) was sketched underground to show the conditions in a raise from the 800 to the 700 foot level. The exposures show a formerly solid quartz-pyrite vein, consisting chiefly of dense, fine-grained, dark-colored quartz, mixed with shattered and crushed pyrite, partly cemented by later white comb quartz. Many cracks and cavities in the pyrite ore show blue-gray friction clay. Two distinct seams, separated by a horse of mashed granite, are visible. The fault breccia and conglomerate is much wider than the ore streak.

In the western part of the Steward mine, beyond the Clear Grit fault vein, the Steward vein follows a displaced part of the older quartz-pyrite vein; its course is N. 85° E. and its dip straightens to 85° S., cutting the older vein at a sharp angle (see fig. 57). The composite lode shows its typical development on the sixth floor above the 800-foot level, where it has a width of 15 feet. At this point it shows a footwall fissure filled with sand washed down from the upper levels and having rude horizontal banding. Next to this there is 7 feet of solid quartz-pyrite ore. The hanging wall consists of decomposed granite carrying the usual amount of pyrite. Along the 800-foot level the vein narrows to 5 feet, and the sandstone is replaced by a fault muck, composed of ground-up granite and clay carrying balls of rock and of ore. The vein soon widens to 10 to 15 feet, of which 6 feet is solid quartz-pyrite ore. The fracture being uneven, the filling varies greatly in thickness.

A typical cross section of the Steward fault vein, exposed on the east face of the 800-foot level, shows 2 feet of soft clay on the footwall, with 1 foot of banded quartz and pyrite above it, overlain by 3 feet of breccia with numerous clay seams, and this in turn by 6 inches of quartz and pyrite, covered by 2 feet of mashed granite and clay, overlain by hard clay gouge forming the hanging wall. This portion of the vein carries no pay ore and, as indicated by the section just given, is a typical fault vein. The width varies greatly, but is generally least at the eastern end of the property. On the 1,100-foot level it is 37 feet wide, and from this level downward it has an average workable width of perhaps 25 feet; between limiting fractures it is 50 to 75 feet wide.

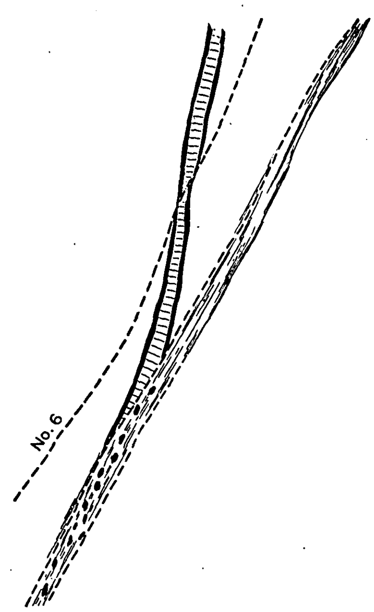


FIGURE 57.—Cross section through Steward and Original mines, showing Steward vein following and brecciating the Parrot lode.

STRIKE.

The Steward shows a marked change in strike between the 900 and 1,300 foot levels, its course being northwest on the 900-foot level, east-west on the 1,100-foot level, and N. 75° E. on the 1,300-foot level; west of the Clear Grit fault its course is more uniform. It shows the same swerving in dip that it does in strike, and in certain places shows marked flattening, which can not be correlated with any intersecting faults as yet recognized.

The directions just given correspond to those distinguished in the east-west veins of the district, namely, N. 70° to 80° E. and N. 70° to 80° W. It seems probable, therefore, that the fault fissure chose a direction of easy fracturing along the earlier fissure systems, that the faulting of the Clear Grit is to be ascribed to a period of fracture not later than that of the Blue vein, and that the Steward and Clear Grit faults were due to simultaneous fissure formation in two opposite directions.

ORIGINAL MINE.

The Steward fault vein shows in the deeper levels of the Original mine, where it coalesces with the Parrot (Gagnon) quartz-pyrite vein, forming the Conglomerate vein, which yielded the great ore bodies of the Original and Gagnon mines (p. 136). If it cuts through and passes southward of these ore bodies, it does so at a level deeper than any yet developed. The occurrence of the Steward vein in the Original mine has already been described (p. 133).

GAGNON MINE.

In the Gagnon mine the outcrop of the Steward fault vein has not been located. The Steward comes from the north and intersects the Parrot at a small angle in the middle of the Gagnon workings. The vein has a dip of about 60° in the Original mine, and intersects the Parrot ledge at the 1,000-foot level. To the southwest the intersection is somewhat higher. In the lower levels the two veins unite (see figs. 49 and 50), the fault vein shattering the older, making a mass of friction breccia and conglomerate, so that the composite vein is often called the Conglomerate vein; in places it forms a footwall streak underlying a slightly broken but continuous portion of the primary vein that now forms the hanging wall.

In the eastern part of the Gagnon mine the hanging-wall ledge of the Parrot is a distinct vein parallel to and 30 feet distant from this composite or conglomerate vein. Westward the compound vein shows fault matter on the footwall, and the workings indicate that the Steward fault crosses the vein in depth. The 1,600-foot east level displays a solid vein of shattered mineralized granite with stringers and two distinct streaks of ore on the footwall side, and the conglomerate vein lies on the east or hanging-wall side and has a north dip.

In the Gagnon mine a segment of the main Parrot vein is cut off by the Caledonia (No. 6) vein above, and is cut by and merges with the Steward vein below. In the eastern part of the mine the hanging-wall ledge of the Parrot vein maintains its identity, running parallel to and at some distance from the No. 6 fault; in the western part, however, it merges into this fault, or at least it maintains identity as a hanging-wall layer only in depth (800 to 1,300 feet) at 1,100 feet west of the shaft.

The Steward as exposed in the Gagnon mine is essentially a fault vein, characterized by friction breccias, clays, and bowlders of granite, bornite, and quartz-pyrite ore, with scarf-like masses of dragged and crushed ore lying in the fault material. It contains a little galena and still less manganese and fluorite. In other words, it has the same mineral characteristics as the Blue vein, has a high silver content, and may be considered as a pyrite-bearing silver vein.

SUMMARY.

Briefly summarized, the Steward fault cuts across primary quartz-pyrite veins, reopening and shattering them along their strike. In this reopening the fissure was not straight, and the resultant fracture varies in width. In places it shows parts of the still unbroken primary vein either attached to the footwall or inclosed within the fault material. More frequently the earlier vein is broken up into a breccia, many of whose fragments are rounded. In places the older vein is only cracked and is enriched along such cracks by glance and bornite. The workable ore shoots consist largely of fault matter, with ore balls. They do not extend to the surface, but lie approximately 800 feet beneath the outcrop. The most notable feature of the primary ore is its zincky character eastward. The most notable feature of the fault fissure is the presence of open spaces, now more or less filled by sandstone, and the occurrence of endogenous enargite and bornite. The vein shows a slight deflection by cross fissures, northwest and southeast fissures producing a displacement of 10 feet and 5 feet, respectively, on the Steward 800-foot level west. The Clear Grit vein produces a doubling and displacement of the older Rialto vein analogous to the shifting of the Blue vein by the Steward.

The upper levels of all the fault veins carry little copper. The faulted and crushed Gagnon vein above the 300-foot level was originally worked for the rich silver ores which formed a 4 to 6 foot footwall streak, but in recent years, when a 2 per cent ore became payable, 50 to 75 feet in width was removed, the copper occurring in the ore as a dense, black, powdery chalcocite. The footwall of the combined vein showed on the 300-foot level a very constant but irregular and small streak of sphalerite, chalcopyrite, pyrite, and galena, but the streak was too small and low grade to be worked. The best and widest stopes occur at intersections.

NO. 6 FAULT OR CALEDONIA VEIN.

The No. 6 fault vein, another member of the Steward system, is seen in the upper levels of the Original mine, extending westward and forming the footwall fault vein in the Gagnon workings from the 300 to the 500 foot level. It unites with the Parrot lode above the 400-foot level, following and brecciating it and making a composite vein. About 500 feet below the surface it passes through the Parrot ledge southward into the hanging wall with an average dip of 50°.

The No. 6 vein is workable above and for 50 to 60 feet below its union with the Parrot vein. This fact implies that the pay ore is in part original in the vein and is not due to fragments of the older lode, but to mineralizing waters which have perhaps derived their copper from the older vein. The cross section (fig. 48) shows a hanging-wall stringer of the main ledge, which may have caused local enrichment and may account for the pay ore below the main intersection. As a whole the vein is zincky and low grade. It shows 3 to 4 feet of clay and a pay streak averaging 3 feet wide of low-grade quartz-pyrite ore relatively high in silver. The hanging wall is of hard granite; the footwall of shattered granite seamed with quartz for 5 or 6 feet from the vein.

Drifts have been run on this lode, and it has been worked on the 300 and 1,000 foot levels of the Gagnon and the 500 and 600 foot levels of the Original. It is also encountered eastward in the deep levels of the Parrot mine, where it is well exposed on the 1,300 and 1,500 foot levels, and in the Neversweat 1,800-foot level it dips about 76° S. It faults both the Blue and the Parrot veins. (See figs. 50 and 52.)

BLUE JAY FAULT VEIN.

The Blue Jay vein is the second largest member of the Steward system. This occupies one of the largest and most persistent fault fissures of the district, extending eastward from the west end of the Blue Jay mine, through the Moonlight and Anaconda mines, to the West Colusa mine. It is known by different names in different parts of its course, being called the Blue Jay fault vein in the Blue Jay mine, the Middle vein in the workings of the Anaconda mines, and the No. 16 vein east of the Rarus fault. (See fig. 105, p. 223.)

The importance of the vein lies not only in the ore, which is extensively mined in the deep levels of the mines east of the Rarus fault, but also in the influence it has had on earlier ore shoots. It has materially affected the mineralization as well as the displacement of the veins of the Anaconda, Mountain View, Rarus, and Leonard mines, not only cutting and displacing the Anaconda vein, but also introducing mineralization into the shattered ground adjacent to the displacements. In the St. Lawrence and Colusa mines its course differs only some 15° or 20° from that of the Rarus fault, running about N. 55° to 60° E., but its dip is opposite. Its strike is also parallel to that of the Tramway vein, but the latter dips north and the Blue Jay south. The throw is to the southeast. Southwestward it splits, one fork passing behind the Anaconda vein near the shaft, and the other crossing and faulting the Anaconda vein. Both the Mountain View fault and the Blue veins are probably displaced by the Blue Jay. The fault breccia contains stringers and lenses of endogenous enargite ore, and many large ore bodies occur where it crosses the east-west veins.

The Blue Jay fault vein is developed in the Mountain View mine from the second level down to the deepest workings. It cuts through the Anaconda (Mountain View South vein) with many subordinate sympathetic fractures, which have been filled by glance. It cuts and displaces the Anaconda, North Connecting, and other veins, as may be seen on the 200, 300, 400, 800, and 900 foot levels of the Mountain View mine. The displacement of the east-west veins is particularly apparent on the 800 and 900 foot levels.

The identity of the Blue Jay fault vein with the Middle fault vein of the Anaconda ground, and this with a vein in the Mountain View and with the No. 16 Rarus, has only recently been recognized by H. V. Winchell. It makes only a small angle with the Rarus fault fissure, but has a steep opposing dip; that is, it dips to the southeast. It is easily recognizable in the Mountain View 200-foot, 300-foot, etc., levels, where it cuts off and displaces the North Connecting vein and the Mountain View South ledge. Its dip is very regular. Under the Sullivan claim it swerves southwest and flattens a few degrees on the lower levels under the Johnstown surface. It is cut off by the Rarus fault on the 1,100-foot Mountain View workings, under the Sullivan claim.

The vein is not recognizable in the workings of the St. Lawrence 1,200-foot level but appears at this level east of the Rarus and has been definitely identified in the St. Lawrence 1,300 and

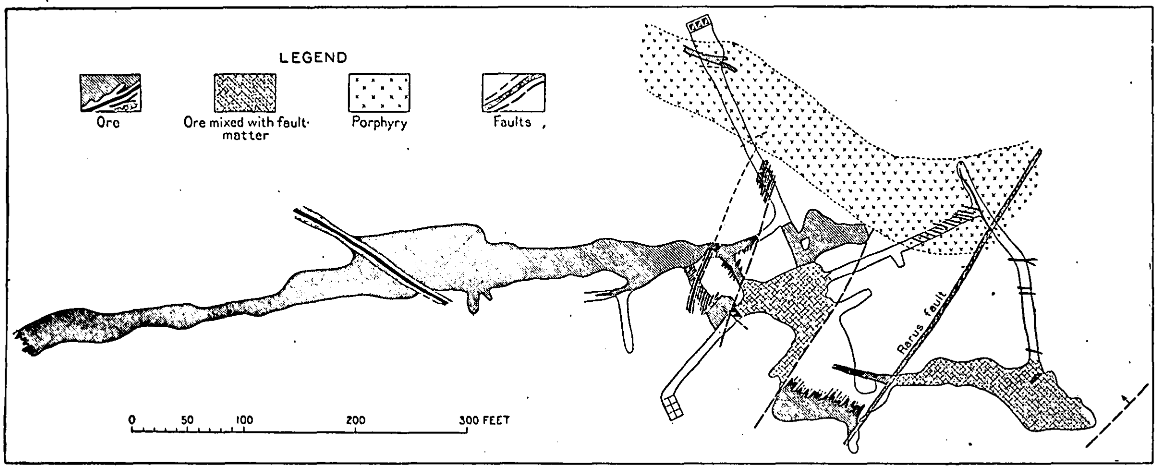


FIGURE 58.—Plan of 1,400-foot level of the St. Lawrence mine, showing relation of flat ore bodies to fault veins.

1,200 foot levels, where it (the Middle fault vein) makes an angle of 25° with the east wall of the Rarus (as seen in the 1,200-foot level of the St. Lawrence).

The fault is also well exposed on the 1,200-foot level of the Pennsylvania mine, where a long north crosscut successively encounters the Mountain View fault, the Blue Jay fault, and the Rarus fault. Its occurrence in the Rarus area is described on page 223.

The Blue Jay fault vein has been mined for 300 feet in the Rarus mine, where it is encountered underneath the Rarus fault. It carries from 8 to 10 feet of ore, and in places on the 1,200-foot level of the Rarus has as much as 20 feet of good ore, the chief production of this level coming from this Blue Jay, which here faults northwest veins Nos. 14 and 17, whose correlations are not known.

The correlation of the Blue Jay fault with the No. 16 vein of the Rarus is based on its position and character. As there is some uncertainty as to the exact point at which it is cut off by the west fissure of the Rarus fault, this correlation is not perfectly satisfactory. However, its mineral character and structural features seem to indicate plainly that the Blue Jay corresponds to the No. 16 beneath the Rarus fault.

In the St. Lawrence mine the vein takes an important part in the shattering and crushing of the rocks now heavily impregnated with enargite and chalcocite forming the great flat ore bodies of the 1,200, 1,300, and 1,400 foot levels of this mine (fig. 58).

On the 1,200-foot level the vein shows a quartz-pyrite streak, carrying secondary glance, in the crushed and altered granite and clay that fills the fault fissures. The 1,600-foot stopes show a lode 26 feet wide, containing 6 feet of ore, half of which is high-grade enargite ore.

The 2,200-foot level of the Anaconda has a good ore body on the Middle or Blue Jay vein. It shows 50 feet of fairly good ore, with 10 feet more of solid glance ore. The Anaconda vein at this level is very lean, lying just under the Rarus fault. The Rarus fault on the 2,400-foot level is but 40 feet wide, whereas on the 2,200 it is 80 feet wide. Veins Nos. 4 and 5 are hanging-wall splits to the south.

OTHER VEINS OF THE STEWARD SYSTEM.

As already stated, the Bell fault belongs to the Steward system, but its description is given with that of the other veins of the Bell-Diamond area. Several other fault veins of the system occur in different parts of the district, especially near the Syndicate lode and south of the Anaconda belt in the Belmont and Colorado mines. These faults have shown little or no ore and are, so far as known, of no commercial importance.

INTERMEDIATE COPPER BELT.

MINES AND VEINS.

The broad tract of ground lying between the Anaconda and the Syndicate lodes is for convenience called the Intermediate belt. It contains few and relatively unimportant mines, although it is traversed by a number of wide and persistent veins of the Anaconda system, as well as by the three great fault veins of the district. The greatest production is from the Blue vein, which is worked in the Little Mina, Nipper, and Oden mines, diagonally across the entire width of the belt. The Parnell mine has opened up the central part of the area. With these exceptions the mines are not worthy of especial mention. The North crosscut from the 1,000-foot level of the Anaconda to the Bell mine passes entirely through the belt and cuts some 21 veins, a few of which are workable, though of low grade. Five diamond-drill holes driven horizontally across the belt at elevations between 5,000 and 4,000 feet above sea-level, and at distances about 600 feet apart, have cut the same veins as the Anaconda crosscut. South of the Green Mountain mine one of these holes shows the existence of six veins aggregating 59 feet of quartz in a width of 149 feet and, farther north, of three veins in a width of 400 feet.

The Clear Grit, Steward, Skyrme, and other fault veins with numerous lesser fissures, cross the belt, but are only locally mineralized, if at all, and are seldom traceable for more than short distances. It is a noticeable fact that some of the strongest quartz outcrops cover veins that are inconspicuous and carry little or no ore. The Parnell mine develops ore in the Parnell, Schweitzer, and L. E. R. claims.

PARNELL MINE.

The Parnell mine contains several veins, three of which have been productive during the short period of the mine's activity. The veins are comparatively narrow and tight, and the ores are peculiar in that they more closely resemble silver than copper ores. Those produced have been high in silver and rather low in copper. Much of the quartz is extremely dense and fine grained; the sulphides, bornite, chalcocite, and pyrite, occur in minute particles disseminated through it and so interlocked with it as to be difficult to separate by concentration. The veins are thinner and less promising than those in the eastern continuation of the belt in the Mountain View or northwestward in the Syndicate mines.

The workings extend to a depth of 760 feet. The shaft is 650 feet deep, with long crosscuts to the south on the 550 and 650 levels, and one to the northeast at a depth of 450 feet. A number of veins of the Blue and Anaconda systems have been cut and three of them have been worked, yielding ores unlike those of either the copper or the silver mines of the district, though less unlike the silver ores. Two other veins, opened by drifts, contributed to the output of the mine during the short period it was worked, before it was closed by injunction, pending decision regarding its ownership.

The northernmost of the developed veins, seen only in a drift 118 feet north of the shaft on the 650-foot level, is not identifiable with any surface outcrop. It is an east-west quartz-pyrite vein, with steep (73°) southerly dip, reopened by strike faulting, with crushing of the vein filling and the fault clay seams. The vein varies in width, averaging about 32 inches. Where cut it is 3 feet thick, but lean and unworkable. Generally, it shows 2 feet of barren quartz, separated by several inches of fault clay from a footwall streak of crushed, mashed, and altered granite, carrying streaks of black copper ore.

The Coquette vein, also an east-west quartz-pyrite vein, outcrops north of the shaft and has been developed and worked on the 250, 350, and 450 foot levels, with an ore body stoped both above and below the 350 level. The vein has an average width of 2½ feet of dense fine-grained quartz-carrying bornite. In the fourth level the ore is crushed by fractures accompanying a fault vein of the Steward system, which has cut and dislocated the vein in the west drift about 15 feet from the crosscut. The vein is not developed below the 400-foot level. The Steward system vein runs N. 80° E.; like the Coquette vein it dips 72° S.

The L. E. R. vein has been the most productive of the mine. It is a member of the Blue vein system and has been often correlated with the Mountain View fault vein, with which it corresponds in character and composition. Its course is northwest and its dip 56° to 64° S. It has smooth, sharply cut walls averaging about 5 feet apart, with fault breccia and clay, save where a shoot of hard blackish quartz fills the vein from wall to wall. In the ore shoot the quartz carries covellite as well as pyrite, with enargite and bornite in the fault clays, the extreme width seen being 16 feet. The rich ore occurs in a band about 16 inches across, carrying about 5 per cent of copper and 5 ounces of silver per ton. Drifts explore the vein for about 300 feet on the 550 and 650 levels, with a winze on the ore shoot down to the 700 level. The fault clays carry rock and ore fragments, and show some rhodonite, a mineral peculiar to the silver veins. The vein is opened by short drifts on the 450-foot level, where it is cut by a cross fault running N. 50° E. and dipping 60° SE. and is shifted about 6 feet to the south. This same cut-off appears in the 550 and 650-foot levels, but here no displacement was seen.

The L. E. R. vein is developed for a distance of 650 feet on the 5,200-foot plane, and for a depth of 400 feet vertically, being worked in the 650 to 800 foot levels of the Parnell mine, and cut in the Anaconda north 1,000-foot crosscut, about 1,030 feet north of the shaft. At this point the vein is 13 feet wide and carries a 6-inch streak of good ore. It is a northwest vein whose course projected intersects the Anaconda lode in the St. Lawrence mine, where, however, no cross vein is recognizable on the 700-foot level, though the crosscuts and laterals of the 600-foot level (5,300 feet) do show a small cross vein.

The Parnell vein is 200 feet south of the L. E. R., being recognized in both the 550 and 650 crosscuts, and opened by a west drift from the lower of the two. It is an east-west quartz-pyrite vein dipping south, and carrying streaks of low-grade pyrite ore along each wall. The vein averages 8 feet across, with a foot of fault breccia along the hanging wall.

The Schweitzer, the most southerly vein developed in the mine, has been worked by a drift running west from the 650-foot crosscut, with a winze going down to a short drift 160 feet below. It is a northwest fault vein, vertical, or with very steep (86°) southerly dip. The vein is about 8 feet wide in the stopes, consisting of fault matter a few inches to a couple of feet wide, with lenses of quartz ore, carrying streaks and bunches of bornite in barren quartz. (See fig. 59.)

Two other veins are seen in the sixth level crosscut north of the Schweitzer. The east-west vein, 10 feet from the Schweitzer, is opened by a short west drift, showing about 2 feet of lean quartz and pyrite with an 8-inch band of pyrite. The second vein runs northwest and dips at 50° N. This vein also carries quartz, the width varying between 2 and 5 feet, being thickest in the raise.

A third vein at the elbow in the crosscut shows a course of N. 78° W. and a dip of 50° S.; it displays 6 inches of clay and quartz but no workable ore.

Three other undeveloped veins are seen in the 600-foot crosscut between the Schweitzer and L. E. R. veins. One, 25 feet south of the L. E. R., runs S. 85° E. and has a southerly dip of 60°; a second, 160 feet south, runs N. 78° W. and dips 50° S.; the third is 200 feet from the L. E. R. drift. All three are thin and carry no ore in the crosscut. The northernmost of these same veins is seen in the 500 crosscut, but is small and not workable. They are mostly east-west veins.

A big fault vein cut on the 400-foot level 10 feet south of the shaft shows 6 feet of fault breccia and clay, with ore fragments. It has a dip of 45° S. and an east-west course. It is nearly 15 feet wide on the 550 and 6 feet wide on the 650 foot crosscut.

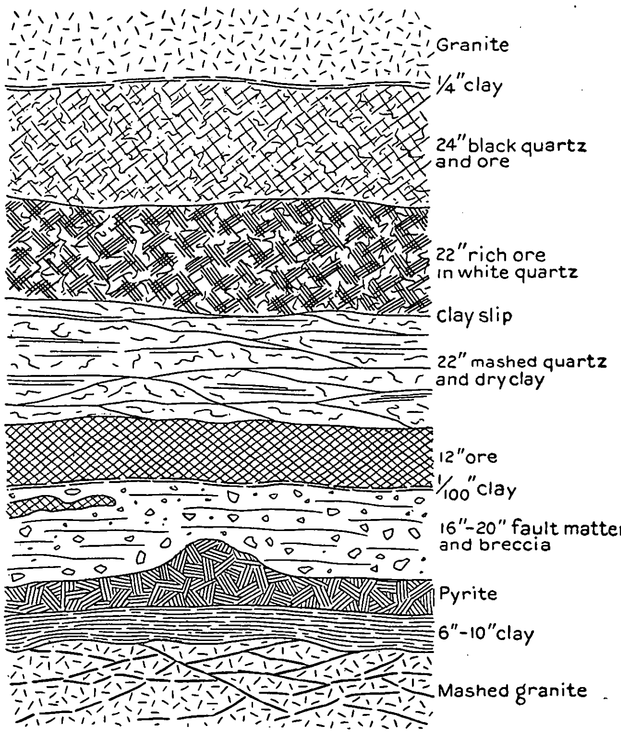


FIGURE 59.—Cross section of Schweitzer vein, Parnell mine.

The veins of the Parnell can not be positively correlated with those of either the Bell or Mountain View mines, though their position and course are similar.

LITTLE MINA AND NIPPER MINES.

The Little Mina and Nipper mines have already been discussed (pp. 136 to 145) in connection with the Blue vein system in the Anaconda belt.

SILVERBOW SYSTEM.

CHARACTER AND AGE.

The Silverbow system of enargite veins was not recognized for many years, because these veins have been so generally reopened and faulted by later fractures. (This later faulting, as so often noted, is the most important economic feature of the veins, as the richer ore bodies are dependent upon it.) The veins run nearly northwest, and are generally vertical or dip steeply southward. The vein filling is quartz and pyrite, with more or less enargite. In some places the veins have apparently been the cause of displacement of older veins, but in others this displacement is only a feature of contemporaneous formation of two sets of fissures. In most of the northwest veins, particularly in those of the Rarus and Bell-Diamond areas, the reopening of the veins has left little of the original vein filling intact, so that in most places the fault material is readily recognized and the old filling is liable to be overlooked. This is particularly true of the Greyrock and others in its neighborhood.

Veins of this class are often distinguishable from the east-west veins by the presence of enargite, which extends upward to the oxidized zone; in fact, the enargite veins are less deeply oxidized than the east-west pyrite veins and carry fresh enargite at levels in which the ordinary quartz-pyrite veins are completely oxidized.

The age of this northwest system is probably somewhat less than that of the east-west Anaconda system. In some of the veins it is difficult if not impossible to distinguish an original quartz-pyrite character. In most of them, however, the criteria are readily recognizable and there is no difficulty in establishing their relative age in one part or another of their extensive workings.

SILVERBOW LODE.

The Silverbow lode is extensively worked in the Pennsylvania and Silverbow mines, being continuously developed from the western boundary of the Pennsylvania property for 4,500 feet eastward and to a depth of more than 1,400 feet. In both mines it has been continuously stoped to a depth of 600 feet. It has been known as the Pennsylvania No. 1 vein in the Pennsylvania mine, and it was correlated with the Moonlight lode by Emmons in the Butte folio (No. 38).

CHARACTER AND DISPLACEMENT.

It outcrops about 150 feet north of the Pennsylvania shaft, but its apex, though developed at different points by open cuts and pits, is not easily followed, being largely concealed by surface débris. Its general course is N. 65° W., but it curves with a northward convexity in the Pennsylvania mine, owing to a distributed displacement in the Rarus fault zone. The dip is southward, and outside of the Rarus zone is very constant, averaging 68° at the Silverbow shaft. The thickness varies considerably in different places; in the Pennsylvania mine it measures 10 to 15 feet between walls, and in the deeper levels of the Silverbow it is 20 feet across. (See fig. 60.)

The vein apparently joins the Pennsylvania vein westward near the workings of the St. Lawrence mine, but separates again. The junction may be seen in the 100-foot level of the Pennsylvania mine, where the vein dips 45° to 50° S., and shows sharply defined walls with clay selvage, particularly on the hanging wall.

The distributed displacement of the Silverbow vein by the Rarus fault is shown in the upper levels of the Pennsylvania mine, where the vein, though apparently continuous, is cut by a multitude of small cross breaks with slight displacement, so that the plan of the vein on the first to the fifth levels shows a bow or curve very unlike the normal straight course; the dip also is materially flattened. The larger cross faults (for example, one with 15 feet throw north on the 300 and 400 foot levels, 75 feet west of the Pennsylvania shaft) shows the southward movement of the

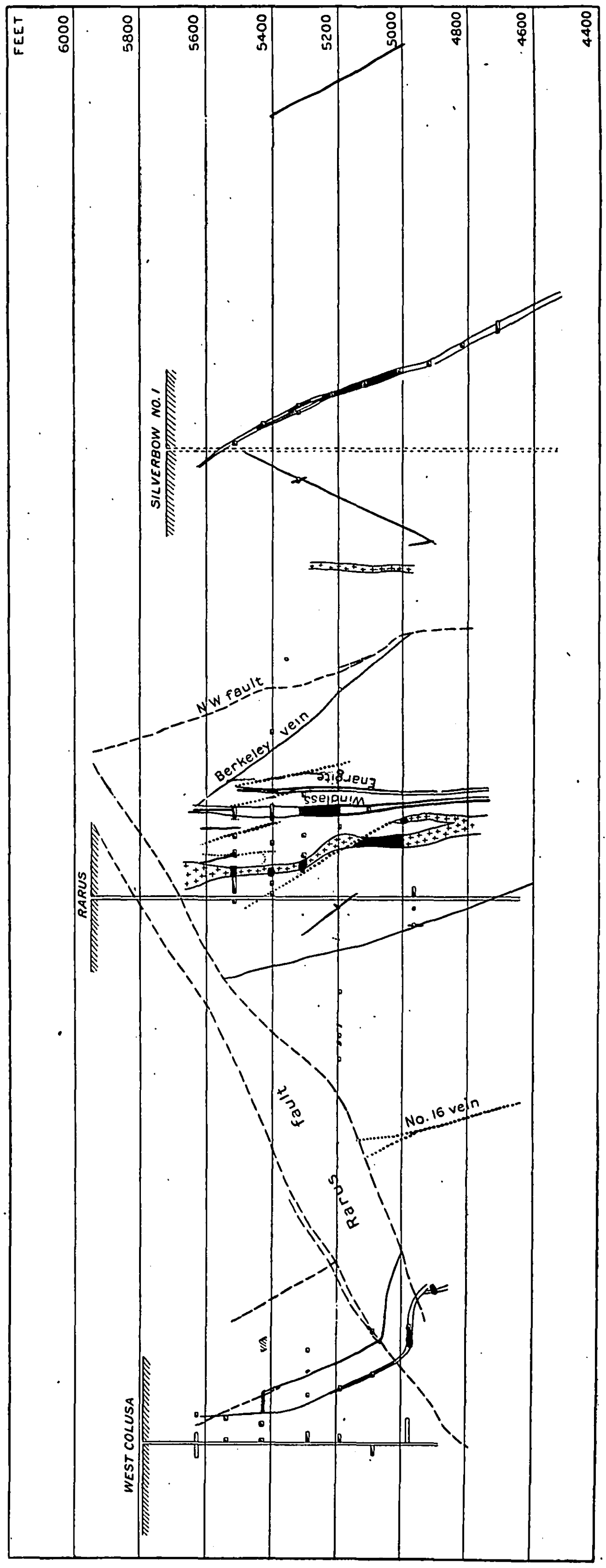


FIGURE 60.—North-south section through Silverbow, Rarus, and West Colusa mines.

hanging wall by drag. The direction of throw is not always the same, for in places a fault is encountered beyond which the ore fails for a few yards and then resumes beyond a second cross slip. These many lesser faults come together downward, so that the Silverbow shows decided shifting on the 800 and 900 foot levels. (See fig. 61.)

The ground for 100 feet or more south of the Silverbow vein is traversed by several small east-west quartz-pyrite veins; on the tenth level five of these veins are over a foot thick, but the ore is irony and low grade. From these veinlets, which are mostly to be considered as hanging-wall streaks of the lode, south to the Iron or Glengarry vein, the ground is cut by many fault slips. In the crosscut south on the tenth level (fig. 62) ten such faults are cut; seven run N. 40° to 60° E., with steep southerly dip; two run east and west; and one runs northwest. These faults reach a foot or more in thickness and are filled by clay, in places holding friction breccia or pebbles and uncommonly streaks of secondary ore.

VEIN FILLING AND RECENT DEPOSITION.

The vein filling is oxidized to a varying depth, averaging about 60 feet below the surface (200 feet in the Silverbow). The leached matter is not rich enough in silver to warrant its extraction, but it has beneath it, above the solid pyrite, a thin layer of partly altered and replaced pyrite that carries argentite and assays 80 ounces or more of silver to the ton.

The primary filling of the vein is quartz and pyrite, which in many parts of the vein is still solid and unbroken and carries relatively low values in copper. In general the vein is but

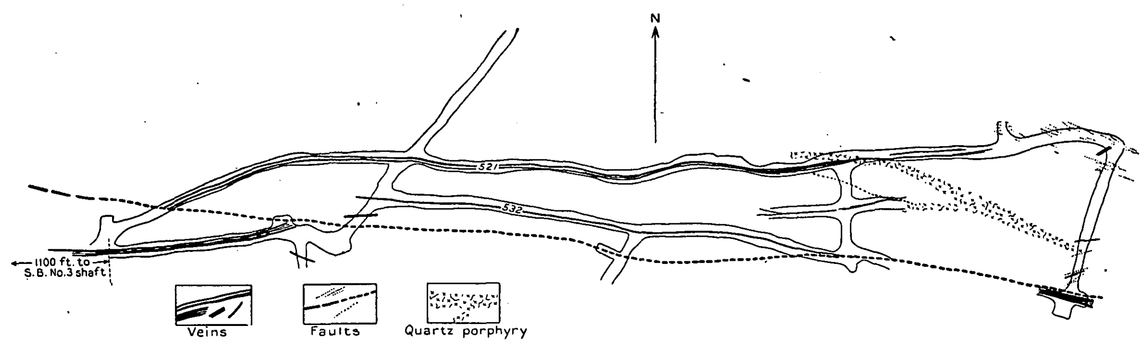


FIGURE 61.—Plan of east end of 500-foot level of Silverbow mine, showing Iron vein (No. 3 vein) cut by fault.

little crushed and broken by either strike or cross faults, but the richest ore consists of crushed vein filling cemented by glance. In general the copper and silver contents decrease downward, except where local fracturing has permitted the ready access of downward seeping waters with the formation of secondary glance. Chalcocite is the most abundant copper mineral and in the upper levels contains native silver on fracture surfaces. Enargite appears but sparingly.

Oxidation has extended to a depth of 200 feet or more below the surface in the Silverbow mine, and its action is particularly interesting owing to the large amounts of copper sulphate deposited in the mine workings. At the west end of the mine free-milling ore was found to a depth of 160 feet; eastward the lower limit of oxidation goes slightly lower, following the contour of the surface.

In the zone of oxidation the changes have been very complete. The oxidized matter consists of a mass of coarse spongy quartz, the crevices of which have been partly filled by iron oxide and by small amounts of silver chloride. No other minerals are present. In the lower levels, beneath this completely oxidized material, the different stages of oxidation are traceable. Blue chalcanthite, the hydrous sulphate of copper, is seen in large quantities in the unused drifts of the 300 and 400 foot levels, where it collects in large quantities on the walls of the drifts and as stalactites and stalagmites on the roof and bottom, coats mine timbers, and impregnates the wood itself with metallic copper. This deposit is collected from time to time and smelted; it is found to contain 13 per cent of copper. The water in the bottom of the drift has a dark greenish-blue color and is so rich in copper that the iron rails have been deeply corroded and for some distances have been found to be entirely replaced by metallic copper.

On the deeper levels, where the oxidizing waters have penetrated as a result of artificial workings, the oxidation is somewhat different. The blue sulphate of copper, chalcanthite, is almost never seen, but the oxidized forms of iron are plentiful, and large stalactites are formed, especially on the 800-foot level (Pl. VIII, *B*, p. 82.) These stalactites have been observed 2 to 3 feet long. They grow with great rapidity, some of them increasing 1½ feet in less than three months. They are typical stalactites and are apparently formed without the aid of algous growth. Commonly they are hollow pipes composed of concentric rings of a light-brown to deep-brown limonite and are usually coated with a thin white film regarded as the oxidized form of iron, freshly deposited from the waters. Continuous streams of water flow down their interiors and, in addition, a considerable amount is always flowing on their outer surfaces. The growth is mainly from the outside.

BAILEY VEIN.

In the older parts of the Steward mine two quartz-pyrite veins are developed. The first (Bailey vein) may be considered a member of the Silverbow system, since it has a course of N. 62° to 64° W. and a dip of 70° to 75° S. It is a dry and tight quartz-pyrite vein, about 4 feet wide, with a 1½ to 2½ foot streak of pay ore, which carries much sphalerite, partly replaced by chalcocite. The chalcocite is friable and soft and occurs mixed with pyrite and partly decomposed blende. Though the vein is solid and unbroken, it has clay seams on both walls. The vein was worked on the 50, 100, 150, 200, 250, and 300 foot levels only.

OTHER NORTHWEST PRIMARY VEINS.

The Johnstown (North Connecting) vein is a good example of the Silverbow system, as in it but slight later opening has occurred to obscure the character of the earlier vein filling. It runs parallel to the Mountain View fault, but, unlike that fracture, it is a solid, unbroken vein, which intersects but does not fault the east-west veins.

The Windlass, Wild Bill, and other veins of the Silverbow system are described on pages 171 and 218 in connection with the Rarus and Bell-Diamond areas.

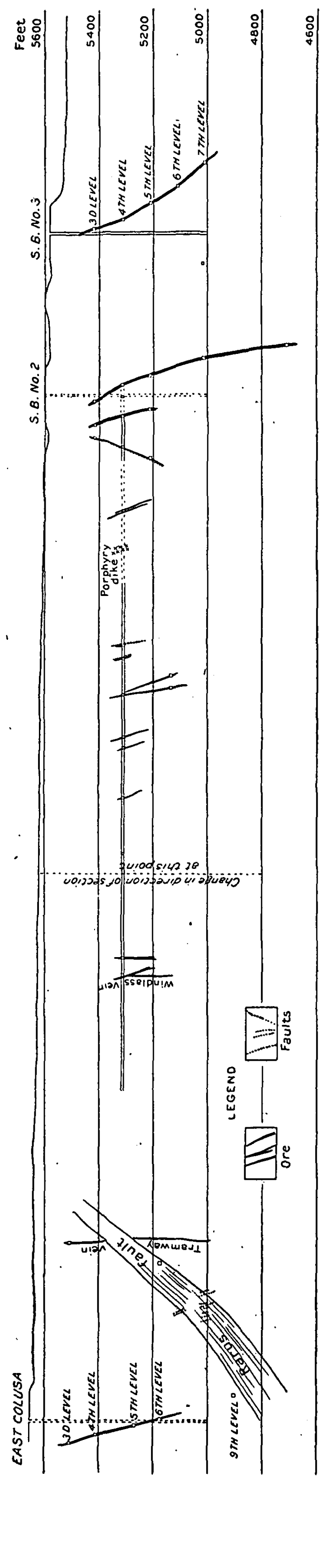


FIGURE 62.—North-south section through Klondike crosscut, Silverbow mine.

SYNDICATE LODE.

COURSE AND DEVELOPMENT.

The Syndicate lode is one of the most regular and well defined of the Butte copper lodes. In the property of the Anaconda Co. it has been opened by a practically continuous set of drifts for about 3,000 feet along the strike, to vertical depths of 1,000 to 2,200 feet. It has been followed westward about 1,500 feet farther by nearly continuous drifts through the Estella, Poulin, and Moscow mines, but in this extent its exploration has been mainly confined to upper levels within 400 feet of the surface. It outcrops on the south edge of the terrace on which Centerville is built, but its apex is topographically inconspicuous, rising but little above the general surface of the granite. Its course, however, is easily traced, either by the exposed vein, by the collapse of the mine workings which reveal the vein walls, or by numerous shafts which mark its course from the Poulin mine on the west to the Wake-up-Jim mine on the east. The outcrop consists of a firm, somewhat brown quartz, more or less stained by green copper carbonate, but showing no workable bodies of copper ore in the oxidized zone.

No positive correlation has as yet been established between the Syndicate lode and the veins worked in the Bell and Greyrock mines, but, as stated elsewhere (p. 177), there is reason to believe it to be identical with the Diamond ledge. A vertical section through the Wake-up-Jim mine shows that the Syndicate lode is traceable to a depth of 700 feet, but that below that point the vein seems to change from N. 80° E. to a N. 80° W. line of fissuring, which would carry it away from the workings of the Bell and Greyrock. It is possible, however, that the mine workings have followed lean cross fractures.

The lode has a general N. 80° E. course, the outcrop being crescentic. The lode is the resultant of the intersection of two sets of fissures, mineralization following first one and then the other, and as this has been modified by cross fractures and slight displacements the actual course of the lode diverges somewhat from a straight line.

The vein has been developed to a depth of 500 feet for 4,000 feet. On these levels the workings extend from the Moscow mine eastward to the Wake-up-Jim. The zone of weathered and leached ore is apparently shallow; thus, near the Mountain Con. shaft the lode was workable on the tunnel level (6,140 feet), the outcrop being only about 60 feet higher. At an elevation of 6,050 feet the vein was continuously workable from the No. 1 shaft to the Wake-up-Jim shaft, a distance of 4,500 feet.

In the Anaconda Co.'s ground (see Pl. XIV, *B*, p. 114) the lode is worked through the following shafts, which were mined at the time of examination (1906) to the depths given:

Shafts on the Syndicate lode in the Anaconda Co.'s ground in 1906.

Shaft.	Distance east of west boundary of Buffalo claim.	Depth.	Elevation of bottom level.
	Feet.	*Feet.*	*Feet.*
Buffalo	150	500	5,530
Mountain Con. No. 2	600	1,200	4,944
Mountain Con. No. 1	500	2,200	3,940
Green Mountain	1,000	2,200	3,535
Wake-up-Jim	500	1,000	5,150
Easternmost	250	600	5,550

The table shows that the workings are deepest in the central region and shallower at either end. The reason for this is that at the east end, as will be shown below, the lode is either displaced northward or the fracture system spreads out into a series of small veins and the ore apparently ends. At the west end, although the lode continues strong and well defined as far as it has been developed, it became so poor in copper and so high in zinc on the lower levels as to be unprofitable.

The lode dips 65° to 75° S. in the greater part of its extent. Near the surface, back of the Mountain Con. No. 1 shaft and around the Wake-up-Jim shaft, it assumes a somewhat shallower angle, and at places in depth it bends down to or even past the perpendicular for short stretches.

SPLITTING OF THE LODE.

In the upper levels the Syndicate lode is practically single, that is, it does not consist, as do many of the prominent lodes, of two or more distinct veins separated throughout the mine workings by a considerable extent of fresh or only slightly altered granite. Lower down, however, it splits into two branches, but the depth of bifurcation differs in different parts of the lode. In a cross section through the Mountain Con. shaft the split is seen at the 900-foot level, in a similar cross section through the lode at the No. 2 shaft it is on the 1,100-foot level, and at the Green Mountain shaft it occurs at 1,200 feet.

The two branches or splits of the Syndicate lode are known as the North and South veins, respectively. In one cross section an intermediate split is seen, which is locally called the Middle vein.

THICKNESS.

The lode is unusually thick. For considerable distances along its length ore has been stoped to a width of 25 to 65 feet and in places even to 100 feet, and points have been observed where the zone of vein matter is as much as 200 feet wide. On the other hand, in many intermediate portions it narrows to less than 6 feet. A very considerable part of the wider and poorer portions, however, is merely impregnated or but partly altered granite, and in some parts it is impossible to determine definitely whether introduced or original material predominates. In the richer portions the lode is generally of more moderate width, say from 15 to 20 feet. In a broad way, banding or sheeting parallel to the general plane of the lode is everywhere recognizable, though where metallic minerals are most abundant it is somewhat effaced. These minerals first fill small veins that traverse the lode material in every direction, and are finally so concentrated as at times to form a solid mass in which all evidence of original structure is lost.

FRACTURES.

The general trend of the Syndicate lode is a few degrees north of east, with a slight southward bend at either end. In the general map (Pl. X, pocket) the curve or bow of the lode is unduly emphasized because the ground on which it outcrops is much higher in the middle than at either end. As the dip is to the south, the middle of the outcrop lies farther to the north than if it were on a horizontal plane. A truer idea of the actual strike of the lode is given in figure 63, which is a horizontal tracing of part of the lode plotted from maps of the mine workings and which shows the relative width of the ore bodies (not necessarily, however, of the fractured zone) on the 700-foot level (5,350 feet elevation) of the Mountain Con. mine. An analytical study of the fractures in the mine shows that their planes both dip and strike in two ruling directions. These directions generalized are N. 80° E. and N. 80° W., the courses varying within a few degrees. The N. 80° E. fractures are predominant in the lode, but a critical study of the mine maps shows that no definite law can be laid down as to the relative width or richness of the veins in either system.

In many places the fractures form mineralized spurs running out from the veins, the ore bodies thinning out and disappearing at short distances—200 feet or so. This is especially true in the upper levels, where the replacement and deposition of glance has gone so far as to obscure the lesser fault planes. There is no reason to doubt that the breaking up of the lode into short blocky segments (as is well seen in the 700-foot East Greyrock vein) also prevailed here, but it is no longer recognizable, owing to the deposition of secondary ore.

The following directions of fissuring are recognized: N. 10° E., dip 73° E. or W.; N. 80° W., dip 80° S.; N. 80° E., dip 80° S.; N. 56° W., dip 65° S.; N. 40° W., dip 75° S., cutting all others; N. 60° E., a cross vein recognized on the 500-foot level between shafts No. 1 and No. 2 of Mountain Con.; and N. 65° W.

Westward the lode is cut off by a great cross fault developed in the Moscow mine. The exact condition of this cut-off is not known, owing to the fact that the low-grade or unworkable character of the vein in the lower levels of the Poulin mine has led to only meager development.

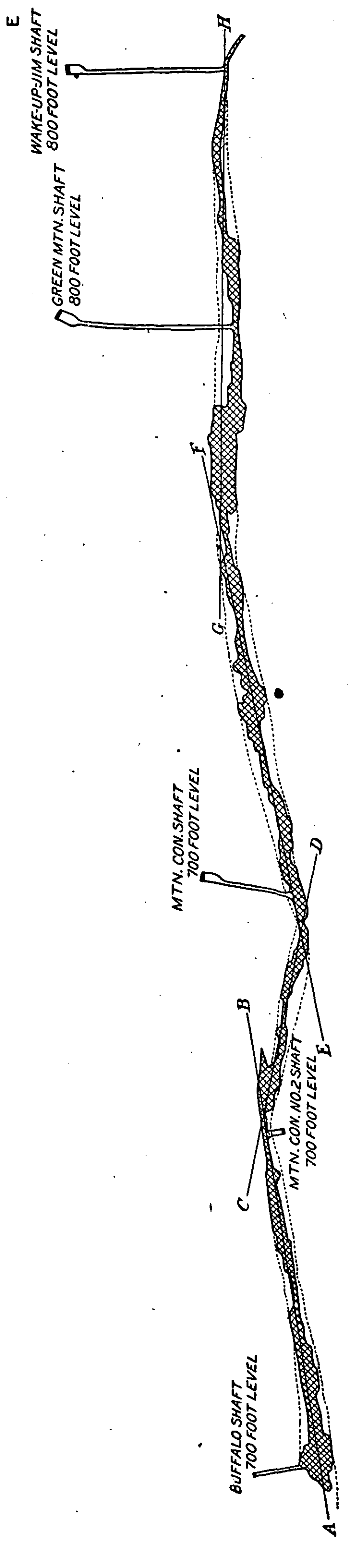


FIGURE 63.—Plan of 700-foot level (5,350 feet elevation) on the Syndicate lode.

In dip the fractures have a general inclination of 70° S., but vertical fractures also occur. The conjugate north-dipping fissures associated with the south-dipping fissures are not prominent in the upper levels, but at a depth of 2,000 feet or more are abundant and well defined. Between the Buffalo and the No. 2 shaft—that is, at the west end of the lode—the dip is vertical or northward, but is reversed in passing downward and in a short distance becomes normal.

In studying the variations of the lode it is necessary here, as it is throughout the district, to discriminate sharply between the original fractures with east-west course and primary quartz-pyrite filling, and the later fault fissures, which have played so important a part in forming the workable ore bodies by their enrichment of the lean primary ores, either by admitting ascending solutions or by affording a channel for descending waters to reach and enrich the primary sulphides. Only by actual inspection can this distinction be satisfactorily determined; sections can not be constructed with certainty from mine maps or stope sheets.

Secondary fracturing and faulting has played an important part in the ore development of the lode, which is known to have experienced more than two periods of secondary movement. Some secondary fractures are parallel with the plane of the vein and others cross it at a decided angle. It seems certain that the latter are earlier than the former; at any rate, some of them fault the vein, and they do not necessarily influence its mineral contents. The parallel fracture planes or strike faults, on the other hand, generally occur within the lode, most frequently in the middle or in the hanging-wall portion. Some of them form a zone of broken granite and vein matter from a few inches to several feet wide, and some form a simple clay seam only an inch or two thick. One or the other form is almost invariably found to accompany the formation of chalcocite or copper glance. That all clay seams or selvages are necessarily of secondary origin can not be definitely assumed, but all the evidence so far obtained points in this direction.

The lode seems to be generally impoverished in depth in its westward extension. In the Buffalo and Stella mines the upper levels contain large ore bodies of high-grade material, but the copper content gradually diminishes downward, and at depths of a few hundred feet is too lean to pay. Similar conditions prevail in the Poulin mine, whose good ore was all obtained from the upper levels; and the same is true in the Moscow mine at the western end of the lode. That this change in value is not alone due to the tightness of the vein or to lack of fracturing is easily seen in the Moscow, which is traversed by many fault fissures, so that the original vein is crackled and wet. It is therefore evident that the center of mineralization, from which the enriching waters spread out, was somewhere near the vicinity of the Mountain Con. shaft, for the lode traced eastward yielded good ore for a depth of 300 feet beneath the surface at the Wake-up-Jim mine, but became lean and unworkable in its eastward extension in that property.

WALL ROCKS.

The Syndicate mines follow the system of working by "laterals"—that is, of cutting working drifts in the footwall about 50 feet from and, as near as may be, parallel to the vein, from which at given distances crosscuts tap the vein—a system that affords numerous opportunities to study the character of the country rock. This is generally of granite, but dikes of aplite, generally parallel with the plane of the vein, are also observed.

The most prominent and well marked of these dikes, near the Buffalo shaft, is 40 to 50 feet thick. On the Buffalo 500 and 600 foot levels it forms the footwall of the vein, on the 700-foot level it is a little distance from it, and on the 800-foot level it is no longer seen. In longitudinal extent it was traced from 50 feet east of the Buffalo shaft west to the end of the claim, a distance of about 200 feet. Although its disappearance in either direction may be readily accounted for by probable divergences in strike and dip between the dike and the vein, causing the former to pass out of the range of observation in mine drifts, it is probable, judging from observations of similar dikes elsewhere, especially at the surface, that the actual extent of the dike sheet is not very much greater than that proved by the above observations, say, under 500 feet long and not more than 50 feet thick.

Although, as compared with other copper veins of the district, the dividing line between vein material and country rock is unusually well defined in the Syndicate lode, places are not wanting where the change from the one to the other is so gradual that it is difficult to say exactly where one ends and the other commences. The country rock is ordinarily impregnated with pyrite for some distance on either side of the veins; but the extent of the impregnation is extremely variable, ranging from a few feet to nearly a hundred. The distance is generally proportionate to the amount of metallic minerals within the vein zone.

Although pyritization leaves the rock hard and fresh looking to the eye, it is always accompanied by a certain amount of sericitic alteration. Alteration accompanied by decomposition, on the other hand, appears to bear a genetic relation to the east-west fractures; in the immediate vicinity of the latter it is very pronounced both in vein matter and in country rock. There is but a narrow zone or band of altered rock on the vein walls of the Blue and Steward systems, in marked contrast to the great extent of alteration about the Anaconda, Rarus, Pennsylvania, and Leonard veins.

Pyritization, with or without copper values, is not ordinarily found to have affected the aplite dikes, possibly because of the absence of basic silicates. In some places, in footwall crosscuts, the aplite immediately adjoining the vein was free from pyrite but the granite beyond was strongly impregnated with it. In the stopes, however, a few veinlets of pyrite and chalcopyrite were observed penetrating the aplite that adjoined the ore body.

In the primary veins the general alteration of the country rock is less along the hanging-wall side than it is on the footwall side. This statement does not apply to the later fault fractures, in which wall-rock alteration is a minor feature.

In the Green Mountain workings the alteration of the country rock extends into the hanging wall for 25 feet and is intense in the footwall for 50 feet or more. Between the branches of the vein is a horse 1 to 8 feet wide, composed of much-altered pyritized granite. In general this intervein rock is somewhat more altered than the hanging-wall material, but it does not show the crushing and mashing characteristic of the latter. The clay seams between the Middle and North veins of the Green Mountain mine, the granite horse, and the footwall rock all indicate faulting, and that the South ledge may be a downthrown part of the North vein.

ORES.

Large ore bodies were found in the first five levels of the Mountain Con. mine. The largest was from 50 to 60 feet wide, several hundred feet long, and had a nearly east-west course. It showed a flat dip and was marked by a large branch or spur vein running off to the southwest. It was evidently formed by the intersection of a northwest fracture with the normal east-west lode, but no reason is apparent why it should terminate so abruptly westward, and its flat dip does not conform to the normal steep dip of the main vein. These ore bodies, which are the most notable on the upper levels, are believed to be due to comparatively shallow enrichment, in which the surface waters deposited glance in the broken ground at fault intersections.

In general the Syndicate lode is remarkable for the continuity of its values. Broad and long ore shoots with a general southwest pitch pass downward from the 400 or 500 foot level to depths of 1,000 feet or more, the line of pitch of the largest shoot passing through the Mountain Con. shaft. In addition, however, to this large rich body, the lode carries workable ore from one end to the other. The large shoots appear to be connected with northwest fractures similar in direction but not identical with that forming the spur to the big ore body found near the surface. Another well-defined ore shoot is found near the Wake-up-Jim shaft; it occurs at the intersection of the N. 80° E. and N. 80° W. fractures and pitches N. 60° W.

Specimens from the lode consist of primary quartz-pyrite vein filling fractured and impregnated with glance and bornite. Much distinct cavity filling appears along later fissures in the vein, the crusts showing quartz, bornite, etc., the quartz being either comby, with isolated crystals in the bornite, or dull and reddish, resulting from replacement of altered rock.

Much primary quartz-pyrite vein matter is visible in the unworked parts of the lode, as well as at the east and west ends of the drifts. In such places the massive pyrite is but little fractured, or if broken the fractures are healed by white quartz. A sample from the east face of the 1,800-foot drift shows clearly that all the bornite and glance is confined to these quartz stringers and that the workability of the lode entirely depends on them.

The quartz is not always pyritous. In many places it carries but little pyrite and grades over into sericitized granite. The partly altered granite shows pyrite developed from hornblende. As the sericitized granite has less pyrite, part of that formed from hornblende may have been dissolved.

Most of the specimens from the deep levels show that bornite and other sulphides are still forming in fractures, even in capillary fractures, in the vein and in the altered granite (2,200-foot level, third drift north), and that the solutions are oxidizing and depositing sooty glance and ferric oxide in places. It is evident that ore formation has been interrupted by the draining away of the water by drifts and stopes.

SUBORDINATE VEINS.

Besides the Syndicate lode proper certain veins which occur in the Syndicate area may properly be considered part of a broad lode zone and described here. The most important is the Keegan.

KEEGAN VEIN.

The Keegan vein lies south of the Syndicate ledge, being the first vein south of the drain tunnel in the 1,600-foot level, Buffalo crosscut. The course is S. 40° W. and the dip 58° S. The ledge, where cut by the 1,500 south crosscut of the Mountain Con. mine, is about 12 feet wide, but the hanging wall is not exposed; the footwall is defined by a clay gouge several inches thick. As a whole, the ledge is well banded and is generally very solid. It is composed of quartz pyrite, with banding parallel to the walls. In places there is much clear, glassy quartz, carrying sphalerite. The ore occurs in bunches in the vein, one shoot being 5 to 6 sets high (35 to 42 feet), and running 6 to 7 per cent in copper. The shoot is markedly lenticular and the vein itself pinches and widens along its course. Above the 1,500-foot level the lode becomes a mere seam without ore and is not recognizable as a vein.

The vein appears to be a solid pyritic vein, cut by vertical fractures and penetrated, to the greatest depths mined, by water, not only in fissures but also in the apparently solid vein. These fissures are marked by chalcocite, and the pyrite itself is generally spotted and is fractured by incipient, almost microscopic, capillary cracks whose surfaces are glazed with sulphides. The ledge carried 26 per cent ore on the 1,700-foot level and good ore on the 1,900-foot, though in the east face it shows a netting of the fractures, with granity quartz between, and is evidently playing out. The vein is worked on the 1,500, 1,700, and 1,900 foot levels of the Mountain Con. mine.

DERNIER VEIN.

The Dernier vein, though worked in the Syndicate mines (see p. 184), belongs to the Greyrock system. It is well exposed on the 1,900 and 2,100 foot levels of the Mountain Con. The vein consists of a mass of quartz-pyrite ore, with secondary bornite, associated quartz, and enargite, the last named being seen here for the first time in the Syndicate workings. The vein is 10 feet wide and expands as it approaches a northwest fissure which cuts it and practically terminates mineralization in this direction. This fissure is a mere dry crack, but beyond it the vein, which appears to go on without displacement, is narrow and lean. This is a remarkable example of the effect of a fault fissure devoid of ore or gouge, which deflects the enriching solutions and by their stagnation causes an enlargement of the adjacent ore body.

OLD GLORY VEIN.

The Old Glory vein, which in recent years has yielded small amounts of copper ore, is located in Centerville, near Main Street. The vein splits downward into two veins, the southerly averaging 5 feet in thickness and dipping about 60° S., and the main vein standing nearly vertical. The ore contains manganese, zinc, and silver minerals, with some lenticular bodies of copper ore, and is thus a transition or composite vein similar to the West Greyrock vein.

The lode is faulted by the La Plata fault vein, so that its downward continuation beneath the fault lies to the north. The latter runs north-south, dips east, and shows in the north crosscut from the 800-foot Mountain Con. level, the first east of the Buffalo shaft. In the drift on the fifth level from the inclined shaft on the Buffalo the vein strikes N. 70° W., with a flat dip from the 200 to the 900 foot level. The 500-foot level of the Buffalo has a long northerly crosscut to the Snoozer vein whose course is N. 70° E. The same vein is worked on the 1,200-foot level, where it splits into a north vein and a southern 2 to 3 foot vein, exposed in the crosscut south from the east end of the level.

RAVEN VEIN.

The Raven vein, lying north of the Syndicate lode, has a general east-west course and a dip of about 58°, rolling considerably between the surface and the 323-foot level. It is a contact vein between aplite on the north and Butte quartz monzonite on the south. There has been some movement along this contact, and the 227-foot level shows clayey fault matter, but no ore or other vein matter.

On the 323-foot level the vein shows 2 to 4 inches of sulphide ore, besides an impregnation of the granite wall rock. The ore carries sphalerite, galena, pyrite, and some copper. It has been opened on the 140, 227, and 323 foot levels. The vein has an average dip of 58° S. from the surface to the 140-foot level. Below the average is about the same, but the vein straightens up between the 140 and 227 foot levels, and then flattens between the latter and the bottom level. The bottom level shows several inches of sulphide ore very rich in silver, with silver ore running out along fractures in the granite.

MINES.

In considering the features observed in different parts of the Syndicate lode, the sections worked in the various mines, namely, the Moscow, Poulin, Stella, Buffalo, Mountain Con. Nos. 1 and 2, Green Mountain, and Wake-up-Jim mines, will be considered in turn.

MOSCOW MINE.

The extreme western end of the Syndicate lode was worked in the Moscow mine, a property that has been idle in recent years, so that but few new notes are obtainable. The property was, however, thoroughly examined in 1896 by S. F. Emmons, by whom a considerable part of the description of the Syndicate lode was written. The mine workings show that a large ore body existed on the 100-foot level, extending downward to the 250-foot level, (fig. 64) the ore shoot lying along a secondary fissure known as the Poulin fault, an easterly fault fissure belonging to the Steward series. In this property the primary lode filling is too lean to pay for working and need not be further considered.

POULIN, STELLA, AND BUFFALO MINES.

The Poulin mine lies next to the Moscow; its workings go down to a depth of 1,200 feet. East of the Poulin lies the Stella, followed by the Buffalo.

On the Stella and on the 400 and 500 foot levels of the Buffalo the drifts extend nearly to the Poulin shaft, and develop large ore bodies of low-grade ore from the surface down to a depth of 400 feet. In the Poulin mine no pay ore has been taken out below a depth of 600 feet; from the 600-foot level to the 1,200-foot level the lode has a strike of N. 70° to 80° E., a dip of 75° S., and is a thick but lean and dry quartz vein. Though crossed by a northeast fault fissure with crushing and shattering, neither the Syndicate lode nor the fault fissure contain pay ore. (See fig. 65.)

The 1,200-foot crosscut from the Poulin shaft southward is cut through hard, very fresh granite, showing joint planes that are well marked but are devoid of clay fractures or other evidences of movement or decomposition. Near the south end of the crosscut a zone of zinc veins crosses the level in a general east and west direction. These veins are dry and consist of quartz, a little pyrite, and considerable zinc blende. The quartz is crushed in part of the vein, but it does not show any clay. Eastward along the level the walls show pyritized granite, with several very small slips. At the point where the level, after bending southeast, takes a general easterly course, a clay fault 12 feet wide forms the footwall of a hard quartz-pyrite vein which runs with the drift. The fault is traceable eastward, showing in a little crosscut running northwest from the main 1,200-foot level, and reappearing to the east. Beyond this point it passes out of the wall to the north, but shows again in the Buffalo crosscut. In general the rock through this level is somewhat altered granite, which shows numerous joint planes, along which the rock has been softened for a thickness of 1 to 4 inches, so that it yields as readily to the pick as a sand. There is no evidence of movement and the decomposition is plainly due to the infiltration of waters.

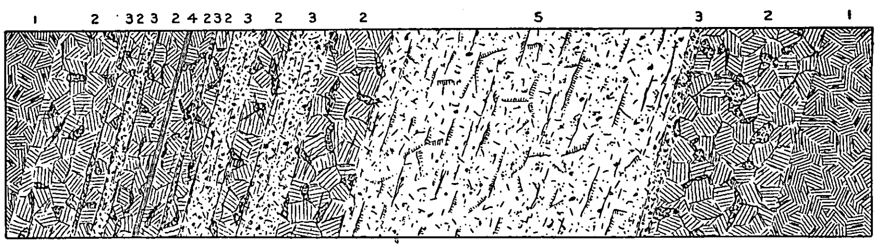


FIGURE 64.—Cross section of Syndicate lode, Moscow mine, 250-foot level. 1, Quartz monzonite; 2, breccia; 3, porphyry; 4, clay; 5, pyritized quartz.

Along the joint planes, in a little vein seen in the northeast crosscut running out from the 1,000-foot level, an excellent specimen of vein formation is taking place above a clay slip, the granite being replaced by waters flowing along the fault plane. At several places in the level the granite shows patches or veinlike masses of altered rock resembling porphyry. This shows greenish feldspars softened to the consistency of cheese and is probably a thoroughly altered material. Much semiaplite was also seen, but as the boundaries were indistinct and the rock fades into granite, the places have not been marked.

MOUNTAIN CON. MINE.

In the Mountain Con. mine the lode consists of two main veins known as the North and South ledges. As the stopes above 1,100 feet are inaccessible exact conditions in them are unknown, and an examination of the stope sheets throws but little light upon the subject. The level maps show that the South ledge has been worked continuously from the outcrop downward, but that the ore body stoped out in the upper levels had a different course from that of the main ledge at deeper levels. The tunnel level and the 100, 200, 300, and 400 foot levels in the vicinity of the Mountain Con. shaft were all driven on very large ore bodies with a nearly due east-west course. Below the 400-foot level the ore shoots seem to pitch southeast.

As bearing upon this feature, the well-marked ore shoot found between the Mountain Con. and the Green Mountain mines is of importance. This shoot seems to come in at an intersection of a N. 80° E. set of fractures (the course of the main Syndicate ledge) and a N. 80° W. set of fractures developed on the deeper levels. The maps show ore bodies extending from the 500-foot level down to the 1,200-foot level along this intersection, which in depth is of course progressively farther and farther east.

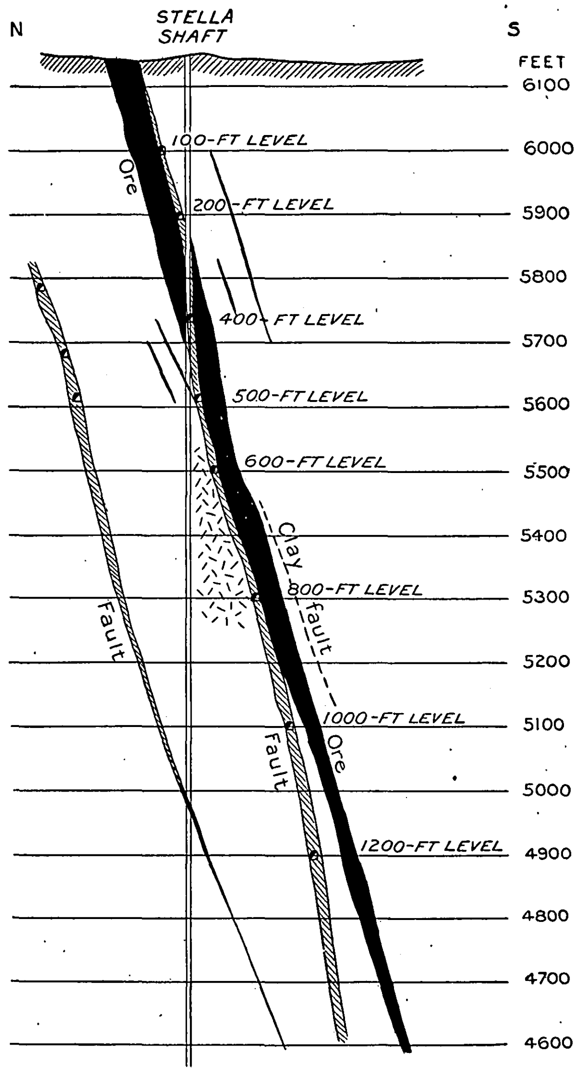


FIGURE 65.—Cross section through Stella shaft, showing the Syndicate lode and the faults that cut it.

In the Mountain Con. mine the North and South ledges come together at the 900-foot level, but as no prospecting is done to the south in the upper levels, whether the veins cross or simply coalesce is not known. The stopes are continuous on the South vein from the 1,300 to the 1,700 foot level, and are practically connected from the 2,000-foot level up.

The North Ledge is nearly vertical from the 1,300-foot level down almost to the 2,000-foot level, on which it bows to the south very strongly east of the shaft, so that the levels show constant offsets until, near the end, the drift runs nearly south. This is believed to be due to an intersection of the southeast fault of the Steward system. The 2,000-foot level leaves the vein on account of this southerly trend and crosses north to meet the raise from the 2,200-foot in the Green Mountain mine. The South vein splits forming the Middle ledge and the South vein proper on the 1,300 to the 1,500 foot level. The raise is mostly, however, in fault breccia.

Rich glance ore occurred only where the veins were wet or showed signs of having recently been so. Thus, the barren fault breccia in the raise from the 1,500 to the 1,700 foot level is dry and dusty, and the vein is dusty generally near the raise and is devoid of good ore, but farther off, where it is wet, it holds considerable glance; in other words, the wet veins are most likely to carry ore, though they do not invariably do so.

In the lower levels sooty sulphides and films of glance coat pyrite. That the ore comes from above and is deposited by descending waters is shown by the North vein on 2,000-foot level, which was drained dry within a few days after it was first cut. The vein consists of a brecciated quartz-pyrite ore, with dull, opaque quartz, showing the characters of replacement quartz, but crushed to an autoclastic breccia and cemented together by secondary crystalline silica which shows comb structure or banding and holds numerous vugs. This brecciated material holds some glance as veinlets, spots, and cementations of crushed pyrite (fig. 66). The most striking feature, however, is the presence of crystalline scales of glance on the fracture surface of the white quartz, or, more rarely, spotting the forms of late quartz crystals. The crevices in the older quartz and in the quartz-pyrite ore are coated with sooty glance, and the whole ore body shows more or less of this incoherent sooty matter. The druses of quartz crystals rest upon zinc blende or in some places on enargite. It is evident that extremely minute fractures in the ore and in the glance are filled with the quartz rather than with the films of such sulphides. Some covellite was also seen.

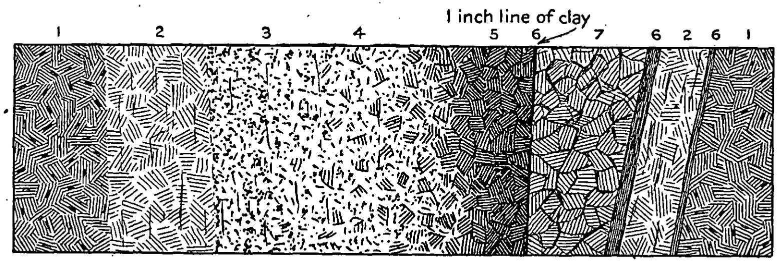


FIGURE 66.—Section of Syndicate lode, 600-foot level, Mountain Con. mine. 1, Quartz monzonite; 2, altered rock; 3, pyritized quartz; 4, pyrite and glance; 5, glance; 6, clay; 7, breccia.

Organic matter can be practically eliminated from the reactions involved in the formation of the secondary ore just mentioned. Some of the deep workings seen are not under any other mine workings, and the surface overlying the veins is devoid of all vegetation. The North vein on the 2,000-foot level west evidently formed a watercourse which when visited had just been deserted. It was moist but not dripping. There are no lower workings, and if the waters came from below they would show in the floor or in the lower part of the face at least. There is no escape from the conclusion that the waters forming the glance ores are descending waters, and that they were still active and were depositing glance when the vein was cut and the action stopped. The action is, however, one of leaching, that is, one of solution and of corresponding deposition, the waters probably dissolving and depositing at the same time, a phenomenon seen in the Skyrme vein, in which skeletons of mossy residues showing dissolution occur.

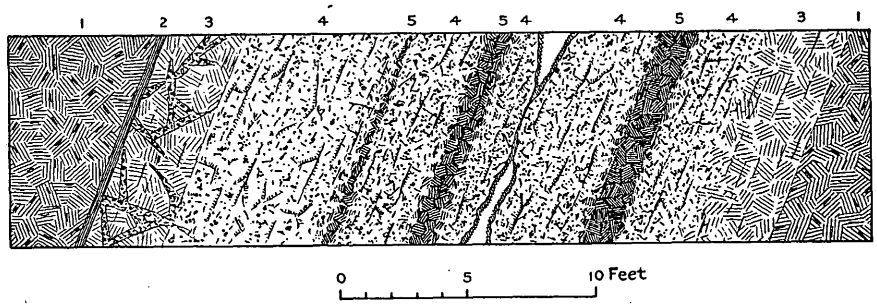


FIGURE 67.—Section of Syndicate lode, 1,100-foot level, Mountain Con. mine. 1, Quartz monzonite; 2, clay; 3, altered rock; 4, pyritized quartz; 5, glance.

The statement often expressed in the district that the footwall ore streak is richer than the hanging-wall band does not hold true in the Mountain Con. veins because the clay gouge shuts off access to the footwall granite, and solutions do not penetrate it. The footwall of the South and North veins on the higher levels is granite, and the change from ore to granite is rather sudden, as shown particularly in the North vein. The granite of both walls of the vein is rather scaly, and the fractures are curved and marked by films of clay (figs. 67 and 68), so that when the rock is mined it slacks off in lumps and exposes smooth bossy surfaces. As the water is drained off this hardens and becomes solid and as a rule stands well, though occasionally the ground runs badly.

Some flat fissures have a prevailing dip of 45° more or less, but as a rule these do not markedly affect the ore. An exception is on the 1,900-foot level of the Mountain Con., where the fissures appear to throw, or rather drag the vein to the north.

Between the two Mountain Con. shafts the Syndicate lode diverges markedly to the southeast on the 600-foot level (see fig. 63), though this divergence becomes less with increasing depth. The vertical element in dip is more pronounced with depth and results on the 1,000-foot level in a widening and splitting of the ore zone into two veins such as were found at the bottom of the No. 1 workings (p. 167). This feature of the lode has thus been traced over a horizontal extent of 1,200 to 1,500 feet. What it will develop in depth remains to be proved. (See fig. 69.)

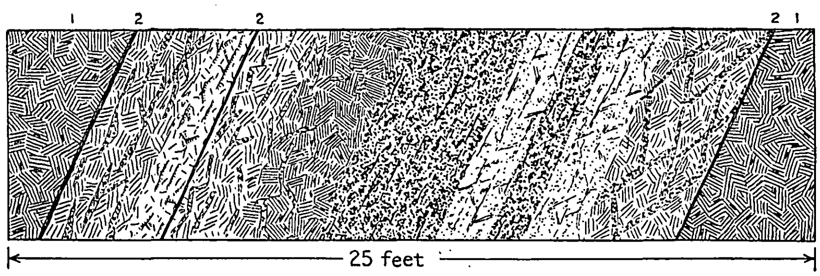


FIGURE 68.—Section of Syndicate lode, fourth floor above 1,000-foot level, Mountain Con. mine. 1, Quartz monzonite; 2, clay.

West of the Mountain Con. No. 2 the lode has a very regular strike in the normal north-of-east direction, but its dip is steeper than the normal, and with this steepening seems to go a widening of the ore zone. In the lower levels explorations have not yet been carried to the western limits of the Anaconda Co.'s ground.

A modern cross fracture running north and south nearly on the line of the Buffalo shaft has been noted on each succeeding level down to the 800-foot; it admits surface waters freely and carries a white mud of decomposed rock material. It pitches slightly to the east. It does not throw the lode nor have any appreciable effect on the character of the ore. It thus seems later and distinct from the secondary fractures which follow the plane of the lode and are traceable wherever notable enrichment occurs.

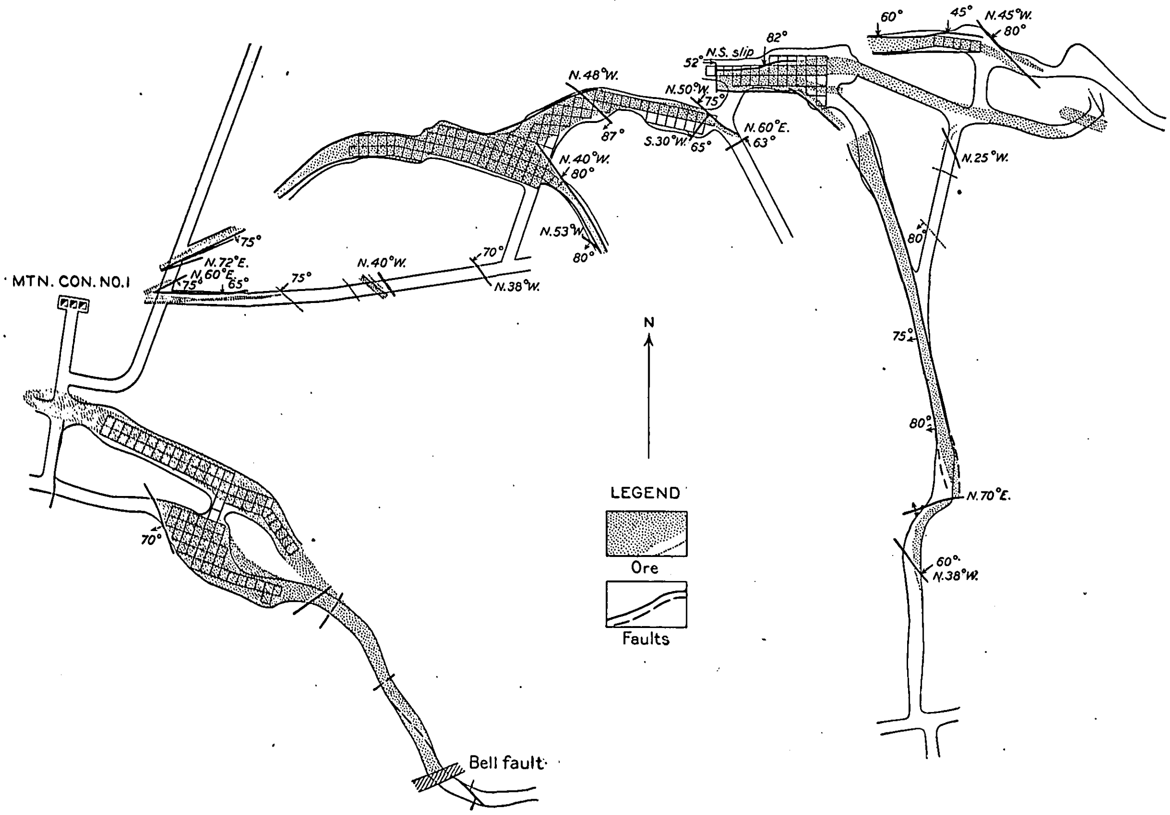


FIGURE 69.—Plan of part of 2,100-foot level, Mountain Con. mine, showing spraying of ore.

GREEN MOUNTAIN MINE.

The various crosscuts of the Green Mountain mine show several small veins and clay seams north of the main ledge. (See Pl. XV, *B*.) The lode is cut on each level but is not stoped, because the vein is too poor to work. In general, the lode is unworkable below the 900-foot level, and even above this level is lean east of the shaft. The ore is very largely pyrite, associated with a dull white to gray quartz, very hard to drill, and lacking the usual fractures of rich ores (fig. 70). The vein on the 1,600-foot and 1,800-foot levels shows some glance, but it is mostly either in films or cracks in the pyrite or in platy veinlets in the fractured quartz, or else it is in vugs of white quartzite. As a rule in these veins the glance and the pay ore occur only in quartz and the irony ore is too lean to pay. Though this does not support the chemistry of the secondary theory, it is evident that it is due to the fact that the quartz ore can be concentrated and the pyrite ore can not. The actual copper value of the pyrite ore may be as high as that of the quartz and yet the ore be not available.

The 1,800-foot level is dry, and inspection confirms the view of the writer that the water all comes from above and that there is no uprising water. This is easily seen in the new workings driven underneath the old workings. In such cases the waters drip from the roof and sides of the drift, but the amount soon lessens and in a few weeks the workings are relatively dry and in a year are perfectly dry. If the water came from below, the level would

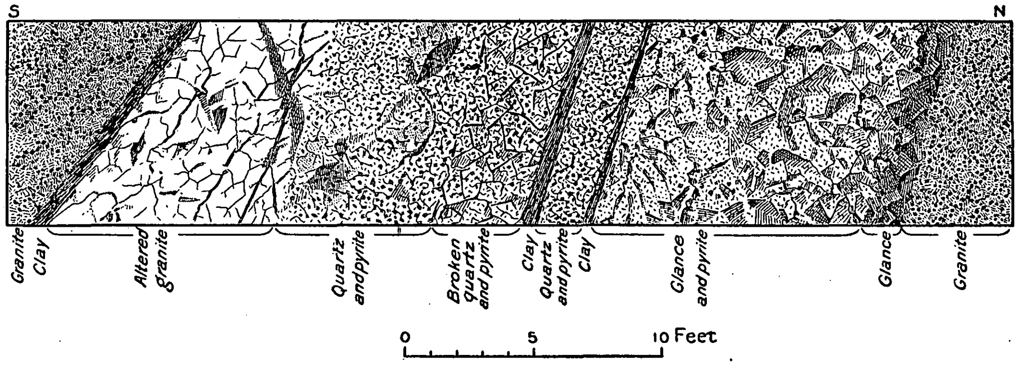


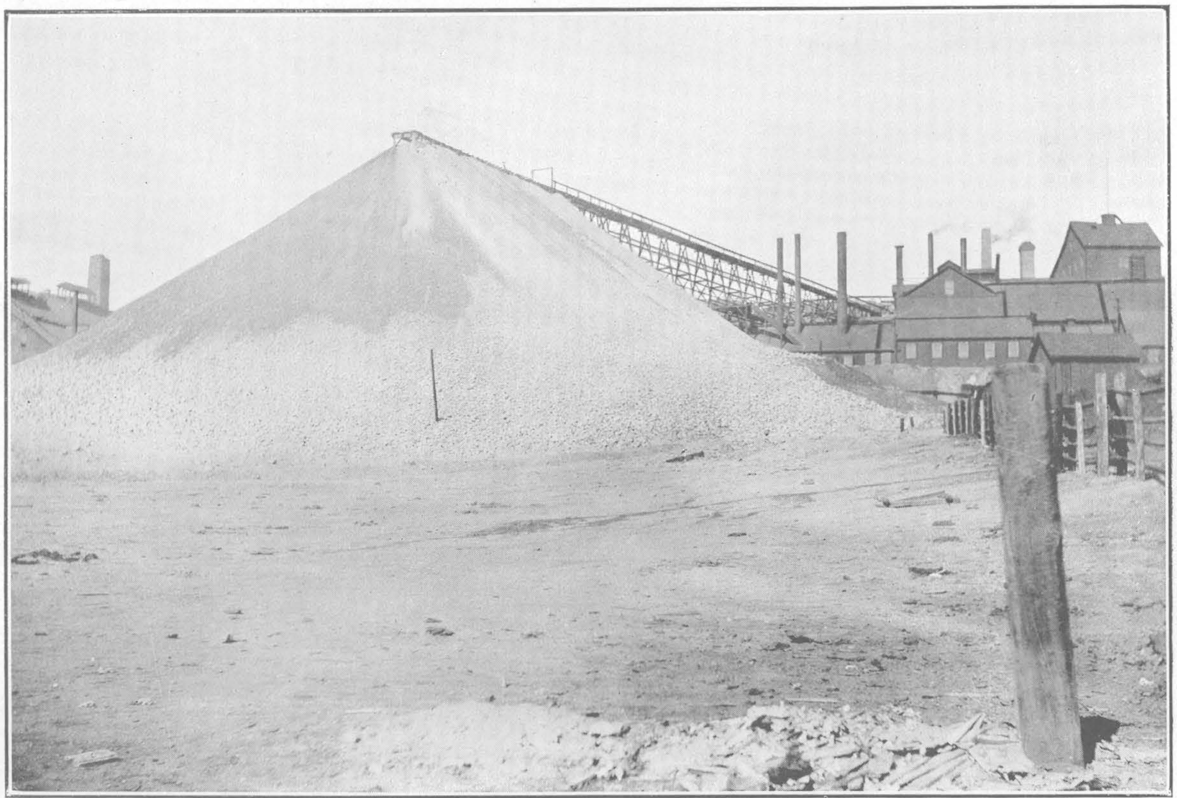
FIGURE 70.—Section of Syndicate lode, 800-foot level west, Green Mountain mine.

remain permanently wet, which seems to negative the idea of uprising deep-seated waters. Moreover, one need not look at the 2,000-foot Mountain Con. a second time to see that the water has recently left it. The structure of the ore indicates that it is still being formed, and there is a marked coincidence of wet vein and good ore, the solid tight vein being dry and unworkable, though explored by a few drifts. The main ledge of the Green Mountain is, however, not dry, though it is not cracked and crushed, and hence is not a good water channel. Samples of water were taken at the diamond drills at the 2,000-foot north, at the north end of crosscut, and the analysis has already been given (p. 101).

In the Green Mountain workings, on the 1,200 and 1,300 foot levels, the South ledge thins out at a point 240 feet west of the crosscut, but is a strong vein, richly mineralized, east of the crosscut. In the Wake-up-Jim workings the vein is double, as already noted; the North branch is lean, and the South branch is small but rich.

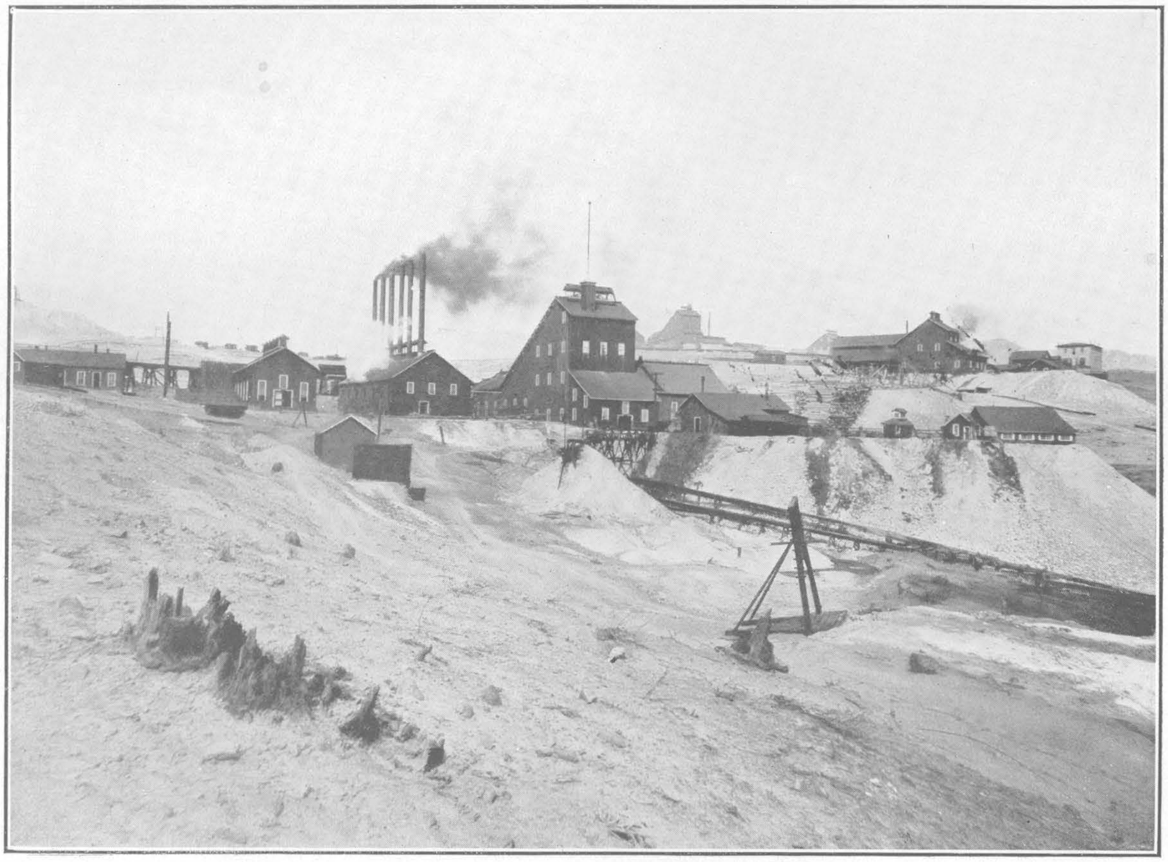
The big Syndicate ledge, where cut on the 2,200-foot level of the Green Mountain, about 150 feet south of the shaft, is 60 feet wide, consisting of altered and silicified granite, with a 3 or 4 foot band of solid but barren quartz in the center and a 5-foot footwall band of pyritic ore. (See fig. 71.)

In the Green Mountain mine the lode is very irregular, changing rapidly in width from a few feet up to 70 feet. The ore appears to be distributed in chimney-like channels within the vein matter. Westward, toward the Mountain Con. lode, it separates into several ore-bearing bands filling overlapping fissures and tending to pinch out successively. Eastward, on the lower



A. MOULTON MINE.

Shows great dump heap of low-grade zinciferous silver ore and waste. See page 244.



B. GENERAL VIEW OF GREEN MOUNTAIN MINE.

levels, it disappears 200 to 300 feet beyond the shaft, its place being taken by a zone of impregnated granite and by southeast striking veins of pyrite a few inches in width and 30 to 40 feet apart.

The development of southeast fissures is a characteristic feature of this part of the lode; they appear in the developed ground mainly as spurs making off in a northwesterly direction into the footwall country. One on the 900-foot level was followed 225 feet in a northwest direction, when it pinched out. Another running northward and extending vertically 100 feet above the level was traced 60 feet northward to where it was cut off by a recent fault, fresh granite appearing beyond a clay seam. This vein carried a rich chalcopyrite ore but no bornite or chalcocite. Five small southeast-striking pyrite veins were cut in the footwall country by the crosscut from the shaft to the vein. (See fig. 67, p. 167.)

Another unusual feature of this part of the lode is the occurrence of faults transverse to the plane of the vein; in one, east of the plane of section, the fault plane dips north and throws the northern or upper portion of the lode downward about 10 feet; in another, east of the plane of section, the fault plane dips 15° S., and the lode above it is thrown 10 feet south; thus both are normal faults.

The lode is cut by a clay fault seam, breaking and slightly shifting the ore. The crosscut for 450 feet south of the shaft westward is cut by numerous slips and dislocated fragments of quartz-pyrite veins; it probably represents a ground ready for vein formation but not yet enriched, for the ore body west is similar, except that later mineralization has replaced and impregnated the granite.

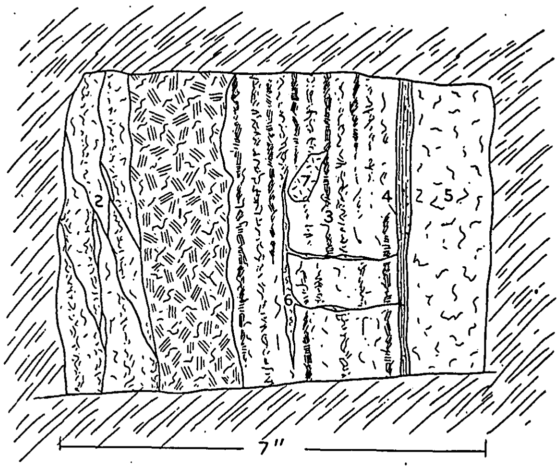


FIGURE 71.—Section of Syndicate lode, 2,200-foot level east, Green Mountain mine. 1, Solid black quartz and pyrite; 2, vertically banded black quartz and vugs; 3, banded quartz, mostly dark, and pyrite; 4, white clay; 5, white quartz; 6, vug, lined with quartz; 7, quartz monzonite.

WAKE-UP-JIM MINE.

In the Wake-up-Jim ground the two sets of fissures, one northeast and the other southeast, are more distinctly developed, as is also the vertical and inclined dip, producing very complicated conditions. The ore near the surface appears to have concentrated mainly on the northeast fractures, but below, on the 400-foot level, the lode trends southeast, the northeast fissures constituting only spur veins. One of these, about 170 feet east of the shaft, has been cut in both 300 and 400 foot levels, which correspond to the 200 and 300 foot of the Mountain Con. It stands vertical and carries about 2 feet of quite unaltered pyrite and quartz. At its crossing the main vein is unusually wide and rich and has apparently faulted the spur vein. A similar spur vein 80 feet west of the shaft, which is in places 5 feet wide, ends in a country rock that has been shattered by secondary action and exceptionally carries chalcocite. Fifty feet west of this spur the main vein narrows to a clay seam, and the ore continues west in an échelon or overlapping fissure 20 feet to the south.

In this mine the main ore-bearing lode has not thus far been traced more than 250 feet east of the shaft nor more than 800 feet downward. The strong and relatively well-defined fissure system appears to be replaced in either direction by a few narrow and diverging fracture planes carrying but little ore.

DIAMOND-BELL GROUP.

GENERAL RELATIONS.

The Diamond-Bell group of veins, situated in the northern part of the copper area and worked in the Diamond-Bell, High Ore, Speculator, East and West Greyrock, and Corra mines, has not only been a large producer for a long time, but has become of increasing importance in recent years through the discovery of new ore bodies in some of the deeper levels. The Diamond vein can be tentatively correlated with the Speculator lode to the east, but the extension of the veins to the southwest is not satisfactorily established. It is reasonable, however, to suppose that the large and persistent veins worked in these mines extend as fractures both to the southeast and the northwest and if not workable themselves have greatly influenced the mineralization of the other lodes in these areas.

The vein relations in the group are complex, no less than four systems of fracturing and vein formation being well developed; but when these are differentiated the apparent complexity becomes relatively simple. Briefly summarized, the mines show an east-west vein, the Speculator, broken into segments by several northwest fault veins of the Greyrock group (Blue Vein system), the displacement being 300 feet east on the hanging wall of the Skyrme vein and less on the footwall veins south of the Skyrme. A third vein system, the High Ore, is a variant of the east-west veins; it has a course intermediate between the east-west and the Blue Vein systems and appears only in short detached blocks, ending against the walls of the fault veins of the Blue system.

These vein systems are broken by the Bell fault (Steward system), which shifts the entire block of ground north of this fault to the northeast. This fault, so far as known in 1906, is not ore bearing, though veins of this system are liberally mineralized in the Steward and Anaconda mines.

The veins of the Blue Vein system having a generally northwest trend, constitute what may be called the Greyrock group, of which a prominent representative is the Covellite vein. A parallel vein south of it, known as the Bell vein (not Bell fault), or the North Greyrock vein, is the next most prominent vein of the series. Both the Covellite and the North Greyrock are fault veins; the former is correlated with the Skyrme vein, which has been worked eastward from the Bell shaft to the High Ore shaft, but is broken and displaced by a later N. 70° E. fault vein, which throws the east portion of the Skyrme vein south of the Covellite and Bell veins.

The High Ore system, earlier than the Blue Vein system, is represented by the High Ore and Wild Bill veins, with a course of N. 65°–70° W.

The Anaconda system includes the Speculator vein, with a general course of N. 65° E., the best-known representative of the system in this group of mines. Some observers have thought the Speculator and Covellite veins are faulted parts of a once continuous vein, but the mine maps show plainly they differ considerably in strike, and a study of the veins themselves shows a decided difference in physical character and in mineralization.

The Bell fault vein, the prominent member of the Steward system, passes through the center of the Diamond and Bell workings and extends eastward into the Speculator ground, where it is encountered in the workings of the mine of that name; westward its direction corresponds to that of the Poulin fault vein, though the crosscuts of the Green Mountain shaft do not afford definite correlation in this part of the camp. (See fig. 72.)

The dip of the veins is generally steep, those of the High Ore and Greyrock being exceptions in showing flat southerly dips. The others have a steep southward dip, but in the deeper levels the Covellite vein splits and its north branch dips northward. (See fig. 73.)

The principal veins of this part of the district are: Wild Bill, Covellite (or Bell north), Bell, Gillie, Middle, Winchell, and Greyrock. All these lie northwest of the cross or Bell fault vein, which runs north of east, is nearly vertical, and cuts the Greyrock and Covellite veins, passing through the Bell shaft. Southeast of the Bell fault are the Higgins, High Ore, Skyrme, and Speculator veins. Several others appear in the lower levels, but not being distinctly recognized above, have been given specific names. These include the Sisters, Diamond (which may be the Middle), Vale, and Christian veins.

The Covellite vein is worked to the northwest in the Corra mine, but the other veins found in that mine seem to correspond to the silver veins of the West Greyrock mine rather than to those of the Greyrock group. The Covellite is worked on the 2,200-foot level of the Green Mountain shaft, being reached by a long north crosscut. It is interesting to note that at this depth both the Covellite vein and the supposedly faulted eastward extension of this vein—the Skyrme vein—contain an abundance of enargite, a mineral almost unknown in the upper levels of all the veins of the group.

Mineralogically the veins of this group of mines present a certain individuality. The prevailing type of ore shows abundant chalcocite in a mixture of quartz and pyrite, but bornite is common, though not in large amount; enargite occurs only in the deepest levels, 2,000 feet or more beneath the surface. The relatively rare mineral, covellite, is very abundant in one vein, called by this name, in the East Greyrock mine and is present in small amounts in other veins. No typical enargite veins occur, though the deep Edith May and Jessie veins contain large amounts of this mineral.

The veins show the usual differences observable throughout the district between the primary quartz-pyrite veins and the later fault veins. The former are valuable only when broken by later movement and enriched; the latter carry ore in lenticular shoots, separated by stretches of barren fault matter. Friction breccias are common, but the conglomerate ores seen in the mines on the Parrot lode are rare. The immense ore bodies found in the Bell and Diamond mines occur at the intersections of the various fissure systems and are apparently the result of several distinct periods of mineralization.

In general the tendency of the veins seen in the lower levels—as, for example, the 2,100 and 2,200 foot Bell and Diamond—is to split up; the granite between these fractures shows silicification but no ore, and the veinlets or individual fractures get leaner in depth. The 2,200-foot Bell-Diamond is a remarkable example of this tendency. The Covellite vein on this level is seen west of the crosscut, where it is very lean, and is mainly composed of a friction breccia, usually without quartz. Eastward the Covellite vein splits, and east of this bifurcation is cut off by a cross fault, beyond which it has not been definitely located, though it seems to correspond to the Skyrme vein.

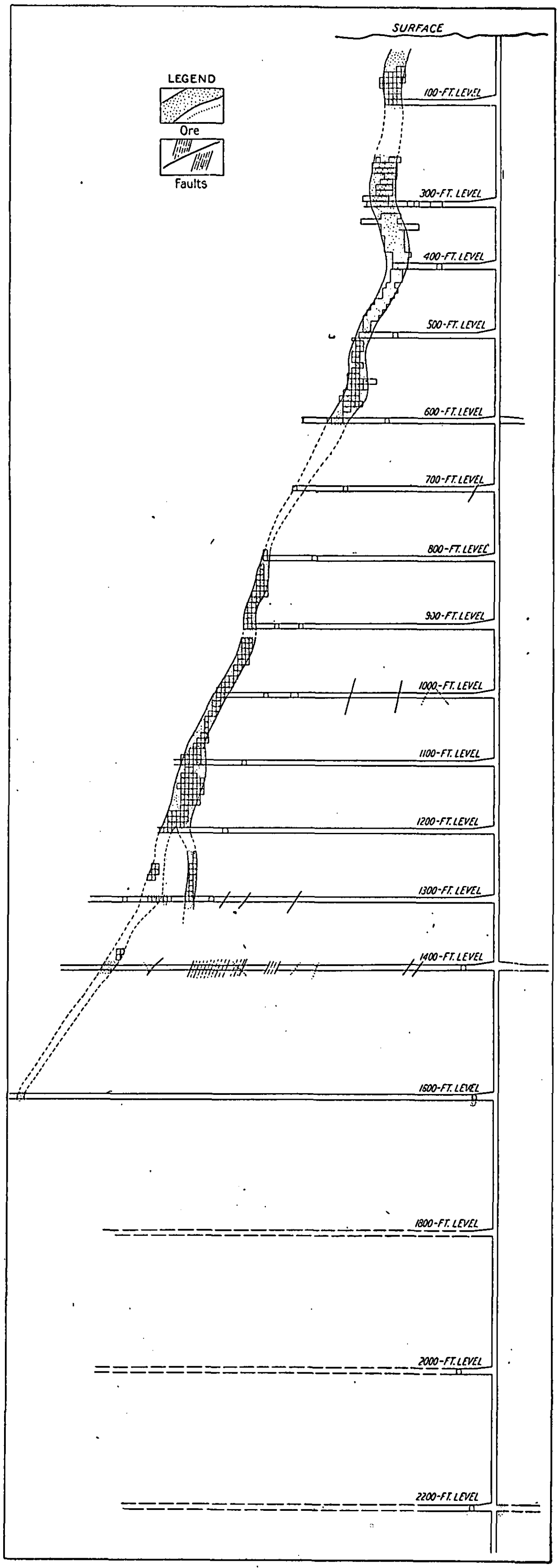


FIGURE 72.—Section through Green Mountain shaft, showing Syndicate lode.

The 2,200-foot, or drainage, level of the High Ore mine shows aplite in abundance at a point 300 feet north of the shaft. It also shows a granite porphyry, or rhyolite porphyry, in which the quartz phenocrysts lie in a groundmass much more granular than usual throughout the district. This level also shows much brecciated granite, which apparently represents the first stages in vein formation.

FAULTING.

The interest in the Bell-Diamond-High Ore group of veins lies mainly in their structural features, the record of faulting and succeeding mineralization being exceptionally clear. Neither in mineralogic nor economic relations do the veins present any especial novelty.

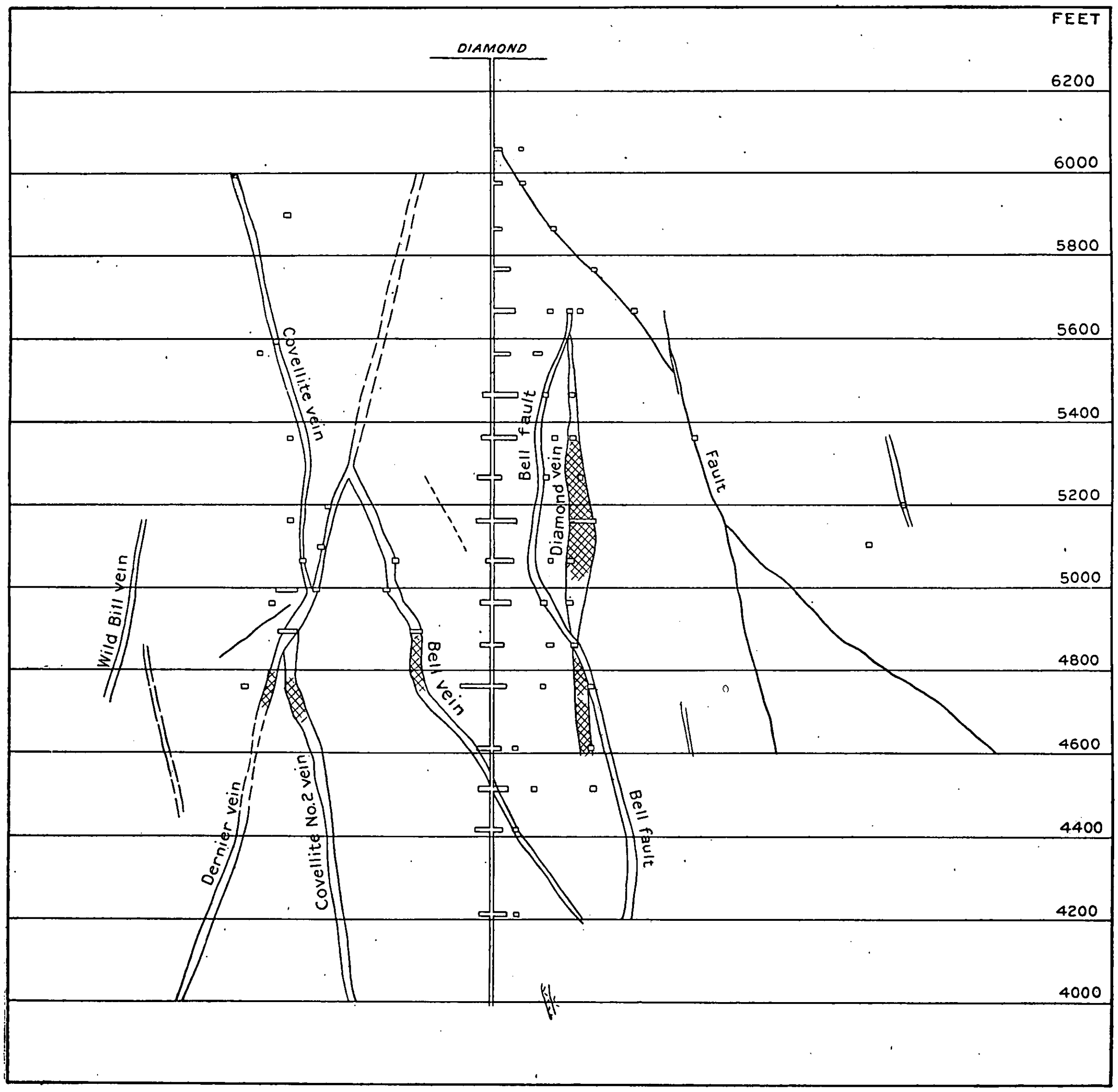


FIGURE 73.—North-south section through Diamond shaft, showing veins of Diamond mine.

The Greyrock group of veins, including the Greyrock, Bell, and Covellite veins, are of variable width and show clear evidence of shifting along their walls. They consist largely of altered granite and friction clay, with long ore bodies which feather out at each end, but are of great vertical extent.

The veins of the Greyrock system (see fig. 73) are shattered and sliced by northeast fractures, producing frequent displacements of small amount, a feature which seems most marked in the lower levels, probably because close timbering, crushing, and filling prevents its recognition on the upper ones. The shift is almost invariably to the west. As noted on the Parrot vein, this faulting in places produces a marked variation in the amount of rich ore, the vein being lean west of the fault. The faults are generally of steep dip, and the filling consists of a few inches of clay, with pebbles of country rock. Owing to the extreme crushing in the vicinity of the Bell shaft the relations of the Diamond vein (part of the Speculator vein), which comprises the greatest ore body of that mine, can not be satisfactorily determined, but there seems little doubt that it is formed by the juxtaposition of the Diamond vein and the faulted Bell vein. These relations are best shown by the map giving the horizontal section of the 5,100-foot level.

The relations of the displaced veins are best shown on the 1,600-foot levels of the mines. The displaced segments of the Speculator vein are six in number, the Diamond being one of the central ones. The Greyrock group displaces the Speculator, and as it is displaced by the Bell fault the resulting structure is apparently complex. If, however, the Covellite vein be correlated with the Skyrme, the Vale vein with the Sales, and the Winchell with the Teague, the correlation is perfect without any vertical movement. In this case the Bell vein corresponds to an unworked vein lying between the Sales and the Skyrme. To correlate the displaced segments of the Speculator one must assume an eastward throw on the south or hanging-wall side of each of the northwest veins. This results in a complete correlation and shows that the Speculator vein was once continuous westward beyond the workings of the East Greyrock mine.

The faulting of the Speculator vein by the northwest veins is repeated westward, where the Wild Bill is cut off by the Covellite vein, and this in turn by the Bell and other fault fissures lying to the southward. The 1,500-foot East Greyrock shows a cut-off of this kind, with a shift of the vein similar in amount and displacement to that produced by the Skyrme vein and by the Covellite vein on the Speculator vein. These facts, which are difficult of verbal expression, are, it is believed, clearly brought out by the maps.

The persistence and straightness of the northwest fractures are very marked, the most notable example being the Skyrme vein, which has been developed on several levels for a distance of 4,500 feet, drifts being run from the High Ore mine to the Bell-Diamond, and on some levels eastward to the High Ore shaft. This vein has been developed from the surface to a depth of 2,400 feet and has also been cut in the 2,800-foot level of the High Ore mine, where it is ore bearing. Counting in its westward extension the Covellite, it has a total workable length of over 4,000 feet, being worked in the Corra mine and probably cut westward of this property in other workings. The other fissures have not been so well developed, but there is no reason to doubt that when they are drifted upon they, too, will be found to contain pay ore. The future of this section of the camp rests entirely on the development of the deep levels of these northwest fractures.

The rich ore bodies in which not only streaks of high-grade ore but intervening sections of mineralized granite have been largely worked in the Bell and Diamond mines, are due to the shattering of the ground by the northwest and northeast fractures. As the latter are later than the northwest fractures it is probable that we have here to deal with two periods of mineralization, the last of which is still going on, as the mine waters, even at the greatest depth, are clearly descending waters and are depositing glance.

Of all the veins opened up in these mines the most productive has been the Covellite and the next most productive the Bell. The Covellite is a fault fissure, but, unlike many of the others, it carries good ore near the surface, which feature is wholly absent in its eastward continuation in the Skyrme. It has been continuously worked to the deepest levels, yielding good ore in the westward extension of the vein on the 2,200-foot level of the Green Mountain mine. Of the northwest veins, the southernmost, called Winchell west of the fault and Teague east of it, has proved very productive in the deep levels, whereas the faulted section of the Speculator, designated J. B. on the map, yielded comparatively little ore in the upper levels, but at 1,400 to 1,600 feet is characterized by a large and rich ore body.

The Bell fault is the latest fracture of this area. It belongs to the Steward fault system. It displaces the Skyrme vein, which, as already noted, is equivalent to the Covellite vein, and it also cuts through and displaces the Higgins, which is the eastern portion of the Bell vein. The workings of the West Greyrock and of the East Greyrock mines show many small fractures parallel to this Bell fault, and these fractures displace the older veins a few feet, though fortunately they do not interrupt the continuity of the workings, but have apparently played an important part in producing rich ore. The fault runs somewhat north of east.

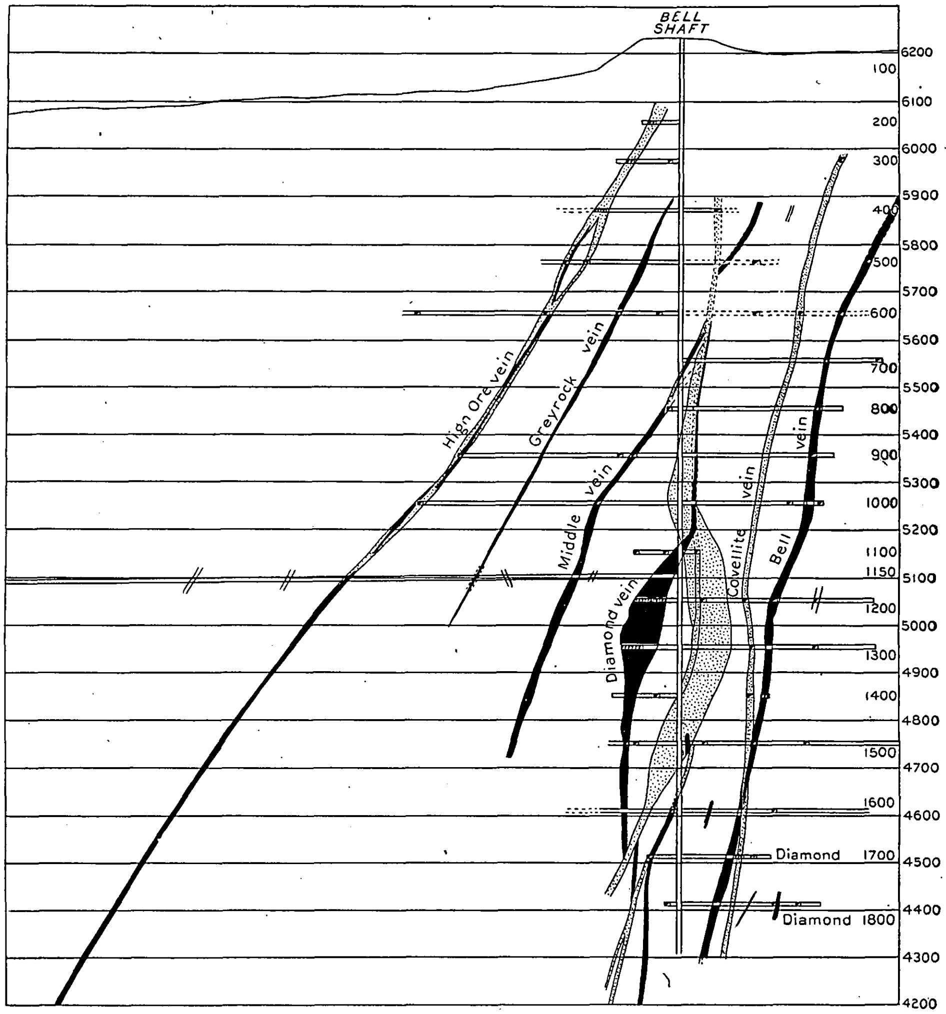


FIGURE 74.—North-south section through vein and faults of Diamond mine on line of Bell shaft.

EAST-WEST VEINS.

The east-west veins include the Speculator and its supposedly detached faulted portions, the Diamond, Swede, Flood, J. B., etc. The old vein filling consists of quartz and pyrite, the latter in places prevailing. When not broken by fault movements and enriched by glance deposited later, these veins are very low grade. When enriched they form large and rich ore bodies, the so-called Diamond vein being the largest and most valuable ore body of the group. All the east-west veins encountered in the mines are now believed to be merely faulted portions of the Speculator (and possibly Syndicate) ledge. Of these, the Diamond has been the most productive. In the Speculator mine the vein dips north down to the 300 level and below this changes to a southerly dip.

The largest of the east-west veins is the Speculator, which is worked in the Speculator mine, and extends westward in a nearly straight line to the workings of the Greyrock and Bell. The Speculator vein is broken and displaced by the northwest veins, and the result is that the detached fragment of the Speculator vein found near the Diamond shaft, and generally known as the Diamond ore body, is limited both on the east and on the west by fault fissures.

There is some question as to whether the great Syndicate ledge is not the westward continuation of the Speculator vein. The Syndicate ledge terminates abruptly eastward, but owing to the barren nature of much of the vein the workings have not been developed up to the point where the Bell fault is supposed to cross. When account is taken of faulting, however, the Syndicate correlates very well with the Diamond, and the Diamond in turn with the Speculator, so that there is a probability that these three ore bodies were once a continuous vein. This implies a very considerable shifting of the hanging-wall blocks of the hill. The displacement by the Skyrme vein is estimated at 300 feet eastward on the hanging wall. The displacement by the Bell fault vein is estimated at 200 feet north on the west side of the fault.

The Diamond is a wide vein, varying from 30 feet on the 1,100-foot level to 100 feet on the 1,200-foot. It is exceptionally rich in copper sulphides, inclosed in massive quartz-pyrite ore. Much of the ore consists of altered granite, peppered with glance and bornite and netted with thread-like veinlets of these minerals. Postmineral or fault clays are absent in the big ore body of the 1,200-foot level. The Diamond vein is not seen above the 500-foot level, but from the 500 to the 1,300 foot levels, carried very rich ore and was the mainstay of the Diamond mine; below the 1,300-foot level it is composed of hard, compact quartz, carrying much pyrite and very low values in copper. The vein is a typical example of replacement and belongs to the Anaconda system. On the 700-foot level the vein shows no walls, the ore merging by insensible degrees into the altered sheared country rock, but the heart of the vein is a clay seam, with quartz and pyrite bands on either side. In places the vein shows bands of altered, partly replaced granite separating quartz-pyrite layers. The central clay seam and bunchy nature of the rich ore shoots are characteristic. The ore body is delimited by faults. The other faulted blocks of the east-west veins, all of which are parts of the Speculator or of the Syndicate lodes, are similar in character to the Diamond, and, though designated on the maps (Pls. XXXV–XL) by separate names, do not merit individual description.

The faulted block designated the J. B. vein is unusually wide. It consists of crushed quartz and pyrite, with long slivers of this material cemented by newer quartz carrying pyrite and some specks of glance.

The Bell shaft is at the intersection of veins whose broken ground has furnished material for the large stopes. Owing to the very soft nature of the ground these stopes were all filled and the faces can not now be examined. In fact no ground is allowed to remain open except in lateral drifts in all this mine, as it is essential for the safety of the miners that the excavated space should be promptly filled by waste. This area is crossed by the Skyrme and the South Bell veins, as well as the Diamond, but the latter makes the big stopes and is the largest ledge of the mine, though the Covellite vein has yielded the most steady output of first-class ore, containing pay ore from the surface down. The Diamond vein ends eastward against a northeast fissure cutting off the East Bell vein. This cut-off makes the vein shorter on the 1,000-foot level than on the 700-foot level, and of course proportionately so between these two. Below the 1,000-foot level it is not cut off but extends farther east, as shown on the map of the 1300-foot workings.

HIGH ORE GROUP OF VEINS.

The High Ore series is a variant of the Anaconda east-west system. It includes the High Ore, Bell, and Wild Bill veins.

HIGH ORE VEIN.

The High Ore vein has a flat dip and extends west to the Diamond on the 200-foot and 300-foot levels, where it forms a junction stope. Its flat dip takes it farther south of the Diamond shaft going down, and thus there are no intersections or fault cut-offs. (See fig. 74.)

The High Ore vein is neither an east-west nor a northwest fault vein, but has a course of N. 70° W., corresponding to that of the Wild Bill vein in the upper levels of the mines. These veins are older than the northwest veins and have been displaced by them.

The High Ore vein has been continuously and extensively worked down to the 1,000-foot level, where it becomes lean. The upper levels show great stopes in the ground east of the Bell shaft, among them of an ore shoot 1,200 feet long on the 300-foot level. The vein has a very constant strike and uniform dip, but the walls are curved and locally irregular and are cut by a multitude of small quartz veins.

The vein filling consists of quartz and pyrite, with enriching bornite and glance, the richest streaks being near the footwall. The usual abundance of fault clays and slips of other veins is lacking, and the ore shoots end abruptly in lean quartz and pyrite.

The vein varies in width from 7 to 40 feet, and has held large bodies of very rich ore at depths of 200 to 700 feet. Underground it appears to split both longitudinally and vertically, the two branches coming together again. There is some doubt whether these splits are not in reality the crossing of fault fissures, the High Ore belonging to one of the older periods. The east-west course found at the surface changes to N. 70° W. in the lower workings. Above the 200-foot level the vein becomes less and less distinct as the surface is approached, and at the surface, like the other veins in the vicinity, it is hard to recognize.

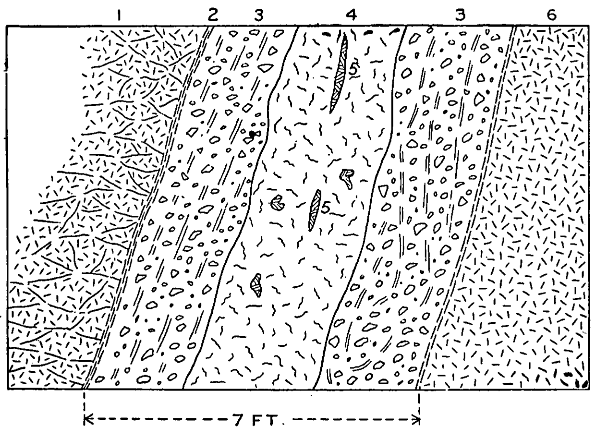


FIGURE 75.—Section of High Ore vein, stopes of 2,200-foot level, High Ore mine. 1, Mashed quartz monzonite; 2, blue clay; 3, fault matter (breccia and clay); 4, hard vein quartz; 5, vugs of quartz; 6, quartz monzonite.

One thousand feet below the surface the High Ore vein is lean and consists of quartz and pyrite, with large vugs lined with quartz and pyrite crystals, the latter often tarnished with some associated enargite (fig. 75).

On the upper levels the largest ore bodies of the Bell and Diamond mines found were those of the High Ore vein. The strike makes an angle of about 20° with the Skyrme vein. The vein has been very regularly developed for a distance of 1,000 to 2,000 feet on its strike and from the 200-foot level down to the 1,000-foot level. Below the latter level it is said to be barren, but the cross sections indicate that the vein is cut off by one of the northwest fault fissures and is not ended by impoverishment. On the 1,600-foot level such a cut-off may be observed westward, the drift following the fault vein. This cut-off is exactly like that seen where the Speculator vein is terminated westward by the Covellite vein, as shown on the 400-foot level.

MODOC VEIN.

The Modoc vein passes westward from the mine of that name into the Sunnyside, and enters the High Ore and Bell ground, where, however, it has not proved workable. As this vein accompanies a quartz porphyry dike, it is readily recognizable.

BELL VEIN.

The Bell vein lies next to the High Ore, outcropping about 250 feet to the north. It strikes N. 75° W., and dips from 70° S. to vertical. The vein has not been worked to as great depths as the fault fissures, and in fact the observations in this part of the camp confirm the general observations gathered elsewhere, that the east-west veins have been the great producers in the upper levels, that is to 1,000 feet below the surface, and that at greater depths the fault veins have been and are likely to prove in the future the great producers. In the Bell-Diamond workings a cross vein with a course of N. 55° W., cuts off the west end of the Bell vein. It runs parallel with the Diamond vein, which has held a large ore body in the intermediate workings. The Diamond vein is only known on and below the 500-foot level of the Bell mine, its upward extension being limited by the fault plane known as the Bell fault. The Diamond has a course of N. 65° E. and a steep southeast dip. It has been worked for a distance of 500 feet, and has an average width of workable ore of 15 feet, which increases in the big ore shoot, being formed by the intersection of other veins, with accompanying mineralization of crushed rock.

The High Ore vein can be traced westward on the surface by various outcrops and mine workings, and runs into the Old Glory claim.

WILD BILL VEIN.

The Wild Bill vein runs parallel to the High Ore (N. 70° W.) on the northern border of the group. It is a typical fault vein, carrying shoots of glance-pyrite ore. It is separated by a clay selvage from the normal granite of the footwall and from the altered slacky granite of the hanging wall. This granite becomes normal and unaltered 3 feet from the vein. The Wild Bill resembles the Skyrme; for long distances it carries no ore, and when ore is found it is in small bunches. On the 1,300-foot level the fault character is less apparent, and the vein is a nearly solid, tight, and dry vein of pyrite, which appears to be composed partly of an old vein filling and partly of new quartz and glance in fractures nearly but not quite parallel to the vein. Westward the vein turns over and dips 70° to 80° N. Where wet it shows 1 to 2 feet of crushed granite, with endogenous white quartz, blende, and pyrite, but where dry and dusty is dense, has but little quartz, and is low grade.

The vein is worked on the 900, 1,100 1,300, and 1,500-foot levels of the Diamond mine. On the 1,100-foot level west it is but 8 to 15 inches wide and is a distinct fault vein, with mashed granite but without pebbles, containing endogenous streaks of glance. The walls are marked by clay films, and the country rock is a slacky decomposed granite which fades into a normal granite 3 feet away from the vein wall. The vein is a typical fault vein, and for a long distance carried no ore, or at most ore bunches or kidneys. The black normal granite forms the footwall.

North of the Wild Bill, a parallel vein 2 feet thick is tight and hard and shows no selvage. It consists of black quartz with pyrite in small bunches and patches, and 4 inches of it is slightly mineralized.

So far as the underground evidence affords any indication of the character of the vein, it appears to be an older quartz-pyrite vein fractured by a later strike fault, and carrying good ore only where fractured.

A crosscut north of the 1,100-foot Corra goes 80 feet north of the Covellite lode, cutting a fault vein 2 to 3 feet wide, with a banding of white quartz, pyrite, and zinc. This vein is tight and has a good hanging wall of pink manganese spar. The footwall is ill defined.

GREYROCK GROUP.

GENERAL CHARACTER AND RELATIONS.

The northwest veins of the Blue Vein system are the most prominent lodes of this section of the Butte district, and are now the most productive veins of the Bell-Diamond group of mines. They include the Greyrock, Bell, and Covellite veins.

The members of this system are all fault veins, recognizable as such not only by their structural relations, but also by the character of their filling. They have a general northwest course, are of long extent and quite regular strike, and dip steeply, usually southward. The walls are generally undulating, and the granite shows varying degrees of alteration, aside from the relatively small amount directly attributable to vein formation. The ore shoots consist partly of solid and partly of brecciated ore, the former in part at least primary but not necessarily part of an old northwest vein reopened by strike faulting, for ore endogenous to the fault would be crushed and broken by movement and adjustments of later date than that of this system.

The veins of this system having been severed and shifted by later movements along the Bell fault, have been given different names on each side of this fault.

Southeast of the Bell fault there are the Skyrme, Custer, Higgins (or Middle), Sales, and Teague veins. Northwest of the Bell fault are the Greyrock, Winchell, Vale (or Gillie), Bell, Covellite, and Dernier veins. The correlation of these veins across the Bell fault is nearly perfect in dip, strike, and mineral character. The largest and richest vein of the series, namely, the Covellite, corresponds to the Skyrme vein east of the fault, where it carries only small and detached shoots of ore down to the 1800-foot level. The High Ore vein does not belong to this system but makes an angle of 20° with it.

SKYRME VEIN.

The Skyrme vein is the most prominent member of the northwest series south of the Bell fault. It has been developed by long drifts on many levels, which connect both with the High Ore shaft and the workings of the Diamond and Bell mines. These levels have developed but little ore for some 1,600 feet beneath the surface. A few ore shoots were found on the 1,600-foot level, but the lenses were short, having a vertical extent of 40 or 50 feet, a horizontal extent of not more than 300 feet, and a width of 6 to 12 feet. Thus on the fourth floor stope above the 1,600-foot level the ore consisted of pyrite and a little quartz, and no secondary sulphides, and was so lean that it barely paid working. There is some doubt as to whether this ore, which is nearly solid pyrite, was deposited in the fault fissure, or whether it was a remnant of an earlier vein filling similar to that found in the Johnstown (North Connecting) vein of the Rarus group.

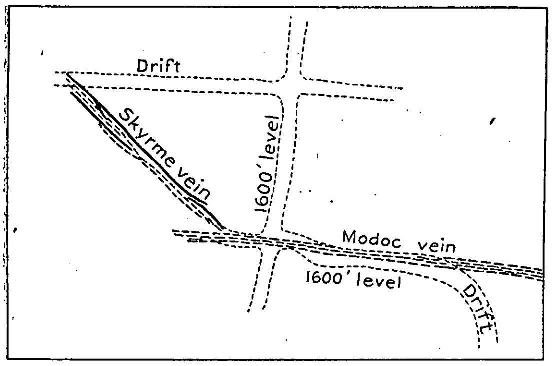


FIGURE 76.—Plan showing cut-off and displacement of Skyrme vein by east-west Modoc fault vein, 1,600-foot level, High Ore mine.

In general the deeper levels, 1,800 to 2,800 feet, show that the better grade of ore consists of a dense massive mixture of very fine grained quartz intimately intergrown with pyrite, bornite, and a little enargite. These minerals are not banded, but occur irregularly scattered through the mass. The quartz is dark colored and all of the replacement type, showing none of the coarse crystals or vuggy character of a cavity filling. The ore is fractured but is not badly crushed, and the minute joints show mossy deposits of glance.

An ore shoot, developed on the 1,600-foot High Ore level near the boundary line between the Diamond workings, shows 2 feet of ore that is very pyritic, but is incased by 5 to 8 feet of loose granitic material that has a netting of clay seams on the north side. The shoot is evidently true quartz-pyrite ore, showing a banding due to the arrangement of the quartz and pyrite into leaner and richer streaks, but shattered somewhat irregularly by faulting with crushed quartz and breccia in some parts of the vein; the north wall is indistinct and has much mashed granite where the vein is widest. The glance occurs as films or very thin plates in fractures cutting the original ore and also as spongy masses in the ore where the crevices are most abundant. It is certain that it is in part of secondary origin and is deposited in favorable places. On the contrary, the inclosing apparently solid ore is specked with particles of glance and is emphatically a glance-enriched vein. The vein is wide where stoped, being 20 to 25 feet across west of the crosscut that leads south to the drain tunnel to the High Ore mine. At this place it shows probably what is enargite mixed with glance. The faces of the stopes were carefully searched for galena, but none was found. Throughout the extent of the long 1,600-foot level the vein can not be over a couple of feet wide, including the clay seams. At any rate, the walls are hard granite and show no clay except near the south crosscut, where it is possible that the strike fissure crosses the vein.

The Skyrme vein is a fault fissure. In the stopes which were seen the vein is a fairly solid mass perhaps 2½ feet wide, with a well-defined hanging wall, the glance-bearing streak being on the north or footwall side of the vein proper; there is 10 feet or more of mashed granite north of the vein mined as waste for filling. The vein is apparently traceable to the South Bell workings. It is cut off and displaced in the High Ore mine by the east-west Modoc fault (fig. 76).

The east end of the Skyrme ledge, shown in the High Ore workings, indicates that the vein, though persistent in extent, occupies a true fault. The vein has not been a great producer from the surface down to the 1,600-foot level, though some good bunches of ore have been found on it. In October, 1907, the High Ore shaft was 2,860 feet deep and showed good ore at that depth in the Skyrme vein.

COVELLITE VEIN.

EAST GREYROCK MINE.

The section (fig. 77) through the shafts and crosscuts of the East Greyrock mine clearly illustrates the relative positions of the main veins worked. The section has been carefully constructed from detailed notes made on each level of each crosscut through both the East Greyrock and the Diamond mines. The northernmost vein is the Covellite (or North Greyrock). It appears to be cut by a northward-dipping clay slip having a general northwest direction, which displaces it, shifting it along the fault plane for 50 feet. In the upper levels this fault fissure is not clearly shown, but it may be seen in the raise between the 700 and 900 foot levels wherever the timbering permits. It dislocates the Covellite vein and, as it is ore-bearing below the line of intersection, it has generally been assumed that it is the Covellite vein, which is supposed to have changed from its normal steep southerly dip to a northerly dip. The workings extend downward on this fault slip to the fourteenth level, where the top of a cut-off vein, known as the Dernier vein (see p. 184), is encountered. In reality the Covellite maintains its normal dip and has been developed beneath the fault from the 1,100-foot level to the 1,700-foot level.

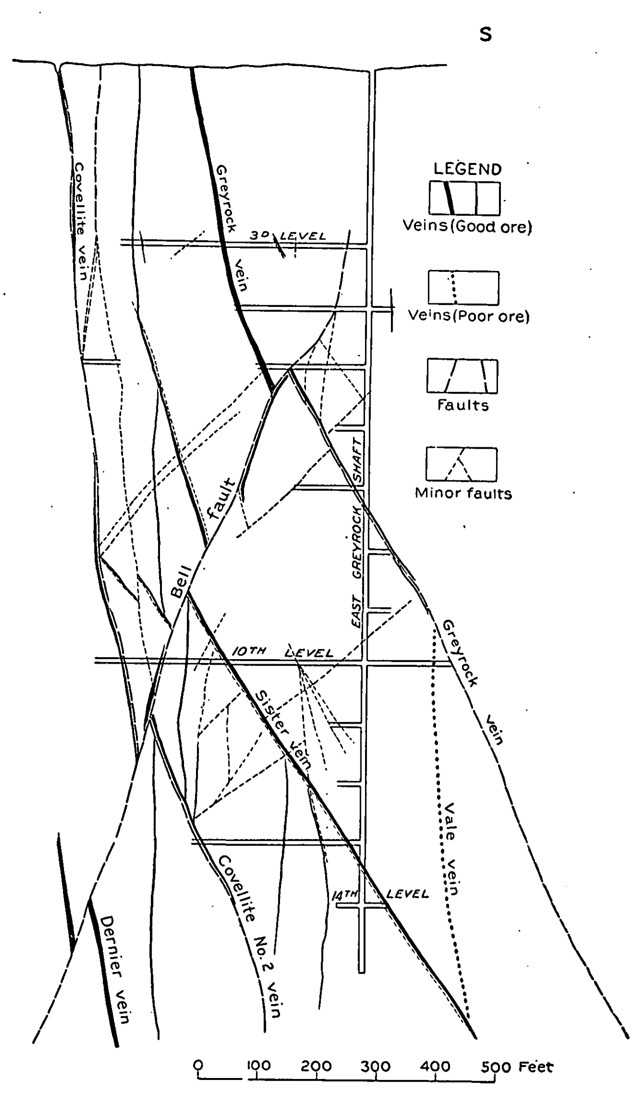


FIGURE 77.—Cross section through East Greyrock shaft.

The Covellite vein is typically developed on the 1,500-foot level of the East Greyrock mine, where it varies in width from a few feet to 15 to 18. The walls are irregular in dip, but are generally smooth, with clay selvage present on both sides of the vein. The prevailing dip is toward the south, for the workings go toward the north, though the south wall is nearly vertical.

The occurrence of covellite in the Covellite vein is unusual, inasmuch as the mineral is somewhat rare, not only at Butte, but throughout the world. It is found in abundance in the Covellite vein, where it is associated with glance and in some places with small amounts of chalcopyrite. It is found on the 1,100-foot level, where the amount of reducing material seems to be greater than that forming glance. The mineral occurs only in the fault clays and is associated invariably with sericite and not with the blue and unreduced clays commonly found in the fault veins. Bornite is found, but is not abundant. The evidence indicates that the covellite is formed by descending solutions and that its presence is due to the abnormal conditions which prevail in certain sections of the mine.

CORRA MINE.

The most westerly workings on the Covellite vein are in the Corra mine, whose drifts are continuous with those of the Greyrock. An ore shoot passes from the Greyrock into the Corra and extends westward for 50 to 150 feet. The vein is 5 feet wide, and appears to be a fault fissure along an old quartz-pyrite vein of hard, dense, uniform-textured, massive pyrite and quartz, cracked but not brecciated, with small strike slips of blue clay; these newer cracks are filled by secondarily deposited milky-white quartz and glance. The primary quartz is dark and is easily distinguished from this milky-white quartz of later deposition. The pyrite is mostly primary, is abundant, and occurs partly in streaks, but mostly in patches irregularly flecking the quartz. These pyrite patches are not sharply defined, but show a fading at the borders, and in places where they are impregnated with glance and bornite a spongy texture is observed. Sphalerite also occurs, but it is secondary, and most abundant in the footwall clay slips. These observations apply particularly to the 1,000 and 900 foot Corra levels.

DIAMOND MINE.

Eastward from the 900-foot Corra into the Diamond mine (the connection being on the twenty-fourth floor or 1,100-foot level of the Diamond mine) the vein expands to 15 feet in width. In the western part of the Diamond workings the vein shows a greater amount of faulting than in the Corra. Possibly the fault passes into the hanging wall westward and the crackling of the ore body in the Corra is simply due to sympathetic strains—that is, to footwall stresses.

The vein is really compound; one ledge is composed of a footwall band 5 to 8 feet wide, with films and threads of quartz and specks of glance, delimited by a clay footwall; its hanging wall shows 2 inches to 6 inches of black clay selvage. The other ledge is a primary, older quartz-pyrite vein, 10 feet thick, composed mainly of dark, granular pyrite, carrying some eyes of quartz and here and there bunches and patches of solid glance. The hanging wall of this compound vein (that is, of the old vein) shows slickensides and a band of crushed quartz and granite. As this wall rolls very decidedly, it is evident that the hanging wall of the old vein was fissured when the accompanying strike-fault vein was formed. In many places the rolls pinch the vein and cut out the old or primary quartz-pyrite vein filling. The newer fault vein shows friction bowlders and clay. One section showed (*a*) footwall clay slips; (*b*) 10 feet of crushed granite, carrying a little quartz, with crushed quartz and pyrite and glance films; (*c*) 2 feet of solid vein; (*d*) three hanging-wall slips in mashed granite 3 feet wide. A notable feature is the making of ore along barren southwest-northeast fissures, dipping 60° S.

The vein wall in the Diamond, like that seen in the Corra, limits the decomposition of the granite; that is, this alteration extends only about 5 feet into the wall.

The deepest development is on the 2,000-foot and the 2,100-foot levels of the Diamond mine. On the 2,000-foot level the drift run on the vein west of the main crosscut shows it to be about 6 inches thick and to be formed of clay and gouge, without any quartz or pyrite. This applies to the portion of the vein nearest the upraise to the 1,400-foot level. West of this raise, however, the streak thins out to about one-half inch of clay, and the quartz-pyrite streak comes in, the ore body sending out spurs to the west into the hanging-wall granite. The extreme west face, at the time the property was visited (1902), showed 12 feet of vein matter, with the south or footwall streak of nearly black quartz-pyrite ore, carrying bornite and calcite in nodular masses. The main streak shows a seam of clay one-fourth to 1 inch wide, lying between the normal quartz-pyrite ore body and the altered granite of the hanging wall. A fault vein of low dip (45° to 50°) comes in from the north and intercepts the vein immediately below the level. This quartz vein crosses a streak of zincky black quartz containing pyrite.

The Covellite vein is supposed to be the extreme northernmost vein worked on the north crosscut from the 2,000-foot level of the Diamond. If this is so, the vein must be worked in a faulted block. A raise goes up on the vein to the 1,800-foot level, establishing its continuity upward. The vein is vertical and terminates eastward against a fault running N. 55° E., with a dip of 65° S. The eastward continuation of the drift is through granite cut by a number of clay slips but showing no vein of any kind.

HIGGINS (EAST BELL) VEIN.

The Higgins or East Bell vein is the Bell vein east of the Bell shaft. It is seen only on the maps on the 700, 800, 900, 1,000, and 1,300 foot levels but has apparently yielded considerable bodies of ore. It seems to be cut off by the Bell fault fissures running northeast and southwest. (See fig. 78.) The vein is very irregular in dip from the 700 to the 1,000 foot levels, but must straighten up between the 1,000 and the 1,300 foot levels. On the other hand, the South Bell vein is practically vertical from the 900 to the 1,200 foot, but takes the southerly dip between the 1,200 and 1,300 foot levels.

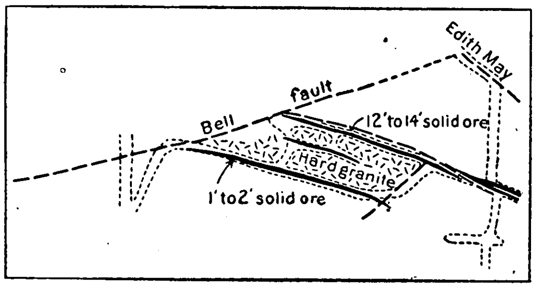


FIGURE 78.—East-west Speculator vein, with 12 to 14 feet of ore and two parallel footwall veins, terminating abruptly against the northwest Bell fault on the 1,600-foot level of the High Ore mine.

MINES.

EAST GREYROCK MINE.

GENERAL RELATIONS OF VEINS.

In addition to the Covellite vein the section (fig. 77) through the East Greyrock workings shows several subordinate veins, known as the Sisters, Dernier, Vale, and Greyrock. The Sisters vein, which lies beneath the north fault, has a dip of about 60° S. It is exposed from the 900 to the 1,700 foot levels and is workable in places. The Vale vein lies east of the shaft and underneath the Greyrock vein. It is known from the 1,000-foot level to the 1,600-foot level and carries good bodies of pay ore in the deeper levels. The Dernier runs parallel to the Covellite. The Greyrock, next to the Covellite, is the chief vein of the mine; it is more fully described in connection with the West Greyrock mine (p. 184).

All the veins have a general northwest course and are more or less similar in character, being fault veins in which remnants of an older quartz-pyrite filling appear to be recognizable at intervals. The walls are well defined, generally smooth and slickensided, and the granite appears to be fresh. The thickness of the veins varies from 2 or 3 feet to 25 or 30 feet. On the 700-foot level the Greyrock vein, for instance, has walls but 4 to 5 feet apart and the fissure is filled with crushed granite and clay, with occasional balls of hard ore. Followed along its course, shoots of newly deposited ore occur and the vein carries good values. In general, the Greyrock vein shows a very hard footwall, with a dip of 79° to 86° to the south. The footwall has a clay selvage lying between the solid vein matter and the normal granite. The hanging wall of the vein is generally marked by a clay gouge or a series of clay seams, and this wall rolls so that at times it has a dip opposed to that of the footwall.

SISTERS VEIN.

The Sisters vein is a hard quartz-pyrite vein 3 to 5 feet wide, having a course of nearly N. 50° W. and a dip of 61° S. It shows a clay selvage on the hanging wall, but this is not constant, and when present is in places separated by the crushed granite from the main body of the vein. Including the mineralized rock lying between the ore streaks, the vein has a total width of about 20 feet. It is cut by flat fault slips, which appear to be strain cracks, due to the settling of the fault blocks, and are not persistent fissures. These fault cracks have not only produced slight displacement of the ore bands, but have had a marked effect on the richness of the mineralization.

DERNIER VEIN.

The Dernier vein, which is also worked in the Mountain Con. mine (p. 165), is parallel to the Covellite, which it closely resembles. It is generally marked by clay selvage on both walls, and has a width of 5 to 10 feet, with 3 to 4 inches of clay on the footwall. It dips 88° N. or is vertical, and its general course is N. 45° W. Northwest its northward dip is quite pronounced, but as shown on the 1,300-foot level this may be merely due to the intersection of the ore-bearing fault.

The ore from this vein is an exceptionally dense mixture of glance, sphalerite, bornite, and enargite, with scattered specks of pyrite. It occurs on the 1,900-foot level where the vein is cut off and is evidently associated with faulting, as the ordinary ore of the vein is a mixture of quartz and pyrite with patches and irregular smearlike masses of bornite and enargite. Vugs in the ore show masses of white quartz crystals associated with and inclosed in but not inclosing enargite. The zinc vein near the Dernier on the 1,300-foot level of the Diamond consists of good comb quartz and zinc blende, with much less chalcopyrite, the whole forming a typical silver vein.

VALE VEIN.

The Vale vein, which is extensively developed on the 1,400-foot Greyrock, is a composite vein, in which an old quartz-pyrite filling 15 to 18 feet wide has been shattered by strike faults and slightly displaced by cross faults. The strike fault has produced clay slips, which follow first one wall and then the other, or may pass off into the country rock entirely. These slips have a general course of N. 40° W., a dip of 80° S., and carry from 1 to 2 inches of clay as a selvage. Northwestward the east and west slips, or, more properly speaking, those having a course of N. 80° W., have displaced this vein to the west, producing an irregularity in the workings, which makes the course of the vein, as shown on the mine maps, appear somewhat more sinuous than it is in reality.

WEST GREYROCK MINE.

In the West Greyrock mine five veins, all of which have a northwest course, are developed within a width of 200 feet. Four of these veins are of similar mineral content and are best classed as silver veins. The southernmost contains important copper values, but the ore is nonpersistent, occurring in lenses smaller than but similar in character to those of the Covellite vein. The next vein north (the southernmost silver vein) is persistent throughout the mine and has been developed for 2,000 feet or more. It narrows eastward to a thin fault fissure and is not recognized in the Diamond workings.

All the veins of this mine carried copper in the upper levels but changed to normal silver veins in depth. This peculiarity is also observable in the veins of the Corra mine, where copper ore was mined from the 200 and 300 foot levels, below which the veins changed to typical manganese-bearing silver veins. These observations are directly opposed to the current belief that the silver veins carry copper ores in depth. Similar evidence was obtained in the Flag, Sisters, and Josephine claims, where the upper levels have yielded rich ores with high copper values, and deeper development has shown a marked change in mineral character.

Examination of the workings of the West Greyrock mine was limited to the upper levels by flooding of the mine. The southern or copper vein was found to have a course of N. 45° W., and a variable dip of 87° S. or less. The vein consisted of quartz and pyrite, with considerable zinc blende and some copper glance, and showed an average width of about 10 feet. Between this vein and the silver vein next north, an east-west vein with a southerly dip has been developed on the upper levels, but was too lean to warrant working. The silver vein most extensively worked is badly shattered by cross faults, but shows a general course of N. 45° to 60° W. It has a width of 2 to 7 feet, and contains typical silver minerals and considerable zinc. Cross faults and slips are abundant and have played an important part in the formation of ore, but the displacement along the smaller fractures is not great, and the drifts therefore may be assumed to follow approximately the general direction of the vein before faulting.

The cutting of the Greyrock veins by east-west (N. 80° W.) fault fissures which are vertical or steep is very plainly seen in the Greyrock mine. The shift of the displaced veins is always to the east along the north side of the fault, in this differing materially from conditions elsewhere in the district. On the other hand, the east-west fissures cutting the vein, whose course is regarded as complementary to that of those just noted, have a reverse shift, the displaced vein on the north side of the fault having moved westward. This is observed on the 1,416 raise of the Greyrock mine, where the Vale vein is displaced. In general these displacements seem to correspond to an overthrust movement rather than to normal faulting. The displacement by these lesser cross faults is fortunately not great, varying from a yard to 12 or 15 feet, so that in drifting along the vein it is not necessary to change the course of the drift materially.

The highest-grade ore shipped from the West Greyrock mine in 1900 went 2.8 per cent copper. The veins worked in the East Greyrock mine have very good ore, but the glance and bornite lessens toward the west on the Covellite and Bell veins. One cross fault shows a shift of 15 to 20 feet and limits the pay ore. In the Corra mine the ore from the southern vein carries only 1.5 per cent copper, but the silver values are good. The Sisters vein shows good copper ore on the upper levels, but this plays out in depth. The westernmost end of the Flag claim was prospected by diamond-drill holes for 200 feet each way and showed no pay ore in the veins cut. Copper ores are, however, extracted from the west end of the Josephine claim.

SNOWBALL MINE.

The Snowball mine is 250 feet deep, and develops a vein of zincky quartz ore with spongy cavities showing a little rhodonite, galena, and chalcopyrite, assaying 2 per cent of copper.

CORRA MINE.

The Corra mine is situated on the high ground forming the extreme northern limit of the copper belt. The mine has workings on several veins, but the copper ore comes mainly from two, one of which is the Wild Bill vein, the other the western extension of the Covellite or North Greyrock vein. The latter splits below the 1,200-foot level in the Greyrock workings and forms the south vein of the Corra mine. The new shaft on this mine was sunk on the ore shoot lying near the east line, and forming the western termination of the shoot worked in the Greyrock. It is well developed between the 800 and 1,200 foot levels. Both the veins of the Corra consist of blackish quartz with sphalerite and pyrite, and show a well-developed, banded structure, uncommon in this district. Where the ore occurs at the east end of the claim this quartz is crushed and shows the typical clay selvage brecciation and other features common to fault veins. The primary black quartz is cemented by white quartz, and the pyrite is replaced by glance, with an accompanying relatively high silver value. The ore had an average of 5.7 per cent copper, with 11 ounces per ton silver, these figures being the average of 20 assays made on carload samples. The copper varied between 3 and 25 per cent; silica, 58 to 59 per cent; iron, 5.9 to 6.2 per cent; alumina, 4 per cent.

The veins have sharply defined walls, with only a thin border of pyritized granite between the vein wall and the fresh normal rock.

The ore produced came from a large ore shoot in the Covellite fault vein. This shoot had been worked in the Diamond mine and was stoped out from the 800 to the 1,100 foot level of the Corra mine. It shows about 5 feet of fault matter and clay gouge on the 100-foot level, but does not contain pay ore until a depth of 300 feet is reached. From this point downward to the 600-foot level the shoot is lean but workable, and it reaches its greatest horizontal extension on the 900-foot level.

Three veins are developed north of the shaft on the 1,100-foot level, but none of them can be correlated with the Covellite fault vein. The one nearest to the shaft is a hard quartz-pyrite vein, which has been developed on the 800, 900, and 1,000 foot levels; it shows several feet of high-grade glance ore on the 1,000-foot level, where the vein is devoid of any of the features of faulting. The second vein lies 160 or 170 feet north of the shaft; it shows 18 to 20 inches of 4 per cent ore in a reopened primary vein. The Wild Bill vein, which lies still farther north, carries about 5 feet of 1 to 2 per cent ore. As already shown (p. 179) the Wild Bill is a fault vein belonging to the Covellite group.

SPECULATOR AND ADIRONDACK.

The Adirondack is a nearly vertical east-west vein, 4 to 5 feet thick, consisting of a 1 to 2 foot band of quartz and pyrite in a soft granite mass inclosed in well-defined walls. It is probably developed in the Speculator as well as in the Adirondack, but the Speculator workings were not accessible at the time the field work for the report was being made and so notes can not be given.

MINERS UNION.

The Miners Union vein is cut on the 700-foot level (5,362 feet elevation) of the Speculator, where it shows a thin seam (1 to 2 inches) of quartz and calcite.

JESSIE-EDITH MAY GROUP.

IMPORTANCE.

The discovery of the high-grade ore bodies in deep levels in the two fault veins, the Jessie and Edith May, is most important. Not only do the veins constitute an important addition to the wealth and production of the district, but they also demonstrate that the fault veins contain lenses of high-grade ore with long barren stretches between them and that such veins are worthy of development, not only by crosscuts and by drifts upon them 200 or 300 feet apart, but by systematic drifting for long distances on levels comparatively close together. The discovery is not entirely new, as the Covellite and the Skyrme veins are both fault veins on which extensive drifting has developed ore bodies. The future of the copper mines of Butte seems to depend upon the exploration of these fault veins, which in the upper levels have so generally proved disappointing and unprofitable.

JESSIE VEIN.

The Jessie vein is a typical fault fissure, with northwest course, and it is therefore considered a member of the Blue vein series. It has been developed in the workings of the Jessie mine to 500 feet and in the workings of the Speculator mine to 1,800 feet. The vein contains lenses of ore of remarkable extent and richness. Their maximum thickness is 25 to 30 feet, tapering down to nothing. Beyond the ore shoots the vein contains lenticules of ore, in places consisting of nearly pure copper glance, and these lenticules continue for 100 feet or more beyond the shoot and finally disappear. Beyond these the vein is filled with barren crushed granite and fault material extending for indefinite distances with variable widths of from 5 to 10 feet.

The vein is peculiarly dry, especially where it contains any quartz and ore; indeed, very little water was encountered either in this vein or in the granite for 1,000 feet on each side of it.

The mineralization indicates that the Jessie vein follows in part an old vein which has been shattered and partly included in it. In the upper levels the fault material contains considerable bornite, some chalcopyrite, some gray copper, and fragments of manganiferous ore. In the deeper levels the ore shoot consists of copper glance, enargite, some zinc blende, a very small amount of galena and quartz, with more or less iron pyrite. Enargite is particularly abundant on and along the footwall. There is a streak of zinc blende along the hanging wall, which varies in thickness from a few inches to 2 feet and is persistent for several hundred feet. This zinc blende is commonly associated with or replaced by copper glance.

The walls of the vein are generally well defined and marked by black clay selvages. Very large grooves, with horizontal major axes, were noticed on the hanging wall where it is perpendicular.

The lower levels of the Jessie mine contain no manganese minerals except small amounts of hübnerite. The ratio of silver to the copper is very constant, being 1 ounce of silver to each per cent of copper. The greatest ore shoot of the vein has been developed for a length of 1,000 feet or more on the 1,600-foot level, and for 1,000 feet vertically. The vein has been cut, and is understood to be ore bearing, in northern crosscuts from the Amalgamated properties.

The working of this vein on the Jessie claim proved unsatisfactory, the only ore found being in too small quantity to pay a profit. The discovery of the big ore shoot was made by a crosscut driven for about 1,000 feet northward from the Speculator shaft on the 1,600-foot level. The extraordinarily high-grade ore encountered by this crosscut led to rapid development by raises and winzes, and by drifts extending several hundred feet in both directions.

Transverse fissures cross the ore body in both veins, and it appears that extensive and crushing movement occurred subsequent to the formation of a portion of the ore, and that these movements rearranged the vein, filling fractures, dislocating solid masses of ore, and in many places bringing high-grade ore into juxtaposition with low grade or with barren masses of softened and altered granite. In many places the vein is banded vertically and the ore in the widest places contains strips and wedges of waste, but despite this, the percentage of first-class ore in the vein is much greater than in any other now mined in Butte. (See fig. 79.)

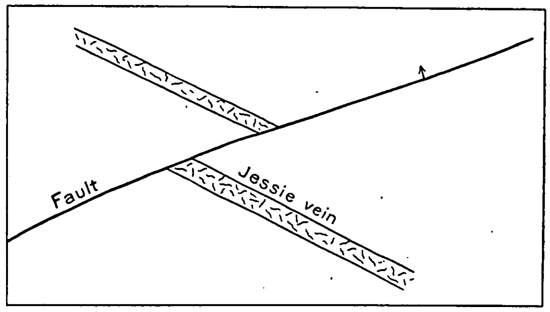


FIGURE 79.—Displacement of Jessie vein by fault of Steward system.

In the Jessie mine the 400-foot level shows the vein to have a thickness of 6 to 8 feet, a dip of 75° S., and a strike of N. 45° W. The vein on this level shows only the usual fault material, except near the west end, where an ore shoot is developed that extends northwestward into the Sioux and Tuolumne claims. The stopes showed an ore body 10 feet wide, consisting of bornite and chalcopyrite with some glance and iron pyrite. Another small lens was encountered above the 400-foot level, but did not extend to the end line. On the 450-foot level of the Tuolumne mine the Jessie vein faults a hard quartz-pyrite vein that is rather lean and has a width of about 2 feet and displaces it toward the west on the hanging-wall side. The vein flattens eastward above the 400-foot level.

The specimens from the Jessie mine show secondary bornite mixed with tetrahedrite and chalcopyrite, or as stringers and veinlets deposited in a rotten and loose granite found in the fault breccia or forming the vein walls. Masses of mixed bornite, blende, chalcopyrite, and tetrahedrite also occur, and vugs in the vein show crystals of chalcopyrite and tetrahedrite coating the cavities. The ore is unlike that of the Gem fault vein in that it contains an abundance of bornite and a relatively small proportion of chalcopyrite and but little tetrahedrite; its physical texture and occurrence are also unlike that of the Gem mine. In general, however, the upper levels of the Jessie vein show many balls of rounded fragments of bornite, which were evidently torn off from some preexisting ore mass by the faulting, and which form the most conspicuous feature of the present vein. It is this occurrence of faulted ore which should have led to the finding of the great ore bodies on the 1,200 to 1,800 foot levels.

EDITH MAY VEIN.

The Edith May vein is a northwest fault vein lying south of the Jessie and greatly resembling the latter in its mineralization and general features. It has a steep southwesterly dip and shows an ore body on the 900, 1,000, 1,200, 1,600, and 1,800 foot levels. Like the other veins of this system, the Edith May has well-defined walls of almost unaltered granite, between which the fissure is filled with fault material in which lenses of ore occur. The main lens, so far discovered, has a maximum thickness of 30 feet and a length of about 1,000 feet, with a height as yet unknown, but certainly 600 or 700 feet. Between the ore lenses the vein is filled with dry crushed granite and clay.

The Edith May vein is peculiarly a chalcocite vein. Enargite is of rare occurrence and is found only in small vugs, associated with drusy quartz. Zinc blende, galena, and manganese minerals seem to be entirely wanting. Quartz and a small amount of pyrite are present. The silver content of the Edith May vein is just one-half that of the Jessie ore, that is, one-half ounce of silver to 1 per cent of copper, the ratio being very constant. The vein walls are well defined, one of them in many places acting as a boundary to the ore. (See fig. 80.) The country rock on either the footwall or the hanging wall may show two or more strong fissure planes cutting through the country rock parallel to the bounding planes of the ore body and thus constituting the ultimate and intermediate hanging and foot walls. The material between these outside walls and the ore is usually a bleached and much-altered and softened granite, little of which contains ore minerals. Like the Jessie vein, the Edith May shows vertical banding and includes strips and wedges of altered granite. Transverse fissures cross the ore body, and there is evidence of extensive crushing and movement, with rearrangement of vein material.

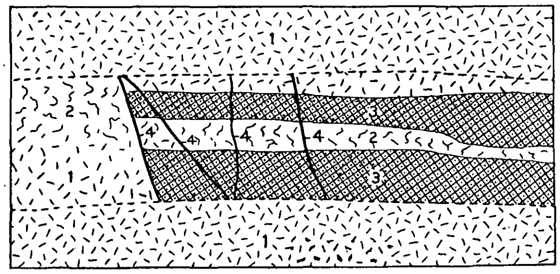


FIGURE 80.—Level on Edith May vein, showing abrupt change from high-grade ore to low-grade quartz-pyrite ore where vein is crossed by clay seam. 1, Quartz monzonite; 2, quartz; 3, high-grade ore; 4, fractures.

Although these two veins are comparatively close together and belong to the same system, they are quite different in the character of their mineralization, the Jessie vein having a preponderance of silver values and containing silver minerals with associated zinc blende and galena, and the Edith May being essentially a copper vein.

GEM VEIN.

The Gem vein is a well-marked fault fissure belonging to the northwest or Blue vein system. It has a well-defined, easily traceable quartz outcrop, barren of copper and recognizable for a distance of several thousand feet through unaltered granite. The vein varies in width from a foot or so up to 30 feet. In the Gem mine it was developed to a depth of 500 feet at the time visited. In the upper levels it contains much zinc blende and a little galena. Lenticular masses of ore formed in the fault fissure are composed of rhodonite, sphalerite, tetrahedrite, and chalcopyrite. (See fig. 81.) These lenses lie embedded in the fault breccia and occur most commonly where the vein rolls or shows enlargements due to rolls of the vein walls. From the surface downward to the 400-foot level the vein carried but little pay ore, the sulphide mass consisting mainly of sphalerite. In the lower levels an increasing amount of gray copper and of chalcopyrite were found. The only pay shoot observed was at the west end, where it was worked not only in the Gem mine but in the Jessie.

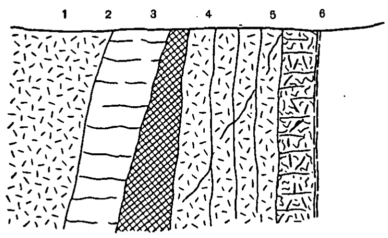


FIGURE 81.—Section of Gem vein, 400-foot level, fourth floor, 75 feet west of shaft. 1, Solid hard quartz monzonite wall; 2, quartz, crackled; 3, gray and yellow copper; 4, sheeted quartz monzonite; 5, crushed quartz with tetrahedrite and chalcopyrite; 6, black clay (½ inch).

The vein shows well-marked slickensides on the hanging wall, indicating a shifting along the wall as well as a vertical displacement. Where the vein fissure narrows to 6 or 10 inches across no ore occurs. Pay ore and water are markedly associated. The vein fissure contains rounded balls of bornite and other primary ores and appears to be a reopened and brecciated silver vein occupying a fractured vein of an earlier generation. A second and parallel vein lies a few yards to the south, but so far as exploration has indicated, is entirely barren of pay values.

On the 400-foot level two ore streaks are observed incased in clay and separated by 6 feet of sheeted granite that is devoid of clay. The ore shoots consist of crackled quartz carrying tetrahedrite, rhodochrosite, and chalcopyrite, with a silver content of 3½ to 4 ounces to each per cent of copper. The vein carries about 2½ feet of soft fault matter, consisting mainly of crushed granite, and the ore streaks are from 2 to 4 feet in width. Eastward on the 400-foot drift the vein shows a 2-foot streak of banded zinc blende and rhodonite, impregnated with copper; it carried about 2 per cent of copper and 5 ounces per ton silver. The west drift shows a 4-foot vein of mashed granite, with irregular lenses of quartz and rhodonite deposited in the fault fissure. The lode walls are very hard normal black granite. On the 500-foot level the vein has a width of 30 feet and is well defined by clay slips. In general it is a dry fault vein which in places is composed of a breccia of quartz fragments cemented by pink manganese.

The specimens obtained from the Gem mine show chalcopyrite and tetrahedrite in a highly-altered recemented material composed of crystalline quartz and altered granite. One specimen shows much purple fluorite and quartz, some of the latter occurring in a mixture of tetrahedrite and chalcopyrite. Masses of fluorite occur interbanded with white and dull-gray replacement quartz. The ore from the 500-foot level consists of an intimate mixture of mottled gray and white quartz, carrying mossy patches and grains of chalcopyrite, massive but not very solid, and showing no crystal outlines. In vugs in this ore chalcopyrite is observed coating quartz crystals and tetrahedrite coating the chalcopyrite. This tetrahedrite shows vitreous luster and well-marked cleavage and is massive and coarse, inclosing unreplaced fragments and mineralized particles of granite. The ore appears to be a replacement of crushed granite, probably part of a fault breccia. A little zinc blende is seen through the ore. On the 500-foot level the ore bodies may be regarded as solid endogenous ore deposited in a fault. Although the ore is original in this vein it has been shattered by later movement. The tetrahedrite shows patches and irregular broadly crystalline aggregates of chalcopyrite, these two minerals being interlocked with glass and white quartz. Vuglike masses of pinkish carbonates also occur. Specimens of the hanging-wall rock proved to be a highly altered granite, with large flakes of muscovite replacing the former biotite and hornblende, one with abundant cubes of pyrite, the balance of the rock being white sericitic material resembling clay. The rock looks porphyritic, but is merely a broken-down and altered granite. (See fig. 82.)

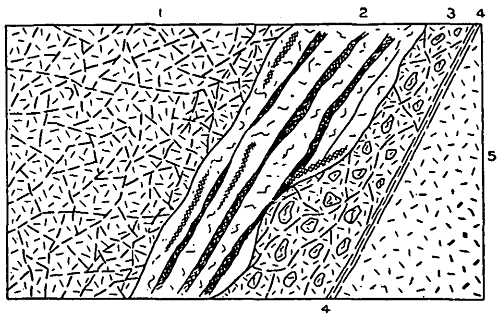


FIGURE 82.—Section of Gem vein, 400-foot drift, east face. 1, Mashed quartz monzonite; 2, quartz and pink manganese spar with streaks of gray copper ore, distinctly banded; 3, fault, mashed quartz monzonite and quartz; 4, clay; 5, quartz monzonite.

EAST BUTTE BELT.

GENERAL CHARACTER

The East Butte belt includes the Number Three mine, south of the Silverbow, and all the territory lying between Silverbow Creek and the Anaconda belt. The most extensive workings, aside from the Number Three, are those of the East Butte and Davis-Daly companies. The Montana Consolidated and other companies also own tracts in this belt. The principal mines are the Number Three, Glengarry, Ground Squirrel, J. I. C., Otisco, Anderson, Cambers, Oneida, Gopher, Lizzie (Hayes), Colorado, Belmont, Preferencia, and Green Copper. In general these properties have rich secondary pyritous ores for a few hundred feet below the surface, which change to lean and zincky quartz-pyrite ores in depth.

The deepest development work is in the Belmont mine, but both the Number Three and the Colorado mines have workings at a depth of 1,000 feet or more below the surface.

A large part of the southern part of the district is held by the Davis-Daly Copper Co., which has explored the ground by crosscuts from the deep levels of the Moonlight and Original mines, as well as from the Belmont, Smokehouse, and other shafts. The results of this work, so far as known to the writer, confirm the general conclusions primarily reached, viz, that this part of the district carries distinct, well-defined veins, but that the ores are zincky and carry only low values in silver and copper.

The belt shows several well-defined east and west quartz-pyrite veins. The Rarus and Blue veins cross the belt, and numerous lesser cross faults have broken the ground. These lesser fault veins have been developed in the Colorado, Belmont, and several other mines, but have thus far been disappointing to their owners. The ore produced in the belt has come mainly from the east-west veins, which show more or less crushing and alteration, with some soft black glance. The primary ore of the deeper levels is lean in copper, consisting of quartz and pyrite, with much zinc blende, the latter in places forming 30 per cent of the ore. In the crushed ground the lodes show relatively high silver values, but the ores are bunchy.

The veins show no evidence of an iron belt, or so-called zone of pyrite and blende, capping richer glance ores, and the deep development work in the Colorado (1,000 feet) and Belmont (1,800 feet) discloses only the same low-grade zincky pyrite veins found above

VEINS.

GLENGARRY VEIN.

EXTENT AND DEVELOPMENT.

The most important vein of the belt is the Glengarry, also variously known as the Ground Squirrel, Number Three, and Iron vein, the southernmost of the larger productive veins of the district. It traverses the low ground southeast of the Anaconda mines and immediately south of the Silverbow mine. The vein has been continuously worked underground from a point under Silverbow Creek westward for 3,400 feet through the Glengarry, Monitor, and Ground Squirrel mines to the J. I. C. mine, where it is cut off by the Rarus fault. Its continuation beyond this fault is not positively known.

The lode outcrops about 600 feet below the Mountain View shaft house. It has been opened in the Number Three mine to a depth of 1,100 feet, in the Glengarry to 800 feet (4,730 elevation), in the Ground Squirrel to 600 feet, and in the Harrington to 150 feet. Its average strike is N. 80° W. and its average dip is 50° to 60° S. Besides this, the main vein, there are two lesser veins 200 feet apart, which parallel it and are similar in character, and several smaller veins. In none of them do the richer copper sulphides extend downward more than 350 feet below the surface.

NUMBER THREE MINE.

In the Number Three mine the Glengarry vein has a general east-west course, with a somewhat curved strike. It belongs to the Anaconda system, being a typical quartz-pyrite vein, with an unusually large amount of pyrite. Its width varies from 8 to 20 feet, the ore merging into the wall rock, except where secondary fractures occur. In the east end of its course, under Silverbow Creek, the vein cuts through rhyolite porphyry, and in the Glengarry mine it traverses aplite, but elsewhere it is incased in pyritized granite. Through much of its known course the vein is free from strike faults, crushing, or clay selvages, and is remarkably regular in width, dip, and character; it, however, is displaced by several cross veins. The lesser vein south of the lode has parallel strike but steeper dip (averaging 80°), so that it rapidly diverges from the Glengarry in depth.

In both the Number Three mine and the Silverbow workings the Glengarry vein has been developed to a depth of 1,100 feet. It maintains an average thickness of 6 feet, with extremes of 2 to 14 feet, and dips very regularly at 65° from the 200 to the 900 foot level. In the eastern workings the proportion of pyrite increases until the ore carries but little or no quartz, with a decrease in the copper content to 1 per cent or less, except where fracturing and local enrichment occur. In general the richer ores extend 300 to 350 feet below the outcrop, occurring in bunches of wet and friable pyritic ore, blackened by soft "sooty" glance. In many sections across the vein it consists of two regular and well-defined seams of ore separated by a thin layer of pyritized granite. To the east the vein appears to join the Silverbow, whose dip is the same, but whose course is northwest. To the west the vein is continuously worked into the drifts of the Trerise shaft. The vein filling is massive and varies from the usual mixture of quartz and pyrite to nearly solid pyrite. The leaner parts show banding, and when cross seams of clay cut the ore chalcocite occurs.

The Glengarry vein in the Number Three mine is cut and displaced by several larger and numerous minor faults. On the 300-foot level the vein splits eastward into two narrow bands, separated by 1½ feet of pyritized granite, and it shows but 2 inches of ore, though 25 feet to the west it is 5 feet wide. Everywhere else it carries at least 10 inches of ore. On the 400-foot level and below the vein is a solid mass of pyrite, with scattered and disseminated quartz, which on this level is rather abundant, mostly white, opaque, and secondary. The sulphides show alteration, with films of black chalcocite on fracture surfaces. To the east the vein is oxidized down to the 400-foot level. The richer ore occurs where the vein is crackled and fractured, and in such places a bulbous expansion of the vein shows 15 feet of 6 per cent ore.

In the stopes a few feet above the fifth level the vein is quartzose and is crushed to a friable mass of white quartz and black sulphide, composed of disintegrated pyrite and freshly deposited glance. The vein on this level shows a footwall seam of clay a foot wide, with 4 feet of 16 per cent ore between this and the pyritic vein matter. As a rule this soft glance occurs in spots and bunches from the size of a pea up to 18 inches across, scattered through the mixture of quartz and pyrite. Enargite occurs scantily in streaks banding the ore where the vein has been reopened.

The Glengarry vein splits eastward and is cut and shifted by a fault of the Steward series, whose relations are well shown on the fifth level about 1,100 feet east of the shaft. The fault runs N. 80° W., and dips of 70° S. It displaces the vein so that the ends overlap 150 feet, the faulting being normal. The 700-foot level runs 2,000 feet east of the shaft and under Silverbow Creek. The inflow of water here is heavy, averaging 200 gallons a minute in 1905, and as the ground eastward is soft and wet further exploration is unlikely.

On the seventh level the rich ore is confined to local bunches and the vein generally consists of massive iron pyrite or of a mass of shattered pyrite, carrying much water, but devoid of copper glance. The eastern end of the workings on this level shows overlapping ore shoots of small size, pinching to clay slips. The vein is also crosscut from the 1,000-foot level of the Silverbow mine. The extreme eastern workings show 3 feet of pay ore in a vein 7 feet thick. The vein is mushy and wet. The same drift westward shows a vein 5 feet to 7 feet thick, of very uniform dip and character to the surface. On this level (1,000) a south crosscut shows the vein 800 feet south of the Silverbow vein to be 5 feet wide, with clay selvages on both walls. The footwall slip runs northeast and dips 70° S., whereas the vein dips 60° S.

GLENGARRY MINE.

West of the Number Three mine the Glengarry vein is continuously developed in the Trerise, Glengarry, Ground Squirrel, and J. I. C. workings. It is cut off and displaced by several minor faults.

In the Glengarry mine the vein shows the usual east-west course and a dip of 65° to 70° S. The width varies from 6 to 15 feet, with "swells" and "pinches" along its course. The filling contains an unusual amount of white quartz, in many places iron stained in the upper levels.

In the stopes the vein is 5 to 15 feet thick and is double, having along the footwall a thin band of pyritic ores less than a foot thick, separated by 8 feet of softened sericitized granite from a hanging-wall streak of pyrite, carrying enargite and chalcocite, 5 to 6 feet wide. Cross fractures making "spur veins" are seen on the 200 and 300 foot drifts.

The workings disclose a quartz-pyrite vein shattered and impregnated with enargite and chalcocite to a depth of 200 feet. These minerals become less and less in amount below that level, the vein becoming a solid mass of pyrite and quartz of remarkably uniform character and carrying but 2 to 3 per cent copper. The hanging-wall rock is highly altered several feet from the vein wall, but the footwall shows only slight decomposition, and that only for a short distance.

Two other veins 150 feet apart are cut on the 100-foot level, but show no pay ore. The first, cut 220 feet north of the Glengarry shaft, is a fault fissure a few feet wide, carrying only bunches of ore. The second is a pyrite vein 2 feet thick, cut some 50 feet north of the shaft and traversed by a strike fault.

GROUND SQUIRREL MINE.

The Glengarry vein extends westward into the Ground Squirrel mine, where it has been opened from three different shafts and developed westward till cut off by the Blue Vein fault and its sympathetic fractures, along which the drift turns northwest because these carry seams of rich ore.

In this mine oxidation has extended from the surface downward to a depth of 45 to 75 feet. The ore immediately underlying the oxidized material is black and consists of a friable aggregate of pyrite crystals coated by chalcocite. The ores of this part of the vein average 12 per cent copper and 13 ounces per ton in silver and nearly $1 per ton in gold; the richer portions carry 23 per cent copper and 53 ounces silver. The oxidized part of the vein consists of a somewhat iron-stained spongy quartz, carrying an average of 20 ounces silver per ton.

In the lower levels this vein shows no features of especial interest. The dip is 65° to 70°. The vein is 2 to 6 feet wide and shows the same double structure seen in the Glengarry. On the footwall three bands of altered granite—unreplaced parts of the sheeted zone forming the lode—carry veinlets of ore. Secondary fracturing of the vein by strike faults is shown by clay selvages and seams, which in places are 8 inches thick and are accompanied by seams of glance of equal thickness.

In general it may be said that the rich ores do not extend more than 50 to 60 feet below the 300-foot level and that the vein, though as wide or wider than above, consists of pyrite, with but little quartz and very little copper. The altered granite north of the vein is netted by veinlets carrying copper values. Cross faults are common, and in one case two parallel northwest fractures drop the vein between them, so that the drift shows no ore.

J. I. C. MINE.

In the J. I. C. workings the vein averages 7 feet in width and dips 70°. It shows the same characters as the Glengarry.

GEYMAN VEIN.

The Geyman shaft is near the Ground Squirrel. The Geyman vein lies about 300 feet south of the Iron or Glengarry vein, with which it is parallel. It is 5 to 8 feet wide and consists of crushed and altered quartz-pyrite vein filling, with rich glance and enargite ore in the upper levels, but the high values do not go down.

BELMONT VEIN.

The Belmont vein dips 62° to 67° S. It is a lean quartz-pyrite vein, 5 to 9 feet thick on the 800-foot Belmont and 8 feet thick on the 900-foot Belmont, showing streaks of pyrite and quartz in mineralized granite, the main quartz streak being 4 feet thick.

MINES.

OTISCO MINE.

In the Otisco mine the only ore developed comes from segments of an east-and-west lode, not yet identified, between the walls of the Rarus fault.

IDUNA MINE.

The Iduna mine is located immediately west of the Ground Squirrel mine, in southeastern Butte. The workings are confined to a single vein belonging to the Blue Vein system, having a northwest-southeast course and a pronounced southerly dip. The vein on the 100-foot level widens from a strong clay wall to a breadth of 12 feet, forming an ore shoot that had been drifted on (1905) for 100 feet eastward, and at the breast gave distinct signs of pinching to a clay wall. This shoot is composed of the characteristic copper vein minerals, chalcocite, enargite, pyrite, chalcopyrite, and more or less sphalerite. The chalcocite and enargite form the matrix of an ore extremely heavily laden with pyrite. The structure of the vein is well seen in figure 83.

The footwall and hanging-wall bands are rich in sulphides and quartz, and between them are numerous bands of fair definition where the body is distinctly an altered granite; the rest of the shoot is composed of varying amounts of sulphides and vein quartz. In places the vein has a very heavy clay seam, which has been developed by movement subsequent to the vein formation. It contains a large amount of broken or ground-up vein material and altered granite.

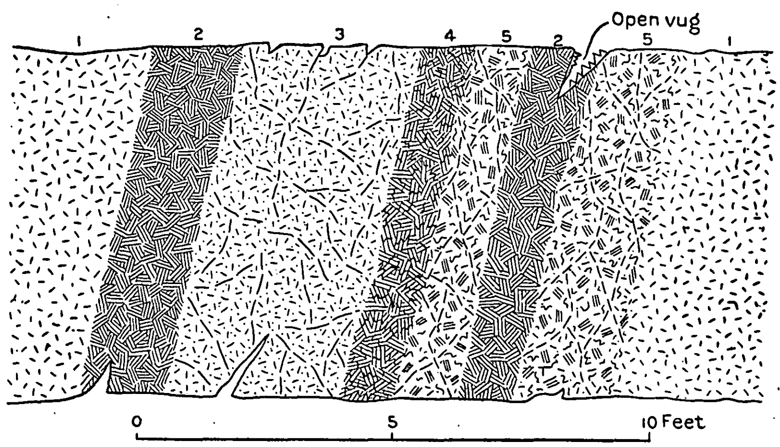


FIGURE 83.—Cross section of Iduna vein, 100-foot level; width, 6½ feet. Vein of ordinary type, with thin clay seam and notable enrichment on hanging wall. 1, Quartz monzonite; 2, pyrite; 3, altered quartz monzonite; 4, quartz-pyrite; 5, altered quartz monzonite, with quartz and pyrite.

COLORADO MINE.

The Colorado claim is south of the Baltic and the shaft is due south of the Blue Jay. Four parallel veins with a general east-west course cross the property. These veins have been penetrated by a shaft located in the extreme southeast corner of the claim which is over 1,000 feet deep, with north and south crosscuts on the 300, 500, and 1,000 foot levels. The first vein is cut at a depth of 45 feet, the second at 75 feet, the third at 230 feet, and the fourth at 300 feet. The veins dip 60° S., and consist of quartz and pyrite, with considerable zinc and very low copper and silver values. A long east level cuts several veins of the Blue Vein system at 210 feet and 500–540 feet east of the crosscut. These veins carry ore streaks from 1 to 2 feet wide, but hold only 2 or 2½ per cent copper. The property is now owned by the Davis-Daly Copper Co.

LIZZIE MINE.

The Hayes shaft, 750 feet due south of the Moonlight, develops a vein traversing the Lizzie claim, which is probably the vein worked in the Moonlight mine on the 1,200 and 1,300 foot levels. The vein, which runs northwest and belongs to the Blue Vein series, is from 2 to 5 feet wide and carries 2 to 2½ per cent copper, with much zinc. In the Moonlight drifts it is also narrow and bunchy. Similar veins are cut in Belmont 500-foot level. The crosscut running 2,000 feet south from the Original shaft on the 1,800-foot level cuts 30 feet of fault matter in a member of the Blue Vein series at 710 feet south of the Original drift, and other similar veins at 870, 960, 1,110, 1,590, and 1,730 feet south. These veins have not been seen, but according to the reports of reliable engineers carry only low-grade zinciferous ore.

CAMBERS MINE.

The Cambers mine is worked to a depth of 230 feet, connecting with the stopes of the Belmont mine. The Cambers vein has a general east-west course, with a flat dip of 30° to 38° S. It is from 2½ to 3 feet in width, with a hanging-wall gouge of 3 inches or more of soft and wet clay. In the upper workings the ore was quite rich, car samples from the 185-foot level showing 16 per cent copper and 13 ounces of silver. In general, however, the vein is of much lower grade, the ore from the 230-foot level, averaging between 3 and 4 per cent copper, with 3 ounces of silver. This vein is opened up and stoped continuously from the 100-foot level of the Cambers down to the 200-foot level of the Belmont. Near the Cambers shaft the vein is cut off westward by cross slips, the one on the 100-foot level of the Cambers having a course of N. 40° E. and a dip of 85° W., showing little over a foot of clay, with some pyrite, limonite, and copper stains. On the 100-foot level a northwest fracture, with a dip of 55° to 58°, shows and cuts off the vein on the west.

The ore consists of friable decomposing pyrite, with soft black chalcocite, and more or less sphalerite.

ANDERSON MINE.

The Anderson mine is situated in southeastern Butte, immediately south of the Belmont mine. It is 400 feet deep; a crosscut to the south extended 600 feet and showed only a small vein of pyritiferous nature. To the north a crosscut extended 250 feet, revealing more satisfactory conditions. The middle vein, which warranted exploration, was cut just south of the shaft, and its course to the east was explored for several hundred feet. It was notable only for its high per cent of pyrite; the copper content rarely exceeded 4 per cent.

HESPERUS MINE.

The Hesperus mine is situated in the Flat almost due south from the Anaconda. In the development work a vein striking east-west and dipping 60° S. was cut. This vein was nearly 8 feet in width and carried 1½ per cent copper, 1 ounce silver, and 30 per cent zinc. The granite which composes the country rock is to all intents and purposes free from alteration arising from mineralizing agents.

VALLEY MINE.

The Valley mine is immediately south of the Hesperus. At the time of visit a shaft had been sunk 80 feet. Two veins in the immediate vicinity have an east-west trend parallel to the vein system of the district. The main vein is 15 feet in width; its dip is 60° S. The vein minerals are principally silica, together with zinc, galena, chalcocite, and iron pyrite. Alteration of the granite is very slight.

HENRY GEORGE MINE.

The Henry George mine is north and slightly west of the Hesperus. The shaft was sunk not more than 50 feet at the time it was visited. No veins were encountered and it is mentioned chiefly because red oxide of copper was observed on the fracture planes of the granite. This oxide was not found in large amounts but is interesting because it is somewhat unusual in the heart of the Butte district.

ADAMS MINE.

The Adams mine is located just south of the Pennsylvania. Workings have been extended 300 feet below the surface and have cut three veins. The croppings of these veins are concealed, but their development underground shows them to be normal, with a course slightly south of east or north of west and a constant dip to the south. The northerly vein varies in width from 6 inches to 10 feet and the south vein up to 2 feet. Near the surface the veins, which are similar in character and mineral composition, have been found to carry a high percentage in silica and a profitable amount of copper. Both the copper and the silica diminish with depth, and at the bottom of the mine the mineral content is almost entirely pyrite. The size of the veins also markedly diminishes.

PREFERENCIA, GREEN COPPER, AND ALLIANCE MINES.

The Preferencia or Green Copper vein lies near the western portion of the belt, on the extreme southern border of the proved copper area. It extends through the Preferencia, Green Copper, and Alliance workings, striking east and west and dipping 65° to 80° S. Its average width is 5 feet, 3 feet of which is ore carrying 3 to 7½ per cent copper and about one-half ounce silver to each 1 per cent copper per ton. The lode is traceable for 1,000 feet or more across the Flat, and has been opened at intervals by shallow shafts.

Development work was stopped in 1906 by litigation. The Preferencia shaft is 125 feet deep and has developed 4 feet of ore for 100 feet along the drift west. The Green Copper shaft is but a few yards to the east. In the Alliance mine the vein has been developed by 235 feet of drifting on the vein on the 200-foot level and by 100 feet of drifting on the 300-foot level. It varies between 5 and 8 feet in thickness and carries 3 feet of ore averaging 2 per cent copper, 3 ounces silver, and 70 cents in gold per ton.

TALBOT & JONES CLAIM.

The Cosgrove shaft, on the Talbot & Jones addition, develops a flat east-west vein which shows 1 to 2 feet of good ore. This vein has a south dip of 45°, which carries it into the 500-foot west crosscut of the Silverbow No. 1 mine. In the Cosgrove shaft it is developed on the 170, 205, and 285 foot levels. The 205-foot level of the Cosgrove lies 220 feet above the 500-foot level of the Silverbow No. 1. The second vein lies 30 feet south of the former. It is from 4 to 8 feet wide and shows from 1 per cent to 10 per cent copper.

WASHOE MINE.

The Washoe mine is situated immediately south of the western extension of the Parrot; it appears to be upon the Blue Jay vein. A number of shafts have been sunk; those at the eastern end—the Wightman and the Washoe—have developed a vein which corresponds in position and mineral content to the Bellona. (See p. 121.) A spur vein has a general course considerably more to the south of east.

GOLD HILL MINE.

On the Gold Hill claim, which is immediately south of the Washoe, two shafts have been sunk. These have developed but a single vein, which appears to be a westward continuation of the Blue Jay vein. It has a normal course nearly due east and west and dips between 65° and 80° S. In places it is 10 or 12 feet in width, but its average is probably under 5 feet.

The characteristic mineral of this vein is sphalerite. Quartz and galena also occur. The percentage of copper is almost invariably below the pay limit.

MOUNTAIN VIEW-SHANNON-COLUSA BELT.

The Mountain View-Shannon-Colusa belt extends from the Mountain View fault to the edge of the flat north of Meaderville. It is traversed by the once continuous Shannon and Colusa-Leonard lodes, which with others are worked in the Mountain View, Colusa, Leonard, and other mines.

MOUNTAIN VIEW MINE.

LOCATION AND CHARACTER.

The Mountain View mine is located on the summit of Anaconda Hill, north of the St. Lawrence mine. The workings (1,400 feet deep in 1905) have developed a network of veins, embracing the Mountain View south vein, which is an eastern dislocated segment of the Anaconda lode; the Shannon, a member of the Anaconda system; the Johnstown (north connecting), a northwest vein; and a number of minor north-south veins belonging to the Mountain View system (p. 202). All these veins are cut and displaced by the Mountain View fault vein and by other members of the Blue Vein system, as well as by others of the later Steward system, with accompanying enrichment of the ores.

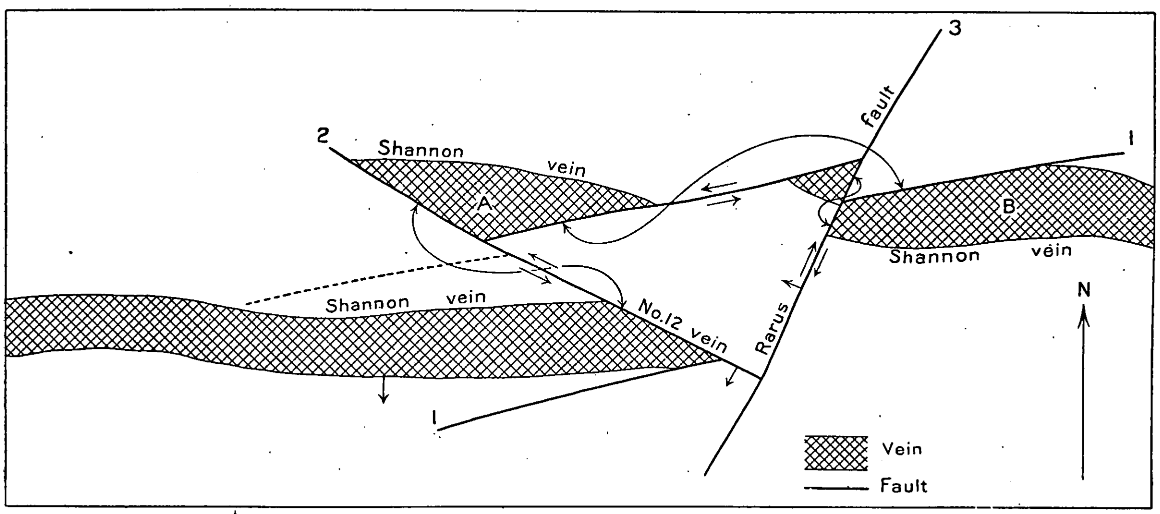


FIGURE 84.—Shannon vein cut into blocks by Blue Jay fault, No. 12 fault vein, and Rarus fault.

The mine has been a heavy producer for many years, the ore supply coming for a long time from the Shannon, the most northerly vein of the mine, from the two veins of the Mountain View south (Anaconda) lode, and from the Johnstown vein. Since 1905 the ground between these veins has also been productive, and great ore bodies have been found along the fault fissures. This network of veins is well shown in the vein maps, particularly the one showing the 5,100-foot plane. Figure 86 also shows the relations of the veins of the Mountain View mine to those of the Rarus and Pennsylvania.

The surface outcrops of the lodes are not readily traceable, as the zone of oxidation is deep, extending generally to the first level, 500 feet beneath the surface. The vein filling in this zone is a coarse spongy-textured quartz, more or less iron stained, but containing residual unaltered masses of pyrite and carrying from 2 to 4 ounces of silver per ton. It is a notable fact that the enargite ores are less oxidized than the glance-pyrite ores, both in the Johnstown and Shannon veins. In the latter a pillar of fresh or but slightly altered enargite ore 50 feet wide extends upward for nearly 200 feet through leached and barren oxidized material.

SHANNON VEIN.

GENERAL CHARACTER.

As exposed in the Mountain View mine, the Shannon (north) vein consists of a group of overlapping blocks, separated by fault fissures, producing an échelon structure. The vein narrows and is apparently dying out in the west end of the mine, but throughout the main workings the ore-bearing zone is 10 to 40 feet wide and shows remarkably little barren ground. The vein has a steep southerly dip, varying from 70° to 90° in different parts of its course; in the 1,000-foot level and for 60 feet below it dips north.

Though considered a member of the Anaconda system the Shannon has a general course of N. 70° E., the same as the fault veins of the Steward system. The dislocations due to cross faulting have not only shifted large blocks between the major faults, but have also produced many minor changes in direction and curves.

The vein shows well-defined walls, whose ore is separated by clay seams, developed during the adjustments accompanying block faulting. The vein filling is quartz, carrying pyrite, with some glance and considerable enargite. In the lower levels the latter is the main copper-bearing mineral.

The Shannon is abruptly truncated westward by a northwest fault near the Mountain View shaft, the displaced lode west of this break carrying ore for a few yards and then changing to a barren friction breccia.

The Shannon has been continuously worked for 2,000 feet eastward from the Mountain View shaft, increasing in width and richness eastward. It is undoubtedly continued in the Colusa lode, but as a big northwest double cross fault (the Gambetta-No. 12, which is probably equivalent to the High Ore) separates the two portions by a displacement of between 200 and 300 feet, the names used by the miners of the district are retained. Figure 84 shows the fault blocks as disclosed underground.

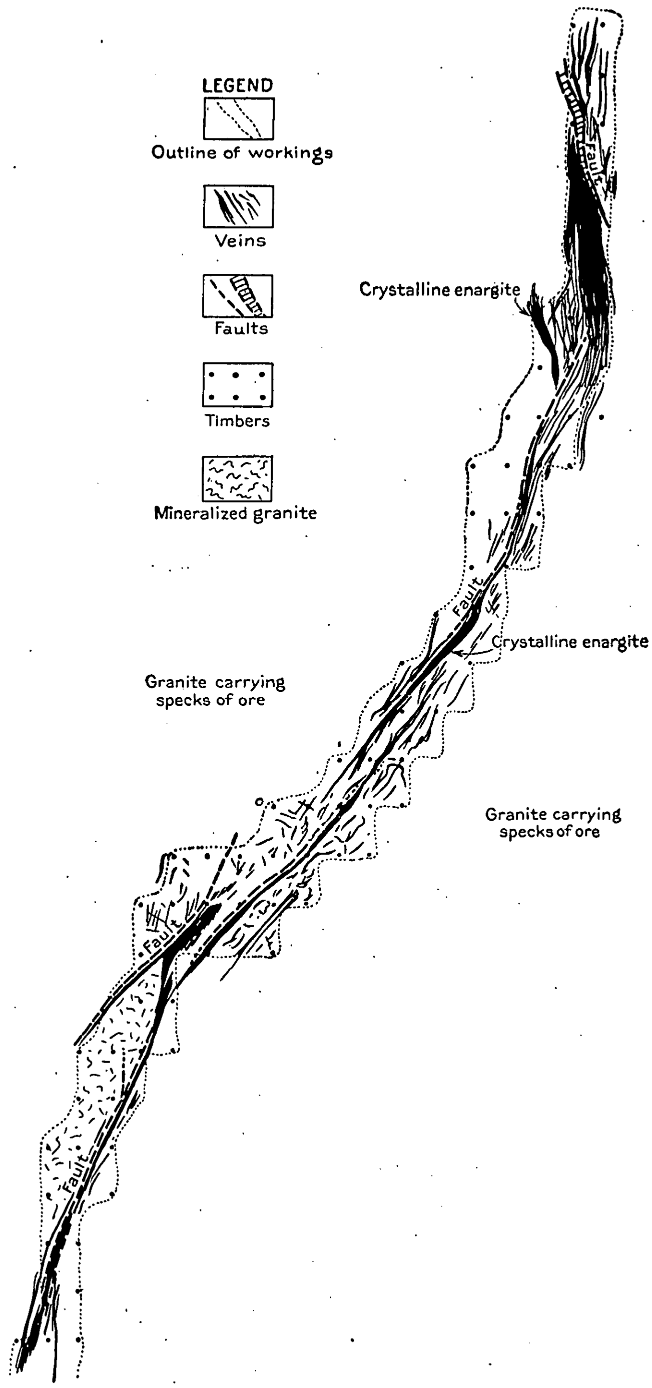


FIGURE 85.—Section in West Colusa mine, 323 raise, showing character of Colusa vein.

Eastward, in the West Colusa mine, the vein expands into an ore body 60 feet wide and minable from the 200 to the 400 foot levels, but its values give out, except on the footwall

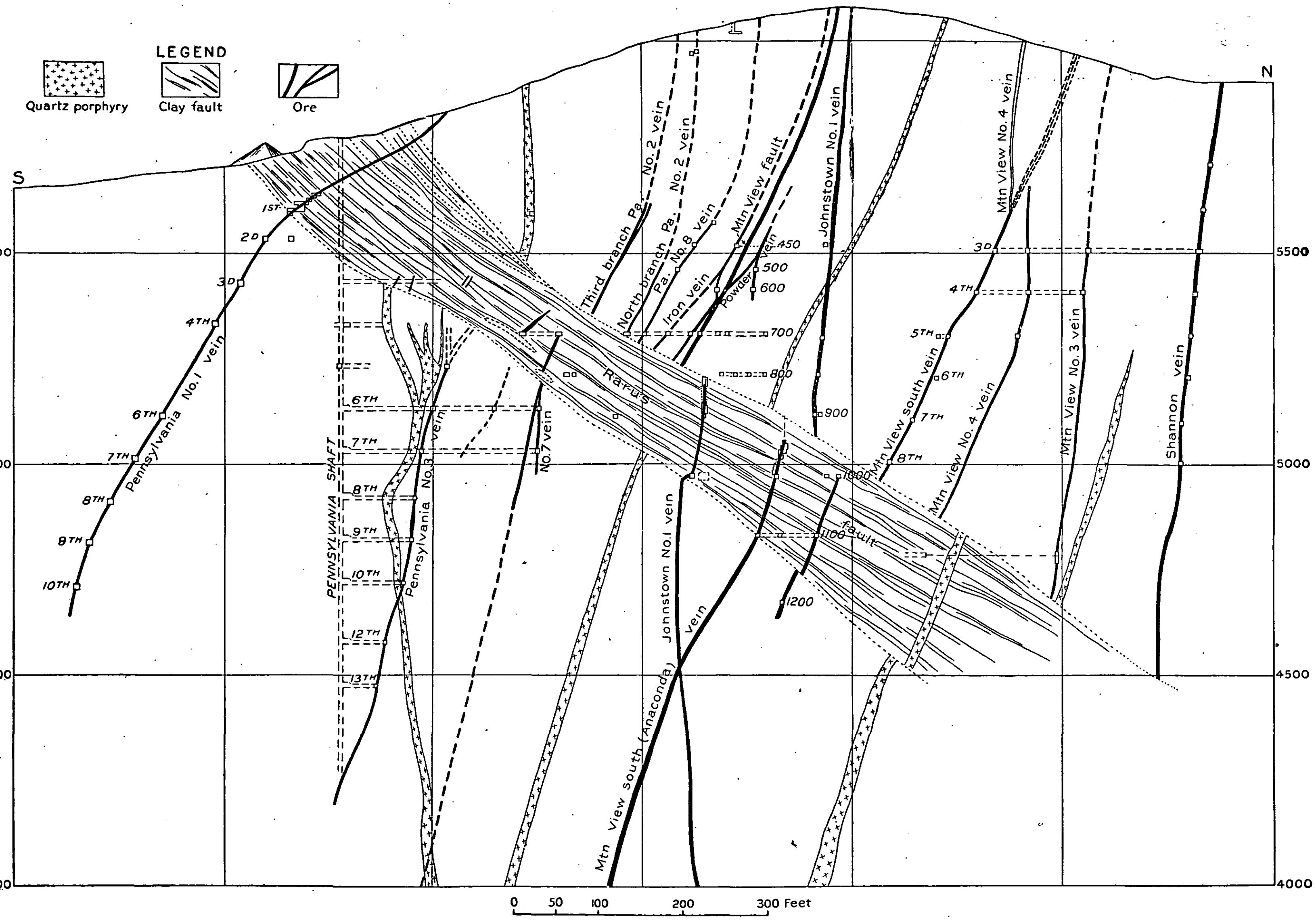


FIGURE 86.—Cross section through Mountain View, Rarus, and Pennsylvania mines.

streaks, below 400 feet, probably because the glance enrichments of the "spray" do not extend downward. In the upper levels of the West Colusa mine the Shannon ore body is a great mass of enargite ore in a crushed quartz-pyrite vein. Solid enargite occurs on the footwall, but the ore body is crossed by northwest (not north-south) streaks, carrying quartz-

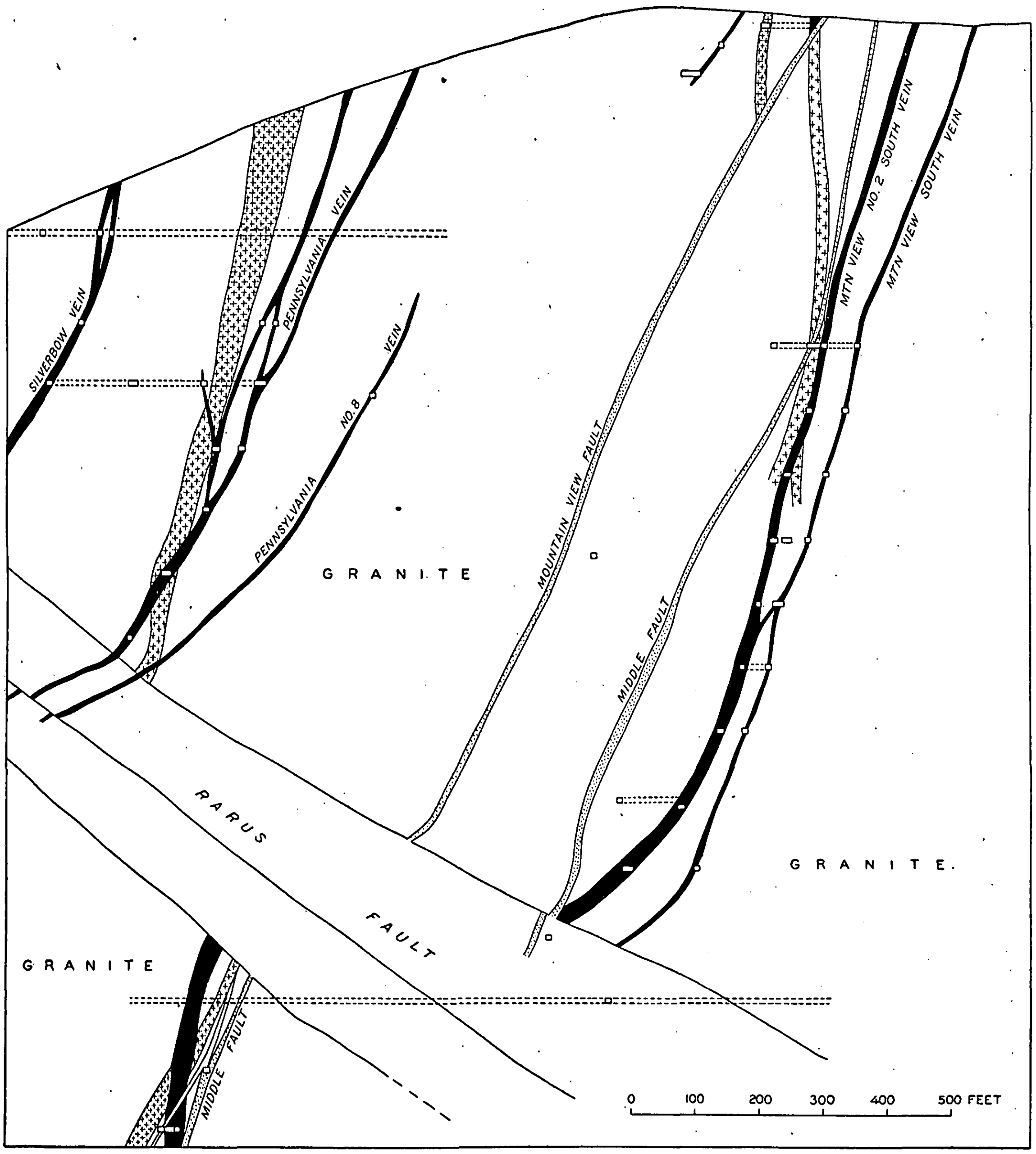


FIGURE 87.—Cross section through Pennsylvania mine.

pyrite filling that shows soft black glance coating the pyrite. The ore body must be the result of rock shattering following an older vein, with mineralization confined to upper levels. (See fig. 85.)

Near the Mountain View shaft the Shannon lode is but 2 to 5 feet thick, but it widens eastward by spur or branch veins to 15 to 25 feet, and maintains this thickness in the great ore body stoped out above the 900-foot level. (See figs. 86 and 87.)

These spur veins carry high-grade glance-enargite ore, and as the intervening granite is altered and impregnated with particles of ore, the entire mass is workable (fig. 88). Not all the veinlets are fault veins, for many of them do not cross the lode but are the result of the settling of the hanging-wall block over the Blue Jay fault.

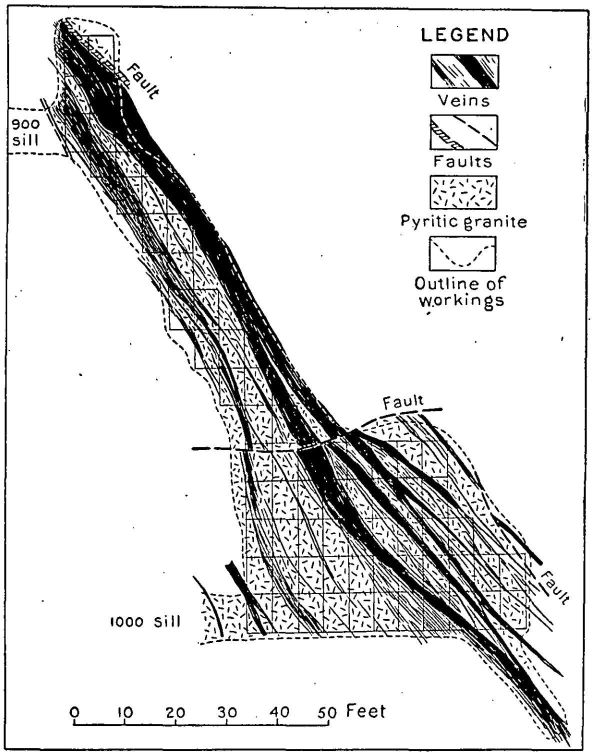


FIGURE 88.—Section of Mountain View south vein, showing streaks of first-class ore, consisting of quartz, enargite, pyrite, and chalcocite, with a little bornite and tetrahedrite, 1,055-foot raise.

The ore body is peculiar and unlike anything else in the district except the Leonard (see p. 211), which is regarded as a faulted part of the same mass.

In the Mountain View mine the continuity of the vein is destroyed by three veins, the Smelter, Sullivan, and Combination, considered by the writer to be members of the Blue Vein system. These cross veins are ore-bearing in the deeper levels, but lean or unworkable for the first 500 feet or more beneath the surface.

FAULTING.

Noteworthy in the workings on the Shannon vein are the northwest faults which terminate against the east-west faults. An example of this is seen on the second and third levels of the West Colusa mine; the true relations being very well shown in the stopes on the fourth level, where it is quite clear that the diagonal northwest fault does not extend beyond the Shannon vein. A reasonable interpretation appears to be that a block of ground of pyramidal shape, with its apex downward, has been moved as a result of faults. The north wall of this block is a hanging-wall fault of the Colusa vein. The south wall is a more or less vertical fault cutting through the Shannon on the upper levels. In depth the intersection of these two walls advances eastward and meets the Rarus fault somewhere about the seventh or eighth level, forming the apex of the pyramid. The east side of the pyramidal block is the Rarus fault. The block appears to have been produced by a thrust upward. A crushing pressure would cause such a block to move upward, and a relief of pressure would allow it to drop downward. The great abundance of crushed granite could hardly be explained on the basis of a settling of the block, even were its weight to rest against irregular sides, with more or less tearing off of irregularities. Moreover, the fault shows on the first level that ore has been dragged north from the Shannon vein, whereas settlement would have caused an eastern and southern drag. The faulting of the Shannon ore body is marked only on the three uppermost levels.

Such an upward movement might be the result of a strong north-south pressure or of a thrust from the east. The latter would force the wedge westward and upward but would also have left its impress upon the country rock on each side of the block in question and would not have produced such differential motion.

MOUNTAIN VIEW SOUTH VEIN.

The Mountain View south vein, the greatest ore producer of the Mountain View mine, is the extension of the Anaconda lode east of the Mountain View fault. It shows the usual pyritous siliceous quartz vein filling, with good definition between ore and country rock on the footwall, and a steep southerly dip conformable to that of the lode in Anaconda ground.

It extends eastward to the west wall of the Rarus fault, where it is abruptly truncated. (See fig. 89.) The vein has the typical character of the Anaconda in mineralization, structure, direction, and dip. It is a double vein, but the branches appear to split up and play out eastward and are not recognized east of the Rarus fault, except in the deepest levels opened.

In the Mountain View ground the lode differs from the other veins, usually lacking much enargite but being rich in pyrite and chalcocite, and also carrying bornite. It is cut by the Blue Jay fault vein with but slight displacement, but is broken, with considerable cracking, mashing, and subsequent enrichment and the formation of much clayey matter, which masks its original character. On the tenth level (fig. 90) the ore consists of crushed and crackled quartz and pyrite containing considerable enargite. The vein is somewhat vuggy along fracture planes, but has neither round nor large cavities. The chalcocite occurs in thick, persistent seams and bunches (see Pl. XVI, *A*) and is solid and unshattered. Enargite, though persistent, does not form continuous streaks but is associated with small bunches of white quartz and in films and seams in the masses of altered and crackled granite included in the vein. It is clearly a later mineral.

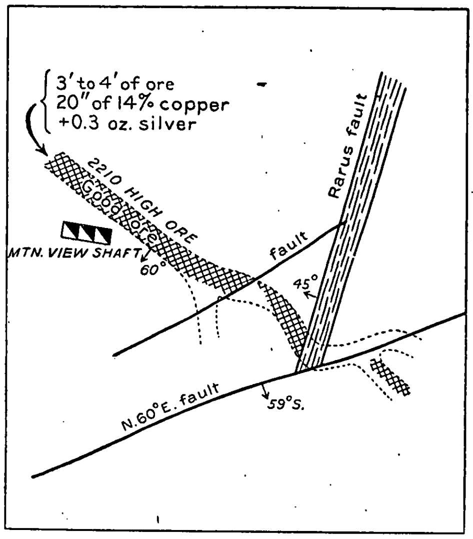


FIGURE 89.—Truncation of Mountain View south vein by Rarus fault, 2,200-foot level of High Ore mine.

The relation between the Mountain View south lode and the rhyolite porphyry is shown on the fifth level of the mine, where the lode cuts through a dike, with impoverishment, narrowing, and splitting of the vein. The footwall or north branch of the vein runs parallel to the Anaconda lode, but the southern branch has a southwest course and shows westerly spurs making off on the north side. The Mountain View fault cuts across the narrowest part of the lode, so that both in the St. Lawrence and Mountain View ground the vein apparently thins near the fault. The tenth level shows the branching very clearly, No. 1 being north and No. 2 south. The vein is double eastward to the Blue Jay (Middle) fault, but single beyond it.

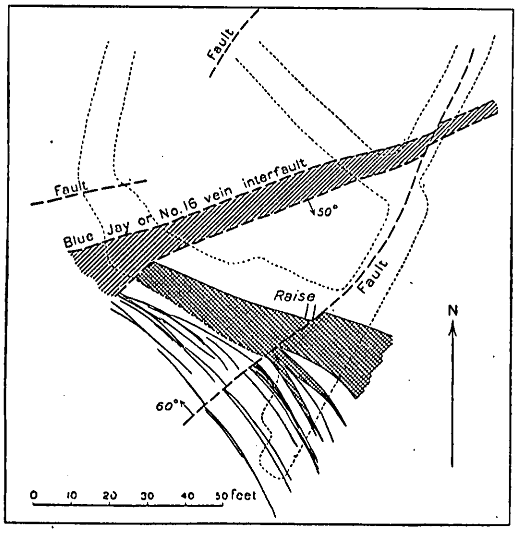


FIGURE 90.—Truncation of Mountain View ore body by Blue Jay (No. 16) fault, tenth level, Mountain View mine.

The vein has been very productive but throughout the workings shows crushing and fault movement, with fault clays and breccias, so that it is difficult to assign the proper importance to the old lode itself. The complex relations of the vein to the Blue Jay (No. 16) fault and to the Rarus are shown in figures 89 and 90.

JOHNSTOWN (NORTH CONNECTING) VEIN.

The Johnstown (North Connecting) vein runs parallel to the Mountain View fault. It varies somewhat in character in different places but is essentially an old quartz-pyrite vein, the quartz carrying pyrite masses and little veinlets.

In Mountain View ground it is narrow, carrying 16 inches to 2 feet of ore, with rather irregular walls of hard, pyritic granite. On the 500-foot level it shows no talc and no enargite, but to the southeast it carries enargite in scanty amount, though it is not a fault vein and seems to lack any fault clay or crushing. It gets poor and tight to the northwest. It dips 72° S., and farther east, near the Rarus fault, it has a good wall, with selvage and good ore. On the 500-foot level it dies out before reaching the Rarus fault. Within the Rarus fault it is not definitely recognizable.

East of the Rarus fault the Johnstown is correlated with the Windlass vein. Here it has a dip of about 80° S., and an average width of 8 feet of vertically banded quartz, abundant pyrite, and some enargite. The north end of the vein, 150 feet from the main crosscut of the mine, is sharply cut off by a fault running easterly. Beyond this fault the vein has not proved workable.

The Johnstown is essentially an enargite-bearing quartz-pyrite vein in which the rich ore occurs in lenses within clay walls. As it is nearly vertical, while the South ledge or Anaconda has a dip of 60° S., the veins must intersect in depth. It becomes narrow, pyritic, tight, and lean, and loses its clay walls as it nears the cut-off by the easterly fault on the fourth and fifth levels. Its course is parallel to a porphyry dike about 50 feet south. From the company records it appears that it carries 6 feet of glance ore on the tenth level, gradually changing upward to enargite, the third level showing practically no glance. This is contrary to the conditions

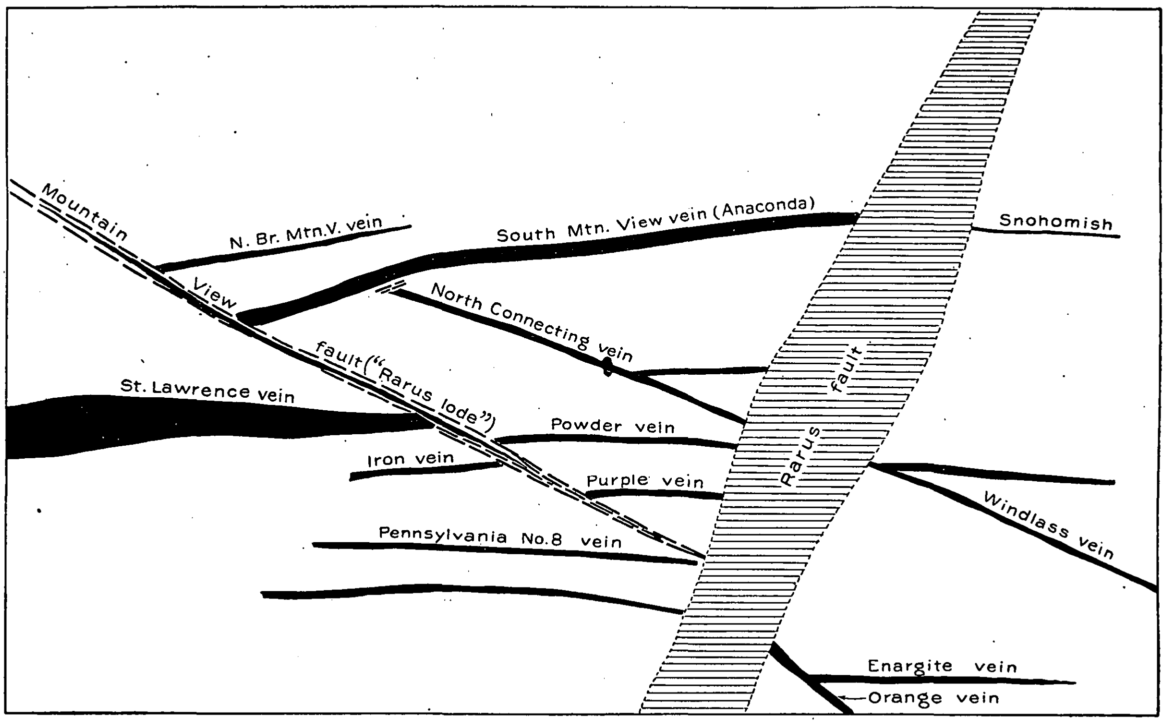


FIGURE 91.—Diagram showing relative positions of veins and faults of the Mountain View and Rarus mines.

prevailing in other veins. If the descending copper-bearing waters contained arsenic it is easy to see how they would become more and more basic or reducing in their descent and would therefore deposit glance above and enargite below.

MOUNTAIN VIEW AND BLUE JAY FAULTS.

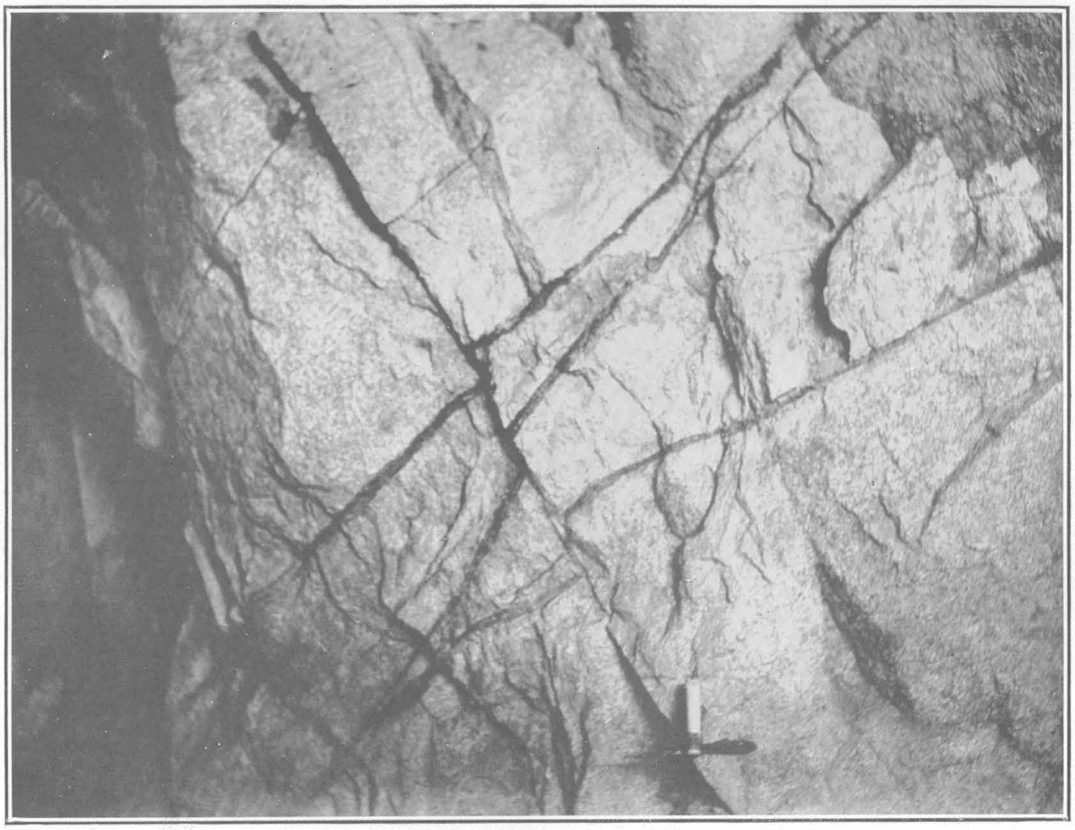
The Mountain View and the Blue Jay faults have already been described (pp. 142, 152). They are structurally and productively important features of the Mountain View property. Their relations to the veins of the Mountain View area are best understood by reference to figure 91.

MOUNTAIN VIEW SYSTEM VEINS.

The different crosscuts driven south from the shaft of the Mountain View mine to the main south ledge afford excellent sections of the granitic country rock and of the lesser fractures which traverse it. (See Pl. XVI, *B*.)

A. SMALL VEINS OF PYRITE IN GRANITE.

Mountain View mine, 1 100-foot level, South or Anaconda vein. Veinlets are slightly displaced by secondary fracture plane, which is nearly parallel to main vein, but pyrite veinlets follow joint planes nearly at right angles to main vein. They diverge, cross, and converge again, as do the seams which make up the large veins. Light part is vein granite; streaks are pyritous veins low in copper. Vertical slip planes separate vein from impregnated country rock. See page 201.



B. FAULTED VEINLETS OF CHALCOCITE AND QUARTZ-PYRITE ORE.

Mountain View mine, 600-foot level, south crosscut, north vein, east vein.

One set of the fractures strikes about N. 35° W. and dips about 80° S. These small fractures are occupied by hard quartz-pyrite veinlets from 2 to 6 inches wide. They supposedly represent the earliest period of fracturing of the granite. The sections do not show conjugate fracturing, the dip being always to the south and varying from 60° to 80°; the strike varies from 30° to 45° west of north.

The earlier fractures are faulted by a multitude of fault fractures belonging to the Mountain View system, which run from N. 70° to N. 90° W. and stand nearly vertical. These faults are filled by crushed, finely ground granite, forming a claylike paste, containing numerous pebbles of pyrite ore and some slabs or dragged particles (Pl. XVII, *A*), up to 6 inches in diameter. They vary greatly in width, running from one-half inch up to 2 feet or more. A few of these Mountain View fault fissures are themselves fractured by a later movement which follows along the earlier pyrite veins; but in general this movement appears to have been slight and the dislocation insignificant. They are considered to be the result of contraction and perhaps of settling.

The number of fault fractures increases with depth, and the number of pyrite-filled seams appears to lessen. Water follows these fractures, depositing considerable limonite on the 1,200 and 1,300 foot levels, but this seems to be a case of surface water draining downward because of the artificial opening. As with the Parrot seams these fault fractures, whose prevailing course is about N. 75° W., have a southerly dip, in places as flat as 65° and in places approximating the vertical. These fractures are all in the footwall country rock of the Anaconda vein, here known as the Mountain View south ledge.

The north-south veins of the Mountain View system developed in the West Colusa, Mountain View, and Rarus ground are of comparatively recent recognition. They form narrow but rich enargite-glance veins in granite, with little or no quartz, but inclose angular fragments and balls of pyritized granite. A good example is seen in the 1,203-foot north crosscut of the West Colusa. They are not so rich above the Rarus fault as they are below it, which probably accounts for their retarded development. Beneath the Rarus fault they appear close together; in the Leonard ore body the entire mass between the veins is taken out, particularly within the Rarus fault, whereas above the Rarus fault only the individual veins can be worked.

COLUSA-LEONARD LODE.

EXTENT.

The section of the district containing the Colusa, Leonard, and Minnie Healy mines is traversed by a maze of connected veins, forming a productive zone that might well be considered one great lode. The northern limit of this zone is the Colusa vein, and its downward (south-faulted) continuation in depth, the Leonard. The Tramway vein delimits it on the south. Eastward the productive area extends as far as Silverbow Creek in the upper levels, but falls more and more short of that boundary as depth is gained. Westward the mines and veins terminate against or merge into those of the Mountain View mine. This area is not only traversed by well-defined veins and cross veins but is shattered by a network of fractures now filled with ore, so that in places all the ground between veins is workable.

COLUSA LODE.

GENERAL CHARACTER.

The Colusa lode, one of the great veins of the camp, is a northeast and southwest vein, with steep northerly dip and a thickness varying from 10 to 40 feet or more. It is an enargite-glance vein, which may be regarded as the "trunk" vein of the belt, as it is the one from which the others seem to diverge. It is large, even for Butte, being worked for a length of 2,400 feet in stopes 20 to 40 feet and, in the fault section, even 150 feet wide. It is continued westward beyond the Gambetta fault as the Shannon vein.

The course of the Colusa vein at the surface is easily traceable. At one place it outcrops strongly as a rough spongy limonite, almost the only good limonite cap found on any of the productive veins. Generally the footwall is well exposed, owing to movement and settling over the old workings, the entire hanging-wall block for several hundred feet out from the foot wall having settled, with serious disturbances of the surface and damage to buildings and machinery. The footwall granite is solid and is unfractured save by the usual joint planes. The alteration of the wall rock is relatively more pronounced on the south or hanging-wall side of the Colusa vein.

The vein has been mined to a depth of 1,400 feet, its downward extension beneath the Rarus fault being distinctly recognizable, though it merges into the Leonard stockwork. Its general course is N. 65° E., but several cross faults and minor fractures have deflected the vein from its normal trend. The dip is steep, averaging 75° down to the walls of the Rarus fault, but the vein is flat through the fault, resuming its steep inclination beneath it. The vein varies between 20 and 50 feet in thickness, except in the flat interfault ore bodies connecting the Colusa and Leonard veins, where the stopes are wider, and has been worked for its entire width.

The lode is a normal quartz-pyrite vein, which, with the crushed country rock accompanying it, is netted with streaks of enargite, pyrite, and chalcocite, and by numerous clay slips and seams. Little solid uncrushed ore is found, for adjustments since ore deposition have been marked and vigorous. Enargite is the most prominent mineral, but on the upper levels chalcocite is equally abundant.

Rhyolite porphyry, part of the Modoc dike, forms the footwall of the lode for a few hundred feet, both vertically and horizontally, near the East Colusa shaft. The granite accompanying the lode is generally well sericitized and peppered with pyrite. In places it appears completely altered to a clay-like mass, in which the original minerals have entirely disappeared, but the granitic texture is still recognizable. As would naturally be expected from its structure, the lode is wet and yields a heavy flow of water, especially where rich secondary ores are found.

FAULTING.

The crushed character of the lode is due to movement along various strike and cross faults. These faults belong to the three systems recognized throughout the district, but the northwest or Blue Vein system is the most prominent and has produced the most profound changes. A great double fault (the Gambetta and No. 12 veins), belonging to this system, cuts off the Colusa on the west and separates it by a shift of nearly 300 feet from its continuation in the Shannon. (See fig. 84 and p. 200.) The Rarus fault cuts through the Colusa and all its neighbors, and the movements along it have further crushed a lode already shattered and altered by cross and strike faults. To the Rarus, moreover, is due the production of the peculiar flat ore bodies which have been observed generally along its course and which are particularly large and important along the Colusa-Leonard lode. Fissures belonging to the Blue Jay system also appear.

The relations between the Colusa and the adjacent veins is well shown in the horizontal section along the 5,100-foot plane (Pl. XXXVI), in which the Colusa is shown to form the trunk lode, with the No. 12, Piccolo Discovery, Gambetta No. 2, and No. 8 veins, apparently branching or diverging from it on the south. These correspond to the Gambetta, Minnie Healy (Betty), and Piccolo fault veins below and east of the Rarus fault zone.

The structural relations of the various veins are best understood by reference to the plans and cross sections through the rather complex group of veins (figs. 92 to 97). Minor fractures are omitted, owing to the small scale used, but there is a marked breaking of the veins by a multitude of cross fissures varying from mere joints to clay and breccia filled fissures, some of the larger of which carry ore: Many streaks of rich ore come up to these cross slips and stop, and though the vein continues with slight displacement it is comparatively lean immediately west of the slip. These fissures are abundant for a few hundred feet on either side of the West Colusa shaft, where the vein shows a marked curve in its course. The strike faulting, on the

A. FAULT BRECCIA, MOUNTAIN VIEW MINE.

Shows cross slips and ore bowlders in north crosscut, eleventh level. Breccia 45 inches wide. See page 203.

B. MINERALIZATION ALONG JOINTS IN GRANITE.

Rarus mine, south crosscut, seventh level. Incipient vein formation, veinlets of quartz and pyrite. See page 224.

other hand, is later than the cross faults, and, though movement along its plane has not been pronounced and has not brecciated the vein, it has broken it and formed the crushed mass of ore and granite that constitutes so large a part of the ore shoots.

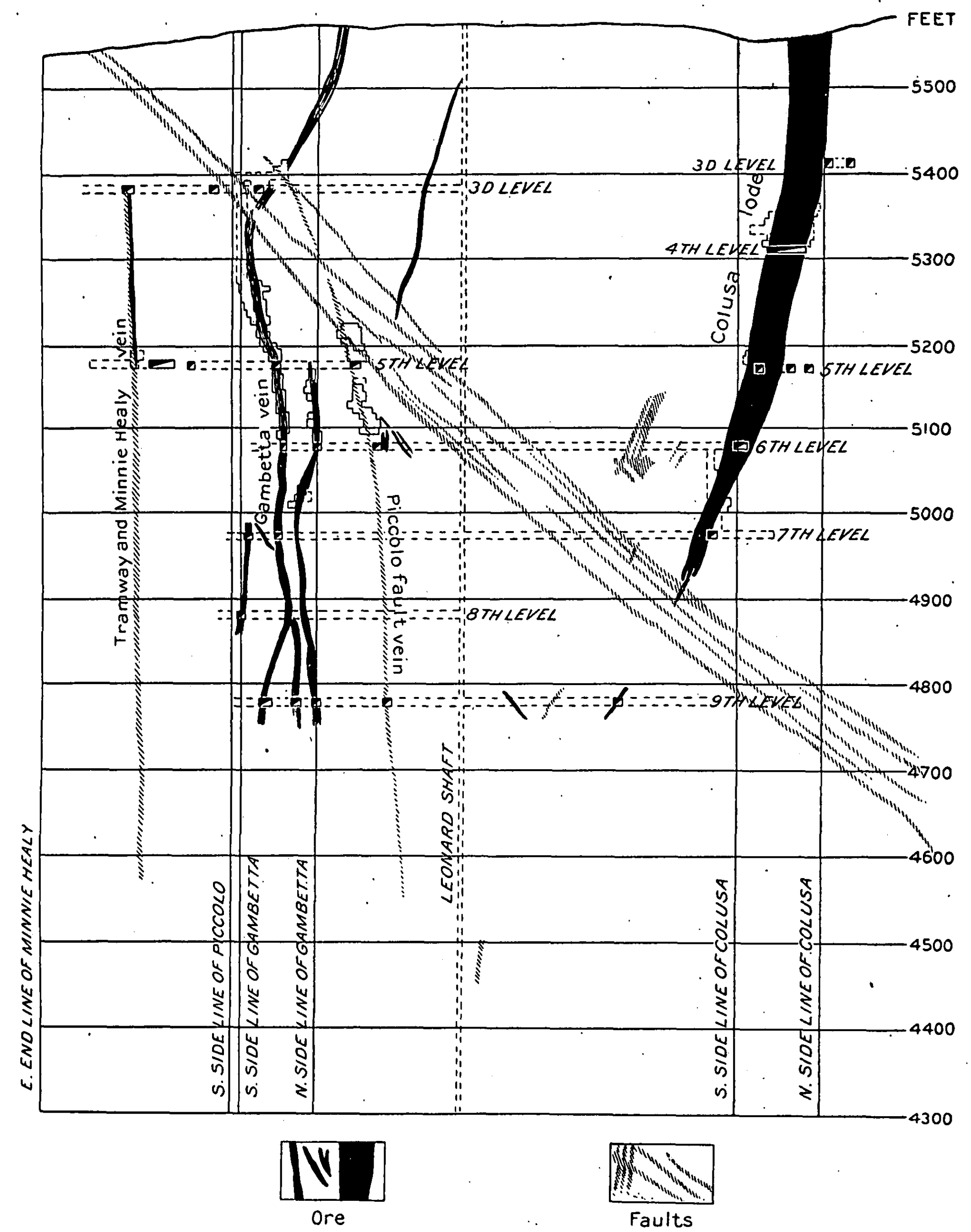


FIGURE 92.—North-south cross section through Leonard and Colusa mines on 5,100-foot coordinate east.

BLUE VEIN FRACTURE SYSTEM.

The most interesting features of the lode are the northwest fractures of the Blue Vein system, which appear to be southeast extensions of these so prominent in the Bell, Diamond, and Greyrock mines. Very generally the minor fractures cut off the rich ores westward, and even where displacement is not noticeable the lode west of the fracture is lean (fig. 93). The combined effect of the lesser slips near the West Colusa shaft is to give a curved course to the lode.

NUMBER 12 FAULT VEIN.

The largest of the northwest veins of the mine is the No. 12. With the Gambetta, a parallel vein 100 feet farther west, it cuts off the Colusa vein and separates it from the Shannon vein on the west. Both faults are nearly vertical and are parallel to the Skyrme vein of the High Ore mine. They cut and shift the Shannon ore body in the Mountain View mine (p. 196).

The No. 12 vein is ore-bearing in some places and has been worked. It is well exposed on the 200-foot level of the Colusa mine and on several of the underlying levels above the Rarus fault (figs. 94, 95). To the west it is abruptly truncated by the Rarus fault, but is probably continued beyond by the Minnie Healy (Betty) vein. On the 200-foot level of the West Colusa mine it cuts the Colusa vein and apparently displaces it slightly, but the main displacement is by the parallel Gambetta fault.

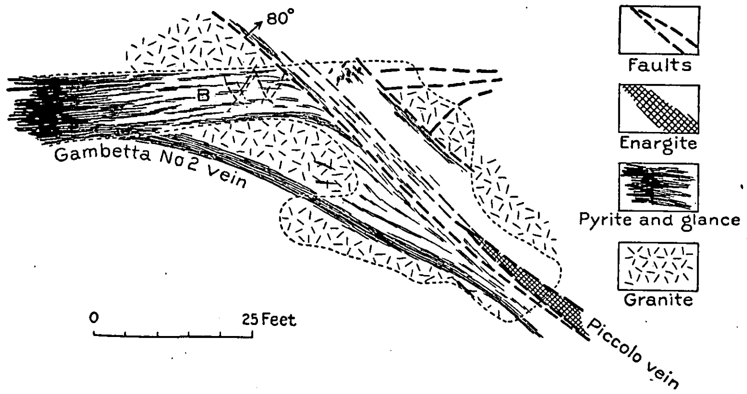


FIGURE 93.—Loss of value in vein approaching fault vein. Leonard mine, 500-foot level, near 514 chute; Gambetta vein cut by Piccolo vein.

GAMBETTA VEIN.

The Gambetta is one of the principal veins of the Leonard mine. It lies beneath the Rarus fault, above which its upward extension is called the Gambetta No. 2. Downward it enters into the complex forming the great stockwork of the Leonard lode. (See fig. 94.) It is a nearly vertical vein, having a thickness of 5 to 25 feet, and a strike of about N. 75° E. In vertical cross sections it shows considerable variation in dip, its course being somewhat sinuous. It is characteristically a fault vein, which in part follows an old quartz-pyrite vein, but in the main consists of crushed granite, with streaks and impregnations of enargite. The vein has an average of about 3 feet of first-class enargite ore. Close examination shows included wedges of granite, with fragments of quartz-pyrite ore belonging to the earlier vein filling; the workings show, however, that the vein does not follow an earlier vein throughout its entire course. Enargite occurs in nests and druses and coats nucleal masses of rock and quartz. This enargite has been shattered by later movement and the cracks filled by films and veinlets of glance. The vein extends eastward to the Piccolo fault vein, a northwest fracture which apparently terminates the mineralization of the Gambetta.

The vein is abruptly truncated by the Rarus fault, but it is believed that development work will show that this vein, like the Piccolo Discovery, will have a flat ore body within the limits of the Rarus fault, which should be encountered between the fifth and sixth levels.

Westward the Gambetta splits into two prongs, which are well shown in drifts 505 and 511 of the Leonard mine. The south prong affords a good example of an old vein enriched by enargite deposition. It is well shown on the 400-foot level of the West Colusa mine. Above this level the vein is narrow and consists of lean white and dense quartz, carrying abundant pyrite. This primary vein filling is traversed by a strike fault, the mashed granite alongside of the fault being impregnated and its cracks filled by seams of solid black enargite. This mineral occurs almost pure, fills the cracks, shows little or no trace of replacement, and is accompanied by little or no quartz or pyrite. The granite alongside of the enargite is unaltered or shows no alteration due to the deposition of this mineral. Between the 400 and 500 foot levels this Gambetta south vein shows 2 to 3 feet of solid enargite. It should be mentioned, however, that the footwall streak on the vein consists of crumbled pyrite mixed with copper glance. The Gambetta vein proper consists of white quartz, with pyrite and nests of enargite, partly in druses, and coating nucleal masses of older rock. The amount of enargite varies greatly in different parts of the vein, and secondary glance is observed filling cracks and films both in the ore and in the wall rock.

The specimens of ore from the Gambetta vein consist of solid enargite, with disseminated grains and irregular streakings of pyrite and occasional nests of friable decomposing pyrite, which may possibly represent an unreplaced portion of the old pyrite vein before the enargite was formed. The evidence afforded by the specimens is not conclusive, but indicates that the

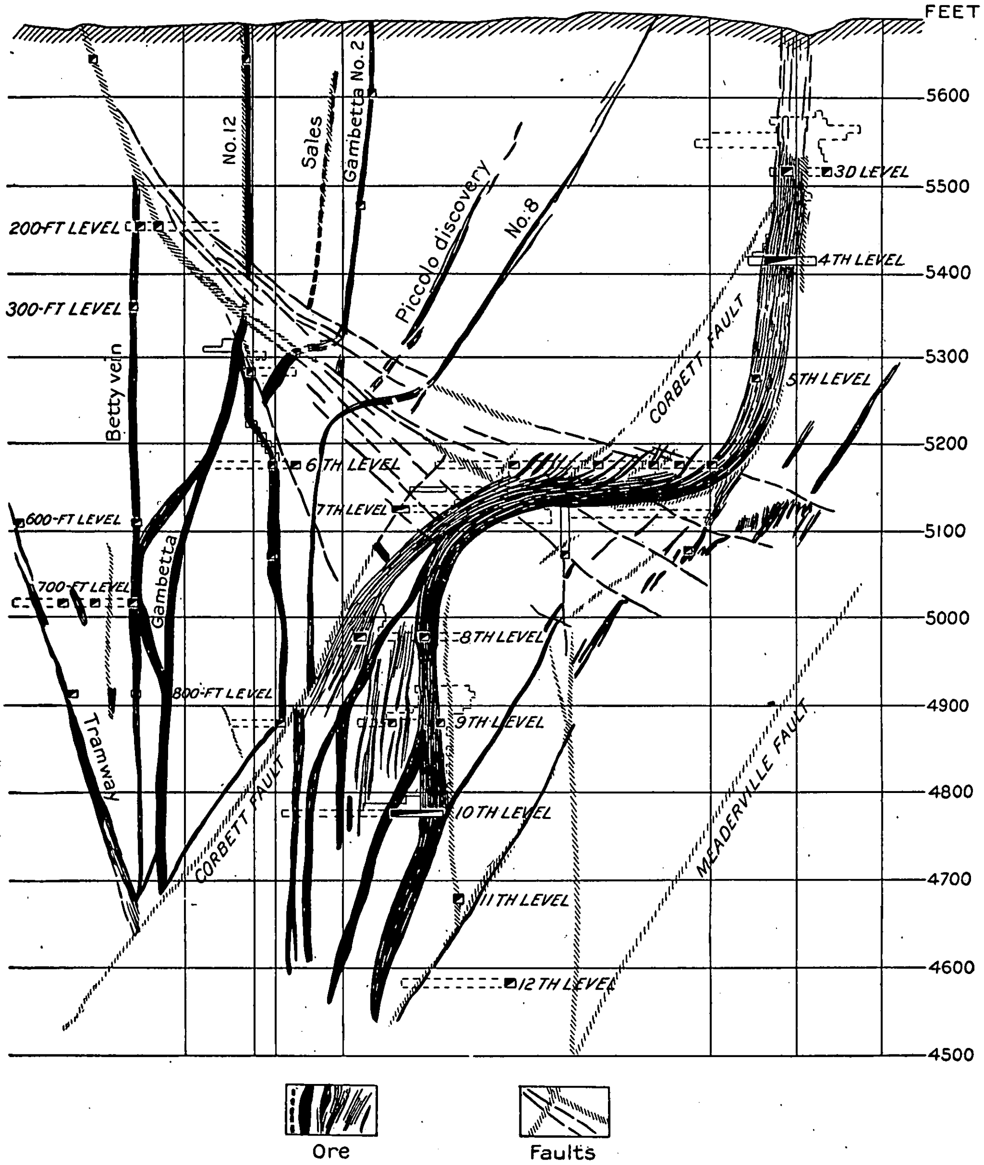


FIGURE 94.—North-south section through Leonard and adjacent mines, 4,800-foot coordinate.

vein filling began in the replacement by enargite of an old pyrite vein devoid of quartz, and was continued by the replacement of the granitic rock.

The Gambetta No. 2 vein is peculiar because what appears to be one continuous quartz and pyrite vein is worthless above the 300-foot level, carries good ore for 300 feet below that level, and becomes zincky again and poor beneath the 600-foot level. This peculiar feature is believed to be due not to a change in mineralization but to an abrupt truncation and dislocation of the vein downward by one of the fissure planes of the Rarus fault, the Gambetta vein lying above another vein of different character, and containing a large excess of zinc.

PICCOLO VEINS.

The name Piccolo is applied to three veins, distinguished as the Piccolo, the Piccolo Discovery, and the Piccolo fault. The Piccolo lies beneath the Rarus fault. The vein has a width of 4 to 5 feet, and consists of fault clay and breccia. It has a clear-cut and regular hanging wall, with crushed and mashed granite on the footwall, very solid granite lying outside of the vein. The filling consists of fault matter, with crushed ore and scarf-like masses of broken and dragged ore. Its course is N. 45° W., and its dip 80° SW., in places becoming

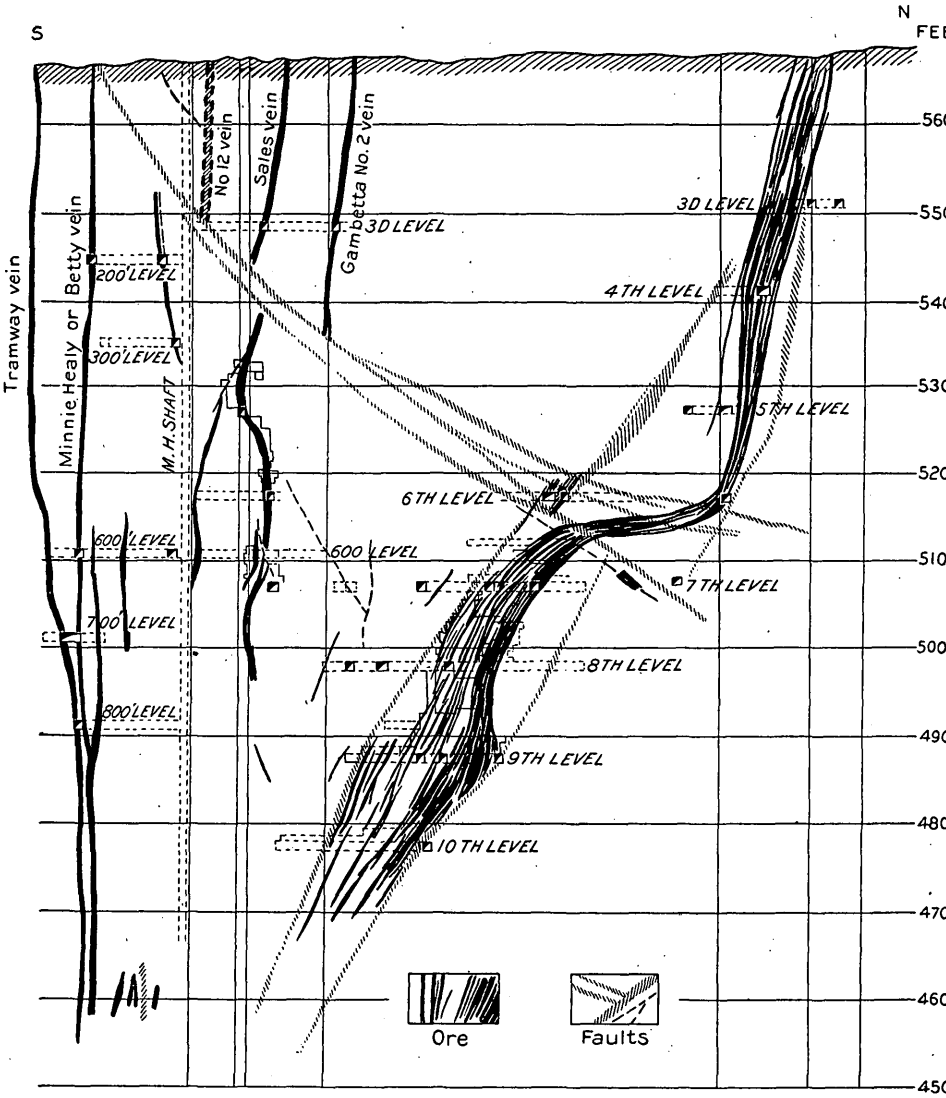


FIGURE 95.—North-south section through Leonard and adjacent mines, 4,900-foot coordinate.

steeper or vertical. Where exposed on the twelfth floor of the 500-foot level of the Leonard mine, the vein is 10 feet wide, consists of mashed granite, crushed quartz, and pyrite, with a little copper glance. Enargite is absent. Endogenous ore is not observed, the only ore streak consisting of crushed ore and clay.

The Piccolo Discovery vein lies above the Rarus fault and is well exposed on the 400, 500, and 600 foot levels of the West Colusa mine. Its course is nearly east and west, but the vein is unquestionably a fault fissure which cuts abruptly through and dislocates the lodes intersected by it. The vein is not known north of the Colusa vein nor south of the Rarus fault, but as it is known to be deflected by the Rarus fault in the deeper workings, it almost certainly extends eastward beyond this fissure. The ore found in the vein is not solid enargite, but is crushed and slightly displaced by the settling of the hanging-wall block over the Rarus fault. The ore is not brecciated and, though mashed granite and clay occur above it, shows no fault breccia or muck.

The Piccolo fault vein is a local fissure, important only as delimiting the mineralization on the east. It is a fault ledge and not part of the stockwork series. In the last few years it has been found to possess a flat ore body corresponding to that of the Leonard vein, and like it, due to the Rarus fault. The Piccolo fault vein is itself fractured by a northeast fault. On the 600-foot Leonard it cuts off the 602, the Gambetta No. 1, and the Gambetta No. 2 veins, but is itself cut off by a N. 45° E. fault with a 30° dip.

Several neighboring veins have been distinguished by numbers.

No. 1 vein shows 2 inches of crushed granite and quartz, with scarfs of crushed ore. It has well-defined walls of firm granite, the hanging wall being hard and solid pyritized graniet and the footwall a leached silicified granite.

The No. 2 vein shows 5 feet of crushed rock, with bunches of black ore, mainly crushed pyrite, partly replaced by glance.

The No. 4 vein consists of solid quartz and pyrite, with some secondary glance, the streak of rich ore being 4 inches wide, and lying in a hard pyritized granite.

The No. 5 vein is a solid pyrite vein, carrying but little quartz, and dipping 70° S. It has a hanging wall of soft and mushy fault matter, and is itself cut off by a fault.

The No. 8 vein of the Leonard and West Colusa mines is a fault fissure which has been developed on a number of levels. (See figs. 94–97.) It has a general east-west course and a rather flat dip to the south. It is a fault vein which is wet and mushy but contains irregular bunches of enargite and streaks of enargite and glance 4 to 6 inches thick, so that the entire vein has a workable width of about 10 feet. In places portions remain of a primary vein filling of white, dense quartz, thickly impregnated with pyrite. This old vein must have been very narrow, as the workable portion of the vein at present is only about 1.4 feet wide. The No. 433 drift shows a sheeted wall rock in which the mineralization gradually fades out away from a streak of pyrite and quartz carrying enargite 1 foot to 2 feet thick. A footwall streak of crushed enargite with clay and fragments of earlier vein filling lies against a clay gouge, with mashed granite on the footwall. As the cracks in the broken vein filling are filled by solid black enargite it is evident that the early vein has been enriched by later mineralization in which enargite has been the principal mineral formed, and that both the earlier ores have been enriched by later deposition of glance.

MINNIE HEALY VEIN.

The Minnie Healy (Betty) vein is a good, strong, quartz-pyrite vein 6 feet wide, crushed by a strike fault, and showing secondary enrichment, with recent streaks of white quartz, and large masses of black, soft, decomposed material, with pyrit As shown in figure 96, it cuts off the ore streaks of the Leonard stockwork in the west drift to No. 822 of the Leonard mine.

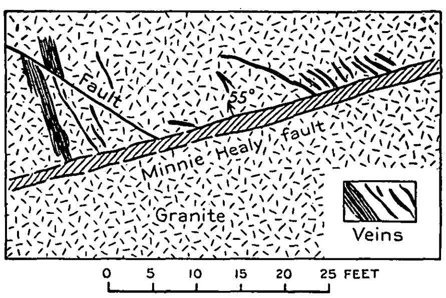


FIGURE 96.—Leonard ore body cut by Minnie Healy (Betty) fault vein.

MINOR FRACTURES.

The northwest fissures of this complex correspond only in part to those of the Bell-Diamond group. A large number of minor fractures (particularly well shown on the 300-foot level) are due to the fracturing of the hanging-wall block of the easterly fault (No. 16 vein) supposed to be the continuation of the Blue Jay. This dips 65° S., whereas the diagonal fissures are vertical or dip steeply north. One of the most prominent of these diagonal fissures is well exposed on the 200-foot level. It extends across the vein, but stops at the footwall fault, cutting off the ore on the first, second, third, and fourth levels. A reasonable explanation appears to be that the strike fault caused a splitting of the southern or hanging-wall block. This adjustment might be due to normal downward movement, the cracks being reopened and intensified by adjustments due to the later Rarus fault. The facts show (1) an abundance of crushed granite, indicating upthrust and grinding along walls; (2) a northward drag of ore from Colusa vein into the fault, showing a northwestward movement, whereas if the wedge had moved downward it would also move eastward and southward; (3) only slight displacement except on the four upper levels, a condition according best with a hypothetical upward movement due to strong north-south pressure.

The veins of this section differ from the quartz-pyrite veins of the Anaconda type. The enargite veins of the Leonard mine carry little pyrite and practically no quartz, and are incased in pyritized granite, the only quartz of any moment being present either as inclusions or as a thin film between the granite and the enargite. (See fig. 97.)

These conditions are well exposed in the Gambetta vein on the 400-foot level of the West Colusa mine, where considerable enargite occurs in cracks in the granite, apparently without regard to the former presence of quartz or pyrite vein matter. Where the enargite is clearly the result of replacement, pyrite nests and cavities occur in it. The vein between the 400 and 500 foot levels shows 2 to 3 feet of solid enargite.

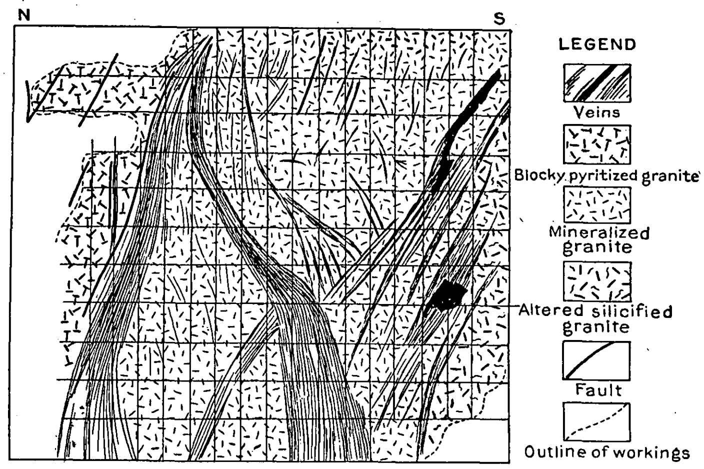


FIGURE 97.—Cross section of part of Leonard lode, from 1,000-foot level upward for 77 feet. The ore streak on the left is main footwall ore, running east-west. The central streak with south dip is a new fissure, containing much pyrite and enargite. The streaks on the right run N. 75° W., dip 67° N., and show 6 to 7 feet of solid enargite. The intervening ground is altered silicified quartz monzonite richly impregnated with glance and enargite, the glance usually filling small cracks and the enargite appearing in bunches.

BLUE JAY FRACTURE SYSTEM.

The largest of the N. 80° E. fractures is either the northeastern continuation of the Blue Jay-Middle fault or a parallel fissure of the same series which cuts through the northwest cross faults, both great and small. This fault shows much clay and fault breccia, but little shifting of the vein structure. The veinlets of rich ore which branch off from the Colusa may be mineralized strain cracks due to this fault.

RARUS FAULT.

The wide northeast fracture known as the Rarus fault is described and discussed on pages 228–230. In this part of the district it cuts and displaces not only the Colusa, but all the lesser neighboring veins. The veins are sharply cut off, but the displacement instead of being concentrated along the two walls of the fault is distributed through its width, probably as a result of slipping and some torsional movement along many fractures. The result is a step faulting of the lodes and the formation of flat bodies. (See also p. 229.) This is well shown in the cross sections, figures 94, 95, and 99.

These ore bodies connect the Colusa and Leonard veins by an abrupt elbow, the lode being seemingly bent almost at a right angle (fig. 94). This feature is most apparent in the Colusa vein, owing to the latter's great size, but it is found also in the other veins of the group, and the position of such ore bodies on all of them can be determined by calculation before development work is begun. The Rarus fault is very well defined in the deeper levels, but is less easily identified above the 600-foot level, and its displacement near the surface appears to be slight.

Between the limiting planes of the Rarus fault the flat ore bodies of the Colusa have been immensely productive, the stope floors being in places as much as 150 feet across. The ore body has a dip of only 10° to 15°, and its connection with the overlying lode and its continuation downward were difficult to understand by any ordinary process of faulting. Figure 94 shows that the ore body consists of a mass of crushed ore and rock netted with clay slips and seams. The planes of displacement parallel to the walls of the Rarus fault are obscured by cross slips and can seldom be definitely located, but there seems no doubt that there has been some movement of the mass since the Rarus fault, with further crushing.

The flat ore body seen in the stopes has a main ore streak, is undulatory in cross section, and rests upon a flat fault that has a course of N. 80° E. to N. 70° W. and a dip of 35° to 55° S., and is therefore a member of the Steward fault series. It has 4 to 6 inches of pebbly clay and 2 to 3 feet of crushed brecciated granite. This fault cuts off N. 35° E. slips, with 50° S. dip. Farther north the ore body consists of a mass of crushed granite, with ore balls and a band of enargite crushed to powder. The granite contains numerous blue clay slips, striking mostly N. 45° W., N. 35° W., and N. 40° W., with conjugate dip north and south. Much of the ore is a crackled mixture of quartz, chalcocite, pyrite, and crumbly crushed granite. Beneath the flat ore body the granite is crushed, with more or less clay.

LEONARD LODE.

GENERAL CHARACTER.

The name "Leonard" has been applied to the continuation of the Colusa lode beneath the Rarus fault, but may perhaps be better used to designate the great ore body of the Leonard mine, composed of various veins and cut by several faults. Though it might be called a stockwork, it is not a network of interlacing veinlets in rock, but rather a trunk vein with a unilateral development of branches. As previously stated, it is limited northward by the Colusa and southward by the Tramway veins. As the Tramway vein has a north dip and the Colusa a south dip, the ore body is wedge shaped and narrows downward. This great ore body shows stringers of rich ore spraying off from the Colusa vein and bending around until they take a north and south course. The best general section is that developed on the 1,000-foot level of the Leonard mine. The map (Pl. XVIII), which represents a horizontal cross section of the ore body on the 1,000-foot level, shows only the actual rich ore streaks. The granite between these streaks is altered and, though solid, is specked with ore, so that it is all mined.

The Leonard differs very markedly in character from any other lode or ore body in the Butte district. It may be likened to a plume, in which the rib is the Colusa vein and the various north and south offshoots curving around from it the small feathers. The entire ore body as mined really consists of the Colusa vein, with stringers spraying off to the east and turning until they go south and end against the Tramway vein. There are no ore shoots in the ordinary sense of the word, but streaks of ore having a northwest to north course run off from the Shannon and Colusa veins in the upper levels and become stronger and richer going downward, until at a depth of 1,000 feet or more they become thinner and pinch out. These stringers of rich ore consist of enargite in altered granite, the definition between ore and granite being sharp. As, however, the intervening rock is impregnated with pyrite, partly or wholly replaced by glance and enargite, the space between the ore streaks is also mined, so the ore body is practically a stockwork. This intervening granite, though highly altered, is unfractured.

VEINS.

The extreme northern limit of the ore body (fig. 98) is the downward continuation of the Colusa vein, whose faulted upper portion is the Colusa vein proper, which farther westward is known as the Shannon. The other veins which form part of the stockwork and which, above the Rarus fault, are independent veins, coalesce downward into the great Leonard ore body, but are still recognizable. One of them, the Piccolo Discovery vein, passes vertically downward apparently without deflection by the Rarus fault, as its termination directly overlies another vein. The level maps of the Leonard and Colusa mines show these veins. Some of them are named; others are, for convenience, designated by numbers.

FAULTING.

The relation of the Leonard lode to the Colusa lode is best shown in the vertical cross sections[1] (figs. 92, 93, 94, 95, 98, and 99), which show that the supposed cut-off or fading out

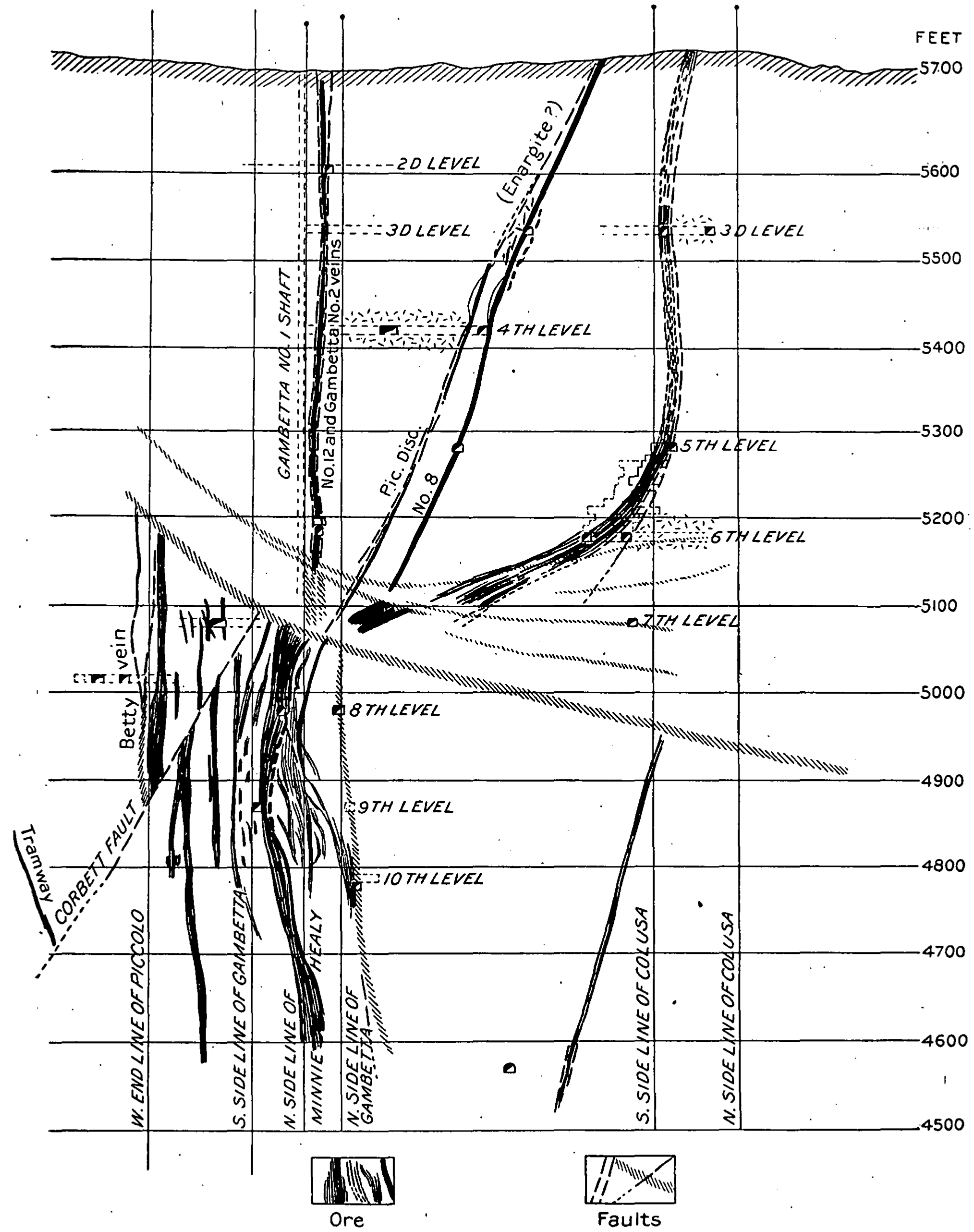


FIGURE 93.—North-south section through Leonard mine, 4,500-foot coordinate.

downward of this vein does not really exist, but that the Colusa vein is displaced by the Rarus fault, forming the great flat ore bodies of the Leonard stopes, and makes up the wall of the great Leonard lode underneath that fault. These relations are, however, complicated by other faults, one of these being the middle or No. 16 fault, which in this ground follows the footwall

[1] These figures are based on cross sections kindly furnished me by Mr. R. H. Sales and checked and amplified by myself.

of the Colusa lode. Another, here called the Corbett fault, has a flat southerly dip and limits secondary mineralization to the south.

Figure 99 shows the veins lying south of the Colusa vein and composing the complex which underneath the Rarus fault is so heavily mineralized. The veins known as No. 12, the Sales vein, the Gambetta No. 2 vein, the Piccolo Discovery, and the No. 8 or Enargite vein, net the ground lying south of the Colusa lode, and beneath the Rarus fault reappear as the Minnie Healy (Betty) vein (a nearly vertical lode), No. 12–A vein, No. 2–A vein, and others to which no definite designation has been affixed. The whole area lying between the Tramway vein on

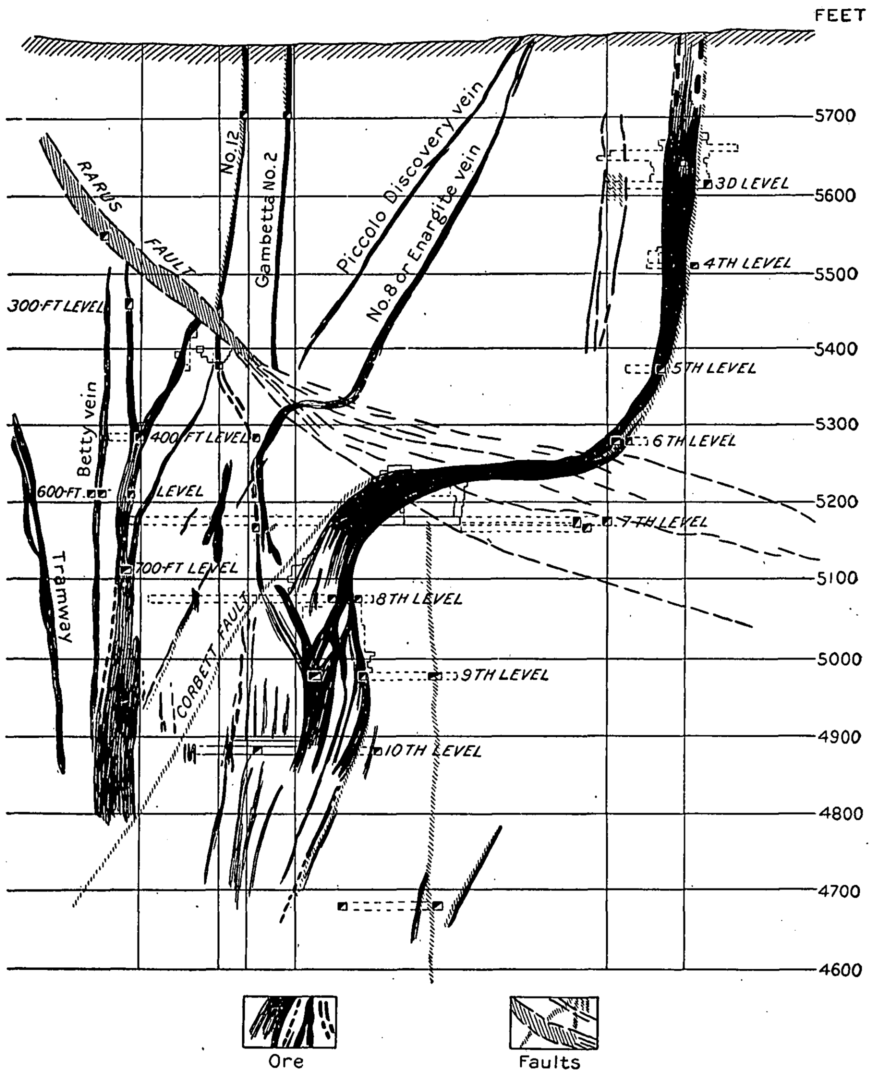


FIGURE 99.—North-south section through Leonard mine, 4,700-foot coordinate.

the south and the fault limiting the Leonard ore body on the north is shattered by faulting of different periods, and has been so impregnated with copper that it forms a vast stockwork of low-grade ore, cut through by veins and streams of high-grade material. Considering the faulting it is rather remarkable to find such a close matching of veins. The formation of the flat ore body by the Colusa as a result of the Rarus fault has been confirmed by search made for the flat portions of other veins also displaced by this fault, and it has been found possible to direct new drifts to locate such ore bodies from the plats made in the office.

On the Leonard 400-foot level the Rarus fault appears to split and a branch coalesces with the footwall strike fault of the Colusa. On the 600-foot the Rarus fault is a strong break with slight displacement, the only abnormal features being those due to the northwest faults. On the 700-foot level, however, the Rarus fault has produced a very marked displacement of the vein, and the flat ore body is here due, as it is within the workings of the Rarus mine, to step faulting or block faulting of the lode, the distributed displacement bringing short tilted blocks so close together that they apparently form one flat dipping mass of crushed but continuous ore. In the horizontal plane of this level the lode apparently swings around to the south as it approaches the limiting fissure of the Rarus fault. These features are best seen in the cross sections (figs. 92, 94, 95, and 98) which show very plainly the strong and well-defined Colusa vein, with its footwall fault dipping downward to the cut-off by the Rarus fault. A strong south-dipping fault is also observed in the crosscut from the sixth level at a distance of 100 feet from the hanging wall of the Colusa vein. The same cross sections show the nearly vertical Tramway vein, with its slight northerly dip limiting the mineralized ground on the south underneath the fault, with the undulating but nearly vertical Gambetta vein to the north of the Tramway, the parallel No. 2 vein to the north of this, and the Piccolo fault beyond.

ORES.

The ore body in many places consists of a mass of crushed granite, with ore balls and bands of enargite crushed to a powder, and the granite alongside contains numerous clay slips, mostly with a northwest course and conjugate north and south dips. The main mass of the ore

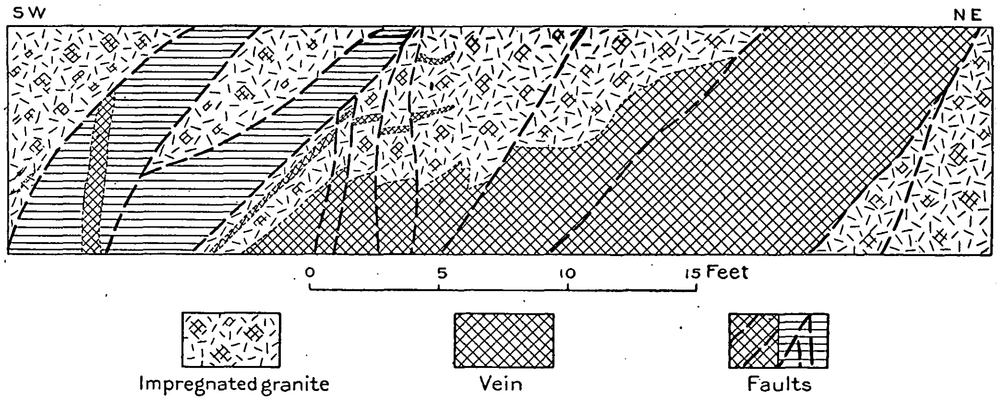


FIGURE 100.—Ore body in south crosscut, 700-foot level, Leonard mine. Shows solid ore (glance and enargite) cut by fault slips dipping with vein.

body is composed of a crackled mixture of quartz and pyrite, with some copper glance, together with crumbled and crushed granite. The granite beneath the flat ore body is crushed and shows more or less clay.

In south crosscut No. 772, from the 700-foot level of the Leonard mine (fig. 100) thick bands of solid ore are cut off by sympathetic fault slips parallel to the main displacement, and the ore generally consists of a shattered mass of quartz and pyrite vein filling, netted by clay seams and enriched by glance. Text figure 100 gives an idea of the broken nature of the ore body and plainly shows how the hanging-wall block has been broken and secondary slips formed by the settling of the main hanging-wall block of ground. In the deep levels of the mine the ore bodies show solid streaks from 3 to 4 feet thick, of bornite, glance, and covellite. These streaks are in solid but highly altered granite, and are cut and displaced by northeast faults, usually steeply dipping, having a displacement of 2 to 6 feet.

An examination of the deep levels of the Leonard mine and the stopes showed that the ground between the veins is netted and that lesser streaks are abundant, and that, in many cases, the granite is not actually impregnated nor spotted with glance and enargite, but is cobwebbed with ore. One is impressed with these facts: (1) That many of the veinlets show comb quartz with enargite between the crusts, and more rarely bowlders incrusted with cockade ore and quartz; (2) that there is no absolute regularity of planes; (3) that the fissures must be open, as N. 65° to 75° W. fractures show dots or spangles of enargite and glance. The larger streaks show noticeable banding.

In the deeper levels, 1,100-foot and 1,200-foot, vein formation seems to have been arrested. The intermediate granite looks as if in a short time geologically it would have been completely mineralized and replaced; the veinlets show arrested filling, with crumbly pyrite crystals and open-textured enargite, etc. The enargite is all loose textured and full of pyrite. The glance appears secondary, and so does the covellite. Vugs are abundant, and barite, hübnerite, tetrahedrite (bronze) occur, though sparingly, and the covellite forms veinlets persistent from floor to floor.

The ore is markedly impoverished from the 1,000 to the 1,200 foot levels; the ore streaks becoming more siliceous and irony and the pitch of the ore body is to the west, though there is no apparent reason either for impoverishment in depth or fading out eastward. Assays of samples taken at 5-foot intervals on the sill floor of the 1,000-foot level show that the entire mass carries 7 per cent copper. The curves of the silver and copper values, when platted by coordinates, follow each other up and down very closely, and though the ratio varies somewhat it is in general about 1 per cent copper to 1 ounce silver.

The Leonard ore body shows streaks and lenses of black enargite in the altered granite. As seen in the stopes, the bulk of the ore mined is an altered granite, carrying disseminated grains of pyrite partly replaced by enargite and glance. Pyrite, however, is not the only mineral replaced, the thin sections indicating a direct replacement of hornblende and biotite by the arsenical sulphide of copper. Direct evidence of replacement is shown in sac-shaped bunches of ore like the one shown in figure 101.

Several systems of fracturing are noted in the ore body. The most important ore bodies occur at the intersections of northwest-southeast fractures with others running northeast and southwest. The northwest fractures commonly dip 60° to 70° N., but conjugate opposed fractures, having the same course, but a contrary dip, also occur. So far as observed, the ore occurs only in shattered rock, where fractures intersect, and is not found along either set of fractures away from the intersection. The rock in the crosscuts is pyritized granite very much like that common throughout the district, and would be called waste if it were not for the great stopes which have been mined. The mineralization seems to be mainly by enargite shattered and cemented by glance.

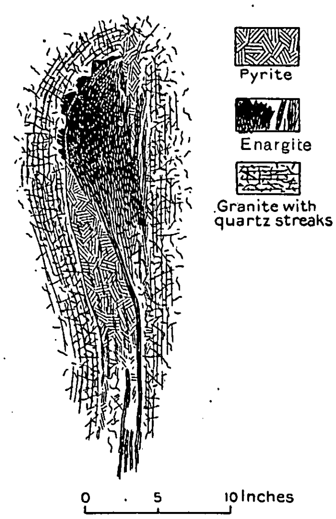


FIGURE 101.—Enargite bunch, 800-foot level, Leonard mine.

TRAMWAY VEIN.

The Tramway is a northeast fault vein, which, unlike most of the veins of the district, has a steep dip north. It has been mined in the Tramway, Minnie Healy, and Leonard mines, where it forms the southern boundary of the great compound ore bodies of the Leonard mine.

The vein is composed of a mixture of crushed pyrite and white, opaque, siliceous matter, representing an earler vein filling that has been crushed, recemented, and indurated. It contains glance streaks, which cross the vein, the streaks appearing to fill torsion cracks. The vein has been extensively developed in the Minnie Healy mine, where it varies from 6 to 20 feet in width, with bands of high-grade glance ore from 1 foot to 6 feet thick. In general, there is a clay hanging-wall selvage 2 inches or more thick, a 2-foot band of rich ore (5 to 10 per cent); a central band of brecciated but hard vein matter; streaks of solid glance and clay slips, 5 feet of low-grade pyritic ore, and a footwall streak of mashed ore, quartz, and blue clay. The walls roll and the vein swells and pinches. The conditions indicate that an old indurated fault vein 2 to 3 feet wide has been reopened and widened by a strike fault, in which glance and enargite have been deposited.

The vein in places shows a matrix of light-colored or mottled material apparently of granitic composition, but really made up of white, nearly pure silica that has a chalky appearance and texture. Isolated fragments of an earlier fault breccia, well indurated, so that the fragments retain their form, occur in this silica. Between these fragments later enargite has formed, constituting the chief value of the ore.

MINES NORTH OF MEADERVILLE.

MODOC MINE.

The Modoc mine is located near the eastern end of the copper district, immediately north of Meaderville. It has two shafts, but only one has been used in recent years. The Modoc is a single vein 5 to 20 feet wide, dipping quite uniformly south at an angle of 55° to 60°. The incasing rock is either quartz monzonite, usually pyritized, or rhyolite porphyry. The rhyolite porphyry forms a series of dikes, which unite at the surface in a single outcrop 100 feet wide at times, forming the Modoc dike. Underground, the vein is nearly parallel to the dikes but cuts through them in places.

The lode is not continuously ore bearing, but consists of a banded mixture of solid quartz and pyrite that is workable only where broken by faulting and enriched by secondary glance and bornite. Chalcopyrite also occurs, and secondary bornite is deposited on the ends of quartz-pyrite crystals. The vein is broken by numerous transverse northwest fissures, by which it is slightly displaced. The pay ore occurs in shoots, which generally pitch westward and do not extend either laterally or vertically for more than a few yards, the largest being 100 feet in horizontal and less than 40 feet in vertical extent. These lenses only extend downward to the 600-foot level. Below this depth the mineralization is still seen, but it becomes less and less until on the 1,000-foot level the vein is scarcely recognizable and can only be traced by reason of its passage through the quartz porphyry. The only mineralization seen on this level is at the extreme western end, where there is a lens of pyrite 25 feet long and 2 feet wide.

The mine workings show that the country rock is crossed by three of the rhyolite porphyry dikes. The one nearest the shaft has a width of 10 to 15 feet and is cut by the vein on the upper levels. A second dike lies some 35 feet to the south of this and has a width of 30 to 35 feet. A third dike lies about 50 feet south and has a width of 8 to 15 feet. These three dikes have a general northwesterly course approximately parallel to the vein. They are well exposed on the 1,000-foot workings in the crosscut from the shaft.

In general, the vein has been disappointing and unprofitable below the 500-foot level. A connection has been made westward with the High Ore mine, but the only ore extracted in recent years has been by men working it on a lease who were therefore able to mine small ore bodies that were unprofitable when the property was worked on a large scale. Fault veins occur in the mine and intersect the Modoc vein at a slight angle. Three small parallel veins are cut on the crosscut on the 600-foot level. One of these veins has been drifted on, but has not shown any pay ore. On the 700-foot level the drift follows a fault slip in which a zone of very rich ore extends for 40 feet east of the main crosscut. This ore shoot is nearly vertical, and the ore is composed of bornite, with quartz and pyrite. Another well-defined shoot of ore extends downward from the 600 to the 700 foot level, being well exposed on the twelfth floor above the 700-foot level, where it has a width of 10 feet and consists of bands of pyrite and chalcopyrite, bordered on each side by a 2-inch seam of rich copper sulphides, separated by 2 inches of gouge from the country rock.

In this mine the rhyolite porphyry contains numerous inclusions of granite which show no melting or other evidence of assimilation and effectively prove the intrusive nature of the porphyry.

REINS COPPER CO. MINE.

The Combination vein, worked by the Reins Copper Co., in the claims lying directly east of the Leonard and Minnie Healy mines, had been developed to a depth of 800 feet in 1904.

It is a fault fissure, showing 7 to 8 feet of clay and crushed vein matter, with an 8-inch streak of high-grade ore, consisting of glance and bornite, with an abundance of native silver in curly wires and mossy masses, lying in fractures and in nests in the crackled copper sulphide. In general, the ore of the vein carries secondary bornite and glance, with more or less zinc blende, but the streak of rich ore just noted, which lies along the hanging wall, also has curly crusts of chalcopyrite, which in this connection are regarded as accompaniments of the silver-bearing solutions. The vein also holds much curly quartz, with crushed and recemented vein matter, the quartz of the latter type carrying specks and stringers of copper glance and a little pyrite. The vein filling shows the best example seen in the district of the replacement of crystalline pyrite by bornite. The pyrite occurs as tiny cubes and crystalline aggregates lying in a matrix of yellow clay and shows the various stages of replacement from the underlying pyrite to the solid bornite.

On the 400-foot level a 65-foot dike of quartz porphyry is cut at a distance of 100 feet north of the shaft. This appears to be east of the Rarus fault.

On the 800-foot level, at 35 feet north of the shaft, a 7 to 8 foot ledge is cut. Samples taken from an 8-inch streak of first-class ore showed glance fractured and with curly native silver particles scattered all over the fractured face. The grains of crystalline pyrite scattered through the waxy yellow clay showed a remarkable replacement by bornite. The ore shows glance and bornite, with some zinc. The hanging-wall streak has curly crusts of chalcopyrite ore.

The second-class ore of the Reins vein is a rather curly quartz, with crushed and recemented quartz carrying glance in specks and stringers and but little pyrite.

SUNSHINE MINE.

The Sunshine mine is located at the head of the gulch west of the Modoc mine. The shaft is 300 feet deep. A vein, seen on the 100-foot level 20 feet south of the shaft, runs east and west and dips south. It is small and shows the usual characteristics of a copper vein.

MAT MINE.

The Mat mine lies immediately north of Meaderville, a few hundred feet north of the eastward extension of the Modoc mine. Its career has been somewhat erratic; it has been worked and abandoned; worked again, and again abandoned. At the time of visit the shaft was 400 feet below the surface, and all the ore came from the lowest level. The country rock is basic quartz monzonite, resembling that in the mines east of Silverbow Creek.

On the 400-foot level a crosscut 50 feet south from the shaft encounters two veins; the first, which runs 16 feet from the shaft, is the mainstay of the mine and has been drifted upon extensively. Beyond this in the crosscut the granite is greatly altered, decomposed, and profoundly shattered. Along these fracture planes a certain amount of vein material has been developed, whether by mechanical or chemical processes it is not possible to say. At one place this concentration was so marked that it has been considered to constitute a vein. The two veins continue for 300 feet, where they unite; they also unite 50 feet above the crosscut. To the east but one vein has been found, and this abruptly dies to a clay wall, carrying little or no vein mineral.

The vein throughout its course is somewhat erratic. At the west end the dip for 200 feet from the surface is to the south; below this it is reversed to the north at an angle of 70°. Midway between the Adelaide shaft and the Mat shaft the vein is as crooked as a squirming snake; at the Mat shaft the dip is persistent 80° S. The width of the vein varies somewhat; it averages 4 feet and in few places exceeds 10 feet. The vein materials occur in long, narrow lenses with a vertical extension of never more than 40 feet, and a horizontal length varying up to 100 feet.

In the eastern end of the workings immediately over the crosscut from the main shaft the north wall consisted of altered granite; adjoining this was a zone of shattered granite, highly altered, containing stringers of ore and quartz 15 inches in width; succeeding this was a 7-inch band of very zincky ore running high in silver and low in copper. Adjacent to this was an irregular 4-inch band of manganese spar, extremely pure but rarely solid; and succeeding this was an 18-inch zone of altered granite containing numerous veinlets of sulphide minerals. Last came a 2-inch seam of clay lying on a footwall of profoundly altered granite. Constantly associated with the band of manganese spar was a threadlike seam of clay. The alteration in the wall rock at this point extends not more than 12 inches on either side of the vein.

At the point of junction of the two spurs of this vein, 20 feet above the latter, the vein is 3½ feet wide and dips 85° N. The south or footwall granite was absolutely fresh; succeeding this was a 4-inch band of rhodochrosite and clay; next a 6-inch irregularly defined band of siliceous ore; then 1½ feet of ore composed largely of iron and copper pyrites and some bornite; overlying this a 1½-foot band of altered, broken, and sheared granite; and, finally, a 1-inch clay seam, immediately underlying fresh granite. The country rock had not been attacked by the mineralizing agents, differing in this from that in the vein section at the eastern end of the mine. Both walls showed distinct and strong seams of clay, and examination showed them to be polished and faintly striated. It seems almost certain that the vein has been greatly changed from its original condition by physical rearrangement of the minerals of both the country rock and the vein.

Farther west the drift has been run in the hanging or north wall for a distance of 50 feet; subsequent work has been through a crosscut 20 feet to the south, and then to the west indefinitely.

The crosscut to the south has developed two walls, one at either end, in comparatively fresh country rock, the immediate zone being occupied by profoundly altered and broken granite, interspersed by numerous nonpersistent seams of vein material; in one case almost entirely quartz, in another almost entirely chalcopyrite or pyrite. On the main south wall, which here is the footwall, one of these veins attains a maximum width of 12 inches. On the 300-foot level a crosscut, now inaccessible, was extended to the north 100 feet and cut an additional vein.

The most striking feature of this mine is the association of its minerals. At the eastern end is tetrahedrite, and consequently a high percentage in silver, but the amount of copper is not sufficient to warrant its removal. Associated with this is a certain amount of sphalerite and rhodochrosite, minerals characteristic of the silver veins. At the western end the percentage of copper is high, and the silver is in the ratio of the northern copper mines. The copper minerals are chalcopyrite and bornite. The vein minerals are, in the order of their abundance, pyrite, quartz, sphalerite, chalcopyrite, bornite, rhodochrosite, and tetrahedrite, an association not to be expected in a typical copper mine. The mine, then, is remarkable for the irregularity and nonpersistence of its ore shoots; the irregularity of the zones of alteration in the wall rocks, which in one place extend a number of feet on either side of the vein and in other places are entirely absent; and, last and most important, in the association of its minerals.

ALEXANDER SCOTT MINE.

The Alexander Scott mine is immediately north of the West Colusa. Work on it in 1906 had not progressed to any considerable extent. On the 200-foot level a small vein was encountered north of the shaft. On the 400-foot level a similar vein was encountered, also north of the shaft. This vein was in hard, fresh granite and within a few feet passed into a thin seam of soft, gray granite, impregnated with pyrite. There were a number of small cross faults, but none of them seem to have any large displacement. The ground should be well mineralized below.

RARUS GROUP OF VEINS.

DEVELOPMENT AND GENERAL CHARACTER.

What may, for convenience, be called the Rarus group of veins is in many respects the most interesting, as well as the most complicated network in the Butte district. The veins are usually continuously ore bearing, lie close together, and belong to two systems of different direction and age, in which the later veins fault the earlier ones, and all of them are cut and displaced by the Rarus fault.

The veins of this group extend westward into the Anaconda ground, northwestward into the Mountain View mine, eastward into the Berkeley, and northeastward into the Minnie Healy, Snohomish, and Tramway properties. In all these mines the veins have been productive, and as their ownership has been a question of bitter litigation, their development and study has been unusually thorough, a large amount of work having been done to determine geological conditions, irrespective of ore development. Fortunately this development—"legal development"—has proved of great economic value, new and formerly unknown ore bodies having been found. It has also shown that few of the veins have well-defined outcrops; that the complexity of structure, resulting from faulting, have rendered continuous development necessary to determine the apex of any particular vein; and that many veins show a subfault apex.

Briefly, a series of nearly parallel northwest-southeast veins belonging to the Silverbow system traverse an altered, sheeted, pyritized granite. Several east-west veins of the Anaconda system, including the Pennsylvania, occur but do not cross the northwest veins. The Mountain View fault (Blue Vein system) cuts and displaces the veins crossed by it. It is parallel to the older (Silverbow) veins in strike, but has a flatter dip and is not continuously mineralized. The Blue Jay fault (Middle) vein of the Anaconda mine dips eastward toward this ground, and movement along this fault led to readjustment in the ground, producing new cracks, which run N. 30° E. All these fissures are mineralized, the later fault veins being, as a rule, workable only at depths greater than 800 or 1,000 feet, and the earlier veins losing their values at about that depth. The ground between the veins is highly altered and often plated, showing pyrite films along the shear planes parallel to the northwest veins and in a few cross veinlets; the inclosing rock also contains scattered grains of pyrite. The east-west veins and joints show as spurs running off into the walls of the northwest-southeast veins. This area is cut by the great Rarus fault, the most interesting and important feature in this vicinity.

Although 13 distinct and continuous veins traverse the Rarus area, practically no outcrops are recognizable. Railway cuts and trenches have cut the veins within 3 to 5 feet of the surface and have found them narrow and composed of rusty quartz.

The ore from the veins of the Rarus area varies considerably in character. In the Windlass and Enargite veins the high-grade ore averages about 9 per cent copper and 2 ounces silver per ton, and the low-grade ore varies from 3 to 3½ per cent and 0.9 ounce silver The No. 16 vein (Blue Jay system), which is worked from the 1,100 to the 1,600 levels of the Rarus, yields high-grade ore, which carries 10 per cent copper and 18 ounces silver per ton, and low-grade ore, which averages 4 per cent copper and 8 ounces silver. The ore from the fault veins varies in hardness, yielding in concentration about 900 tons of soft ore to 550 of hard ore. In general the ore mined in 1902 averaged 4 to 5½ per cent copper, and 3.5 to 5.5 ounces silver. In passing through the mill this is concentrated to a product holding 10.5 to 13.5 per cent copper and 6.8 to 9 ounces silver. The silver loss in concentration is greater than the copper loss. As a whole, the high-grade ore derived from the deep levels varies between 9.5 and 15.5 per cent copper and 6 to 8 ounces silver.[1]

For the purpose of discussion the area in which the Rarus veins occur may be divided into three parts, one west of the Rarus fault, one east of it, and one between its walls.

CORRELATION OF THE VEINS.

In the areas west and east of the Rarus fault two sets of veins can be distinguished, one running nearly due east-west (Anaconda system) and the other northwest (Silverbow and Blue Vein systems). The former includes the Iron and Powder veins, on the west side of the Rarus, and the Berkeley, Flat, Enargite, and Cross veins east of the Rarus. In general the northwest veins have a steep dip and regular course, and the east-west veins a flatter but regular dip. At least one of the northwest veins, the Mountain View fault vein, is a plane of

[1] These figures were furnished by the late George H. Robinson.

movement along which fracturing and dislocation of the east-west veins has taken place, leaving shifted ends which were for a long time regarded as spur veins. The other northwest veins are old primary lodes, which do not, so far as proved, dislocate the east-west veins. The latter, in fact, appear to stop them, as is the case with the Enargite and Windlass veins. The relation of these veins to one another is shown in figure 91 (p. 202).

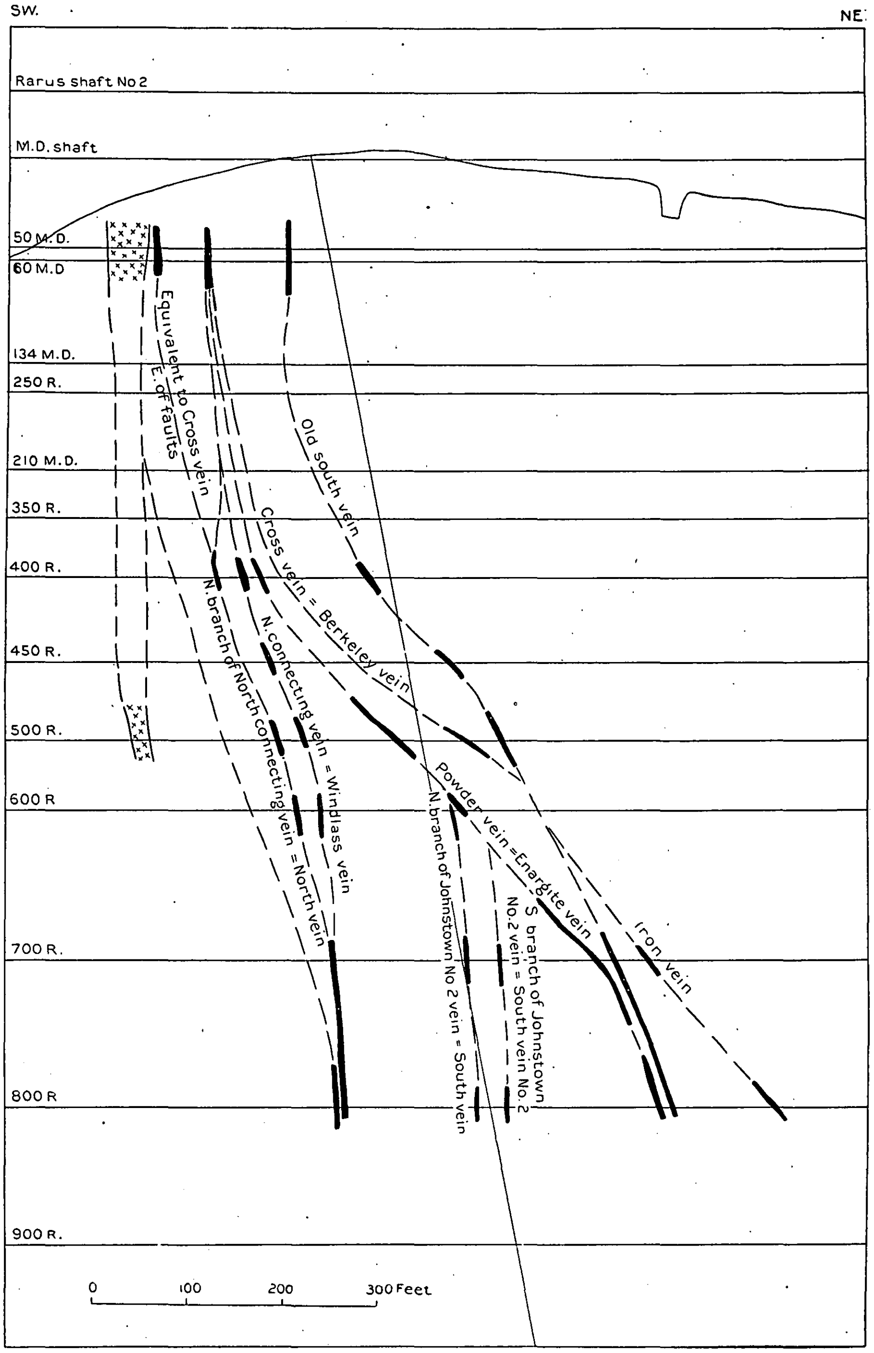


FIGURE 102.—West wall of Rarus fault, showing projection of intersecting veins; dip 42° SW.

The veins of the northwest (Silverbow) system are the more important; they include the Johnstown (North Connecting) vein, which shows two branches on some levels; the Johnstown No. 2 lying next to it; and the Pennsylvania No. 8 farther south. The Mountain View fault vein is parallel to these but belongs to the Blue Vein system and is of later age and different character. East of the Rarus are the North vein (north branch of the Johnstown); the Windlass, correlated with the Johnson; the South, correlated with the Johnstown No. 2; and the Mountain View fault; others which are either not developed, or are not present to the west, are the 612 vein, the Snohomish, and the Snohomish diagonal fault (between the Windlass and the South). (See figs. 102, 103.)

Of the east-west veins are the Pennsylvania No. 2, the Enargite, the Powder-Iron, and the Cross.

The veins and faults of the area have been broken and shifted by movement along the northeast Rarus fault. This is a double fault, having two thick clay seams for walls, with crushed

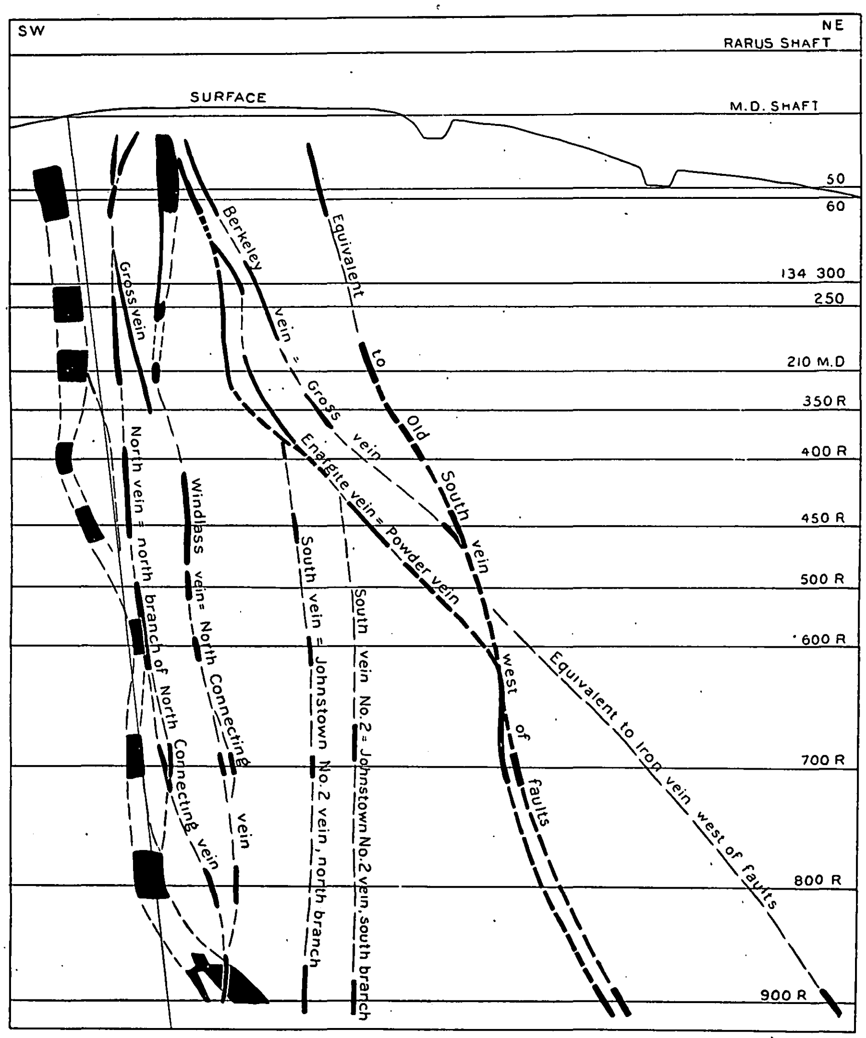


FIGURE 103.—East wall of Rarus fault, showing projection of intersecting veins; dip 54° SW.

vein and country rock between. The faulting was normal, but oblique, with a northward shift of the hanging-wall block. Moreover the two walls are not parallel, but diverge in depth, so that the space between them increases. In the dislocation of the veins the portion of each vein between the Rarus walls has been broken by minor, subordinate faults parallel to the walls, and the net result of this step or distributed faulting has been to produce flat ore bodies, as if the veins had each been bent almost at a right angle, forming an elbow.

In the Rarus ground the fact that on some levels one could stope a vein up to the wall of the fault and, cutting through the 2 feet or so of clay, find ore on the other side, led some observers to believe the veins were everywhere continuous through the fault. As a matter of fact, however, none of the flat ore encountered in the Rarus ground was a part of the adjacent vein; everywhere it showed a widely differing dip, disturbed orientation, and different characteristics. (See figs. 102, 103.)

Many of the veins show marked individuality, particularly the Windlass, the largest of the veins worked in the Rarus mine. By means of these marked individual characters, by the porphyry dikes, and by the aid of extensive drifts and raises, the correlation of the veins on each side of the Rarus fault is now satisfactory.

STRUCTURE.

INTERRELATIONS OF THE VEINS.

The relation of the older east-west veins (such as the Powder-Iron, Pennsylvania No. 2, and Enargite) to the northwest veins—Windlass, Johnstown (North Connecting), and other parallel veins—is not everywhere clear, but the northwest veins are believed to be later and to interrupt and dislocate the east-west veins. Seemingly they cut off the east-west veins. Thus the Enargite runs into the Windlass, and if shifted by it should appear east of the latter, forming the Cross vein, which, however, lacks both the size and the characteristics of the Enargite. It is therefore regarded as possible that in this part of the Butte district the forces that produced the great east-west fissures of the district formed at the same time northwest fissures, which were here dominant, and that the east-west fissuring shows only as cross joints or fissures between the master (northwest) fractures.

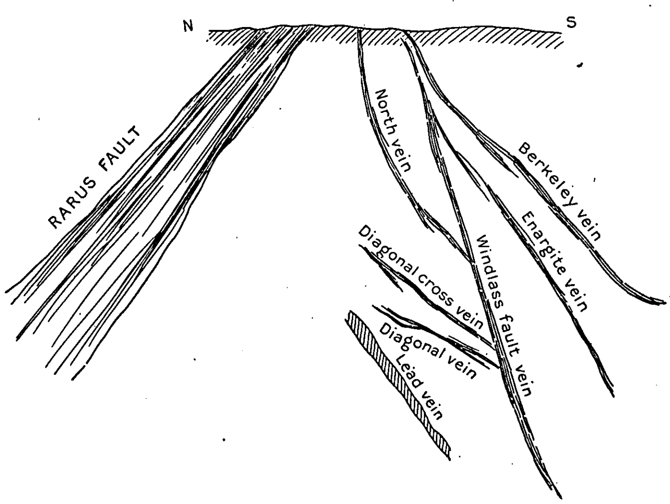


FIGURE 104.—Veins of Rarus area, east of Rarus fault.

Throughout the Rarus ground one may observe slips and veinlets running off into the hanging walls of the veins, and these are commonly called spurs of the vein. Some corresponding droppers on the footwall side are seen, but it is not easy to correlate the seams; and faulting, though the easiest explanation, has not been proved.

FAULTING.

In the Rarus area the true relations of the veins are difficult to depict, since three faults, the Mountain View, the No. 16 (Blue Jay or Middle), and the Rarus are involved in the dislocation. Figures 86 and 91 give details of the intersections. The section given in figure 104 shows that three veins join near the surface, viz, the Berkeley vein, the Enargite vein, and the Windlass vein.

The Mountain View fault vein splits or branches into three lodes east of the Rarus fault. On the Pennsylvania 1,000-foot level it forms veins Nos. 11, 7, and 10 (named in order from north to south), disclosing that fact that the Enargite and the No. 3 Pennsylvania veins are the same, and that two dislocated blocks occur between the No. 7 (Middle) fracture of the Mountain View fault and the Nos. 10 and 11 veins. The No. 10 vein is a crushed zone replaced by quartz-pyrite and some enargite, and as it is well mineralized it hardly resembles a fault vein. No. 11

vein shows but little, if any, mineralization in the Pennsylvania ground. No. 7 shows some ore in places; it varies in width and is locally no thicker than one's finger.

The deeper levels of the Rarus mine (below 1,000 feet) derive their ore supply from wholly different veins from those so extensively developed in the upper levels, most of the latter being impoverished and unworkable at a depth of 1,000 or 1,200 feet (p. 226). The chief supply comes from the vein known as No. 16, which is regarded as the eastern extension of the Blue Jay (Middle) ledge. It is, however, interesting to note that the deflection of ore along intersecting fractures, a feature observed in the upper levels, is here quite prominent, the principal systems along which ore has been made being N. 60° E., N. 60° W., N. 30° W., N. 80° W., and N. 80° E. The 1,100 and 1,200 foot levels show extensive development along these fissures. Thus, the 1,100-foot level shows a S. 80° W. vein (the No. 16), which is strong and well-defined and has been extensively stoped westward to a point where it intersects a N. 30° W. fracture, whence it extends northwest to the Rarus fault. The S. 80° W. fracture continues, but is barren.

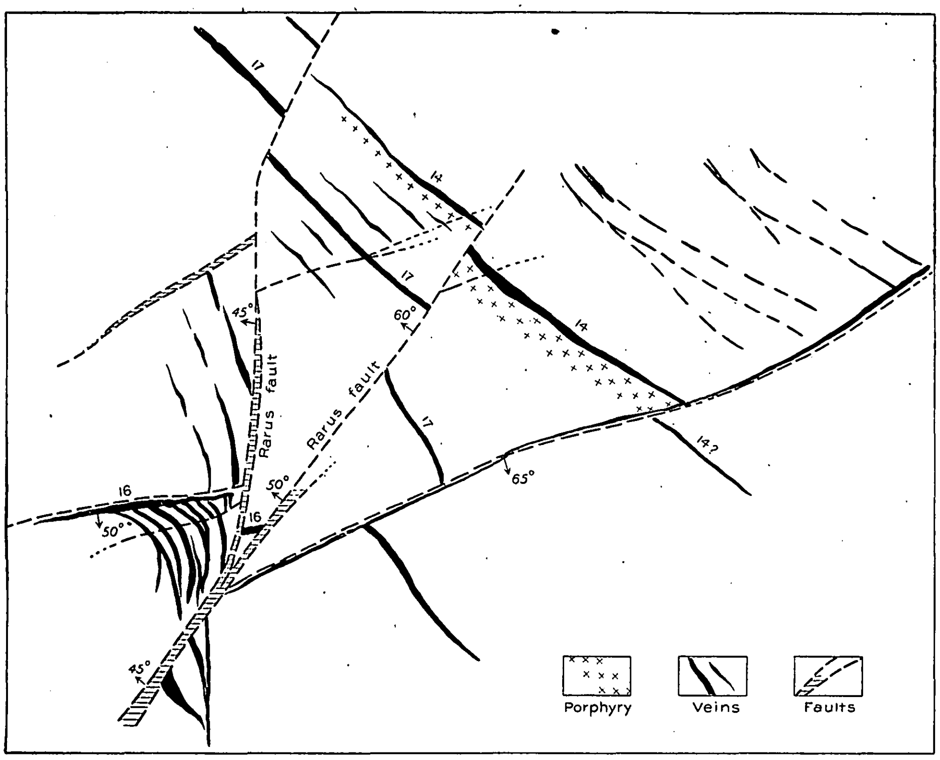


FIGURE 105.—Plan of veins on 1,100-foot level, Mountain View mine, and 1,200-foot level, Rarus mine.

The No. 16 vein is the principal ore producer of the 1,100 and 1,200 levels of the Rarus mine. Its course is N. 70° E. and its dip is 53° S. It is a distinct fault vein, varying in structure from a mass of mashed granite cut by interlacing clay seams with bands of glance and pyrite on the footwall, to a vein 7 to 10 feet or more wide, of which 2 feet is pyrite, impregnated with glance.

The displacement of the veins opened up in the Mountain View and Rarus mines by the No. 16 fault vein, which is itself displaced by the Rarus fault, is well shown on the 1,100-foot Mountain View level, which lies about 15 feet above the 1,200-foot Rarus level (fig. 105). In these workings the principal ore bodies are found as northwest veins, displaced by the No. 16 (Blue Jay) fault, the shift varying from 20 to 60 feet to the east. West of the Rarus the No. 16 fault dips about 50° S., and east of the Rarus about 65° S. The Rarus fault appears to contract where it crosses the No. 16, and in the broken ground lying between it and the Blue Jay a large body of ore is found that appears to have been formed recently. The Rarus fault in crossing splits, one branch running nearly northeast and dipping 60° NW., and the other branch turning nearly north, with a dip of 45° W. and producing a second dislocation of the northwest veins.

The No. 14 vein lies on the footwall side of a rhyolite-porphyry dike. It is itself a fault vein, but of the older Silverbow generation, to which the Johnstown (North Connecting) vein belongs. The displacement by the northwest-dipping Rarus fault, and by the southeast-dipping Blue Jay fault, is similar, which seems to indicate that the latter is an overthrust fault.

A second fault fissure, parallel to the No. 16 (Blue Jay), lies about 250 feet to the north. But little development has been made on this fault fissure, and its relations to northwest veins is not known. So far as indicated by the workings, it does not fault them. The chief significance of the observations on this level lies in the fact that the Blue Jay is shattered by the Rarus, and that the block between the intersections of these two faults is intensely shattered, indicating that down-seeping waters have filled this block of ground with glance and enargite whose downward extension is limited by the plane of the Rarus fault. A detached, isolated portion of the No. 16 fault is found between the two walls of the Rarus.

In the Rarus mine the No. 16 vein shows 6 feet of fault material. The veins displaced by it are two. The southernmost, known as the No. 17 vein, is a hard quartz-pyrite vein, dipping from 85° N. to vertical; it has a width of 2 to 3 feet and seems only slightly enriched. The northernmost vein shows 1 to 2 feet of ore, but is lean and unworkable in the faces seen. It also is a hard and solid quartz-pyrite vein incased in granite and is not recognized westward. It dips 60° S. This same vein is cut on the 1,200-foot drift along the No. 16 (Blue Jay) fault, and in both instances the displacement is to the south on the hanging-wall side. The Rarus fault at this level shows 18 inches of tough blue clay, carrying pebbles. It is very clearly defined and readily traceable throughout the mine.

DEFLECTION OF MINERALIZATION.

The hypothesis of intersecting fissures with mineralization that follows one fissure line for some distance and then turns off to another accords with the facts observed on the Syndicate and Parrot lodes, where N. 80° W., and N. 80° E. fissures deflect the mineral channels, the forsaken line continuing beyond the intersection as a tight and barren crack. At the Rarus one can recognize fractures coursing N. 60° E., N. 60° W., N. 80° E., N. 80° W., and N. 30° W.

Where faulting has occurred and the fault is ore bearing, the ore along a N. 80° E. vein may turn northwest along a N. 30° W. vein; in many places only a barren crack continues the first vein, perhaps to become ore bearing again where the crack intersects another N. 60° E. vein.

In the Rarus-Pennsylvania part of the district it has been found that ground in which the walls of drifts are coated by iron oxide or where much iron oxide occurs is uncongenial for ore.

The altered granite from the crosscuts of the Rarus mine is streaked and banded by films of pyrite coated by black and sooty glance. These films occur in minute joints, too small to be noticed were it not for the mineral. The films vary from pure pyrite to pure glance according to the amount of replacement; on joint surfaces in cross fractures between the pyrite films dendritic masses of sooty glance are seen, so it is evident that the glance is not entirely an actual replacement, but that the mine waters are depositing chalcocite directly. (See Pl. XVII, *B*, p. 204.)

VEINS WEST OF THE RARUS FAULT.

In the ground west of the Rarus fault half a dozen veins are worked in the Rarus and the Mountain View mines. The strongest are those of the northwest series, embracing the Johnstown or North Connecting (the most northerly vein worked which splits near the Rarus into two branches), the Johnstown No. 2 vein, and the Mountain View fault vein (called the Orange or South vein in the Rarus and Michael Davitt trials). Farther south the Pennsylvania No. 8 vein occurs and is extensively developed. Besides these four veins there are several small parallel veins which have not been worked.

All these veins extend eastward to the west wall of the Rarus fault, which cuts them off abruptly and in most cases brings the end of the vein against barren granite.

The veins of the quartz-pyrite series include the Cross, the Iron-Powder, the Pennsylvania No. 2, and others as yet unnamed. These veins are mostly lean and workable only near the Rarus fault.

NORTHWEST VEINS.

JOHNSTOWN (NORTH CONNECTING) VEIN.

The most important vein in the area west of the Rarus fault is the Johnstown (North Connecting) vein. It has a northwest course, parallel to the Mountain View fault. The vein is about 8 feet wide, and in the Mountain View has a dip of about 80° S. It is an old vein whose character varies somewhat at different places, but is essentially an altered and partly enriched quartz-pyrite vein, without clay selvages or other evidences of faulting. Though not a fault vein it carries enargite, which is characteristic of the fault veins of the district. In the Mountain View mine the 500-foot drift on this vein at first shows no enargite, but going southeast enargite occurs more and more abundantly. To the northwest the vein is narrow, carrying from 16 inches to 2 feet of ore, lying against rather irregular walls of hard, pyritized granite, the vein filling becoming progressively poorer and more massive. The dip in this portion of the vein is 72° S. To the southeast the vein becomes richer, and as it approaches the Rarus fault has been reopened and shows a good wall with selvage clays, though the values fade out before the Rarus fault is reached.

The Johnstown vein has a tendency to split, showing a number of branches. The apex of the vein is 30 feet wide, and the bifurcations begin in the Lloyd tunnel, despite which the vein is united and solid a few hundred feet beneath this tunnel. West from the Rarus fault this vein has a dip of 47° to 55° S., changing finally to 70° S. at a point 179 feet west. Toward the surface the dip becomes reversed and is northward.

This vein, though not definitely recognizable between the two fissures of the Rarus fault, probably forms the Cyclone, a flat ore body; east of the Rarus fault it is correlated with the Windlass, which is the widest as well as most persistent and regular vein of the Rarus series.

JOHNSTOWN NO. 2 VEIN.

The Johnstown No. 2 is like the Johnstown (North Connecting) vein and is parallel to it. It is a comparatively narrow vein, averaging 4 feet across, with one-half inch to 2 inches of clay on the hanging wall and with lenses 6 to 8 inches wide of quartz-pyrite ore, the latter coated by glance. The dip is 70° to 80°, being steeper to the west. It is developed by drifts on the 300 and 500 foot levels of the Mountain View and St. Lawrence mines. The walls are distinct, but the footwall granite is plated by pyrite films one-fourth inch thick at intervals 1 to 6 inches apart. (See Pl. XXVII.) Where workable it shows 1 to 2 feet of ore. In the 500-foot Mountain View it has 6 inches of fault clay and 3 to 10 inches of lean ore. The vein as a whole shows wavy walls, the vein widening out only to narrow again along its course and showing many clay slips that run across from wall to wall. Though parallel to the Mountain View fault vein, it is not seen in the south crosscut on the 500-foot level of this mine, and must pinch out.

Between the Johnstown vein and the Mountain View fault vein the rock is a soft and white leached granite for 50 feet, then harder. It is cut by at least three small northwest veins, which have received no names.

Eighteen feet south of the Johnstown No. 2 vein lies a parallel vein 12 inches thick and dipping 90°. Another east-west vein about 30 feet north of the Mountain View fault is 6 to 8 inches wide, with walls of sheeted granite. The vein dips 62° S.

MOUNTAIN VIEW FAULT VEIN.

The Mountain View fault vein and its relation to the Anaconda and Mountain View south veins are described elsewhere (p. 202). It is not important as an ore producer in the Rarus area west of the Rarus fault, but its eastern continuation, in the deep levels east of the Rarus fault, contains valuable ore bodies. Its dip is nearly vertical and parallels the Johnstown vein in the Mountain View mine; where it cuts off the Mountain View south vein it dips 70° S. and is quite uniform on all levels, but nearing the Rarus claim line and farther eastward it bends or arches and dips less steeply in depth than it does near the surface.

PENNSYLVANIA NO. 8 VEIN.

The Pennsylvania No. 8 vein lies southeast of the Mountain View fault vein.

EAST-WEST VEINS.

POWDER-IRON VEIN.

The Powder-Iron vein is in two segments, separated by the Mountain View fault.

PENNSYLVANIA NO. 2 VEIN.

The Pennsylvania No. 2 vein (South ledge of the Anaconda mine) swerves northward in approaching the Rarus fault, near which it lies on the footwall side and parallel to a strong dike of the rhyolite porphyry; it is dislocated by the Mountain View fault, beyond which it reappears as the Enargite vein.

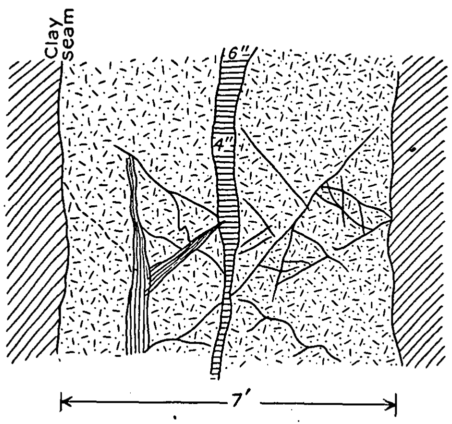


FIGURE 106.—Section of Windlass vein, face of 600-foot level, Rarus mine. Altered granite cut by streaks of enargite, and pyrite coated by enargite.

VEINS EAST OF THE RARUS FAULT.

The area east of the Rarus fault is as extensively fissured as that to the west. Not only are the veins close together and netted by cross veins, but the rocks are plated, fissured, and thoroughly decomposed.

This extensive shattering has led to equally extensive mineralization of the ground, which has proven wonderfully productive for a depth of 800 to 1,000 feet, below which the veins become leaner and leaner and finally unworkable. Other veins, however, appear in the levels below 1,000 feet; and the north-northeast fault veins, which are not seen in the upper levels, are especially productive.

NORTHWEST VEINS.

WINDLASS VEIN.

The Windlass vein has been the most productive in the Rarus mine (fig. 106). It is a large, well-defined fissure vein, varying in width from 3 to 40 feet, with an average of about 20 feet. It has been developed continuously to a depth of 1,400 feet and a length of 3,000 feet in the Rarus, Berkeley, and Silverbow mines. It is the most persistent, regular, and liberally mineralized lode of the group. It lies south of the North vein, but in some places unites near the surface with the North, Enargite, and Berkeley veins, the last two of which strike east-west at an acute angle with the Windlass. In the deeper levels, 1,000 to 1,800 feet, the vein is lean and composed of quartz and pyrite, with little or no glance or enargite; and even in the upper levels the ore yielded by this property comes from the so-called No. 16 fault vein (correlated with the Blue Jay fault vein or Anaconda middle ledge). On the 1,200 and 1,300 foot levels of the Rarus mine the Windlass is a vein of white quartz, with patches and dendritic aggregates of enargite and glance scattered through it.

The structure of the Windlass vein is particularly interesting on the 1,600-foot level, where it shows a shattering of the rock between definite walls and impregnation by enargite along the joint planes. These joints show the multiple fracturing commonly observed when a block of rock is fractured by steady pressure—that is, they are conjugate fractures.

Of the older veins the Windlass seems to be the master fissure, and the east-west veins run up to it and appear to stop. Thus the South vein of the Rarus mine is not found beyond, though calculation shows it to correlate fairly well with the Cross, only the latter does not come to the Windlass. The Enargite, the dislocated east end of the long, strong, and persistent Pennsylvania No. 2 vein, appears to end against the Windlass, as also does the Berkeley. One can not, however, make a correlation of the veins on both sides of the Windlass, as is so easily done with the Mountain View fault vein, and the inference is that the Windlass vein is of the same age as the Pennsylvania, but older than the Mountain View fault. The Johnstown (north connecting) vein is undoubtedly the continuation of the Windlass northwest of the Rarus fault, but is cut off by the Blue Jay (middle) fault of the Steward series and ends against the South vein of the Mountain View mine. As this South vein parallels the Anaconda east of the Mountain View fault, it seems probable that the northwest-southeast and east-west fissures were formed at the same time and that they fault and delimit each other.

SOUTH VEIN.

The South vein, which is extensively worked in the 210, 450, 500, 600, 700, and 800 foot levels of the Rarus mine, merges eastward in the Windlass vein. West of the Rarus it appears as the Johnstown No. 2, but may possibly be the Powder vein. On the 800-foot level of the Rarus the vein is wide and strong and carries 2 to 8 feet of solid enargite.

BERKELEY VEIN.

The Berkeley is a particularly interesting example of an earlier vein, fractured and faulted, and containing large blocks of the original vein filling, lying distributed somewhat irregularly through the fault clay, but not broken into the small fragments and bowlders characteristic of fault veins generally. The vein shows well-defined clay walls on both the north and south sides. The vein has a width of 6 to 8 feet between walls, but carries ore only in bunches and in the fragments just mentioned. It is worked in the deep levels of the Rarus mine (800 to 1,600 foot) where it is an important ore producer.

NORTH VEIN.

The North vein is less regular than the Windlass. It lies north of the Windlass vein, with the Snohomish Diagonal, a narrow fault vein, between. The vein has a width of but 1½ to 2 feet at the surface, but is 15 feet across where the sulphide ore begins and has an average thickness of 10 feet in the stopes.

It has been worked for 600 feet vertically, but becomes narrow and lean at 1,000 feet. The dip is north for 300 feet beneath the surface, and then straightens up and becomes south, until it unites with the Windlass vein on the 900-foot level. On the upper levels of the Rarus mine (450 and 600 foot) the vein becomes lean and narrow as it approaches the Rarus fault, contracting to a 2-inch streak of quartz and pyrite inclosed in sheeted granite. Eastward it splits up and dies out 100 feet east of the Cross vein.

The 1,100-foot level of the Rarus mine shows a long westward drift on the North vein, which is from 1 to 2 feet wide and shows rather lean values. This vein appears to cut off an east-west vein and several parallel streaks lying north of it. The drift passes into and through the Rarus fault, and the branch of the drift turning eastward cuts an east-west vein that is faulted and displaced by the No. 16 (Blue Jay) fault.

SNOHOMISH VEIN.

The Snohomish vein has been stoped in several levels in the Rarus mine, but is not known west of the Rarus fault, though the altered granite north of the Johnstown (north connecting) vein shows a thin quartz-pyrite vein that may represent its westward extension. It is a wet vein, with well-defined walls of hard granite, showing spurs running off to the northeast.

VEIN NO. 612.

Vein No. 612 is 3 to 4 feet wide and has irregular rolling walls of hard granite. It is a granite vein, consisting of crushed rock, with a 2 to 4 inch streak of pyrite, enriched on the hanging wall by bunches of chalcocite ore. The vein averages 30 inches of 6 per cent ore, carrying 6 ounces of silver.

EAST-WEST VEINS.

CROSS VEIN.

The Cross vein runs approximately east and west, its general direction being N. 80° E. and its dip 82° S. It is a fault vein showing 6 to 15 inches of brecciated country rock and clay and some bunches of ore, but is seldom workable. It cuts and slightly displaces the North vein, a northwest fracture, and faulted veinlets of pyrite show the north wall to have a horizontal shift eastward of 10 feet. The vein appears to end at the Snohomish Diagonal vein (another northwest vein) and does not extend to the wall of the Windlass. Neither in character nor dip does it correspond to the Enargite vein.

SNOHOMISH DIAGONAL VEIN.

The Snohomish Diagonal is another small vein of the northwest series, averaging about a foot in thickness but showing swells and narrowings along its course. It shows fault clays with quartz-pyrite bands. The dip is 65° S. The vein is well developed on the Rarus 800-foot level.

RARUS FAULT.

IMPORTANCE.

The Rarus fault is the most recent and in many ways the most important fault of the entire district. It cuts and displaces not only the veins of the mine from which it takes its name, but extends northward through the Leonard and Colusa mines and southward to the Belmont, and on its dip it cuts through the Anaconda lode and its congeners. This, unlike other great faults of the district, is not mineralized, but it has played an important rôle in producing the great flat ore bodies of the Colusa, Leonard, Rarus, and St. Lawrence mines by its intersection with east-west lodes.

An understanding of the Rarus fault is essential to the proper development of many of the mines, and no single feature of the structural geology of the district has been the subject of greater or more bitter controversy. In 1896, when the district was first studied, this fault was clearly recognized by the geologists of this Survey, but a few years later its existence, at least as a displacing fissure, was strenuously denied by many witnesses in the celebrated Rarus lawsuit.

Time and the development of the mines of the district have shown that not only was the Survey's interpretation of the fact correct, but that faulting of the lodes is so common a feature throughout all the mines that no intelligent development can be planned without a recognition of the fact and its influence.

GENERAL CHARACTER.

The Rarus fault is known by mine development work for a distance of over 5,000 feet along its course and to a depth of 2,400 feet vertically. Its apex is indistinct and can only be recognized as narrow iron-stained streaks of indurated clay, but in underground development its presence is easily recognized, as it cuts off the veins crossed by it cleanly and sharply.

The deepest development of the Rarus fault is on the 2,200-foot level of the St. Lawrence mine, where it has a width of 125 feet, being cut by a drift 400 feet north of the shaft. At this point it has a wall composed of rhyolite porphyry and of aplite. It is noticeable that in the country rock there are many slips parallel to the Rarus and many others that lie at right angles to the first set, cutting and displacing them; from this it is supposed that they are due to the adjustment of the blocks (Mountain View system) and not to any fault movement subsequent to the Rarus.

The Rarus is a double fault, that is, it has two clean-cut and distinct fault planes, with broken and crushed material between. As these two fissures have a dip diverging as they go down, the space between them widens with depth, and the fault becomes one of increasing importance as the mines are deepened.

The width of the Rarus fault varies greatly from place to place, even at the same elevation; on the plane 5,000 feet above sea level, for instance, it varies from 30 feet to 300 feet. The east or foot wall is the more regular of the two fissures, the variable width being largely due to a curving of the west fissure.

On the Anaconda 2,400-foot level the fault fissure is 40 feet wide, but on this level, as on the 2,200-foot, the fissure is only a part of the broken ground which at this depth represents the fault. The Anaconda vein within the fault is here definitely recognizable but is lean and almost valueless.

On the surface the two limiting fissures are from 15 to 40 feet apart. They have a general northeast course, with marked local curving. The outcrop having been developed for legal purposes, is well determined in the Rarus and adjacent claims, and may be seen in the railway cut on the Michael Davitt claim. Elsewhere it is recognizable with difficulty, though underground development fixes its position within narrow limits.

INTERFAULT FILLING.

The walls are everywhere marked by seams of blue clay or by its oxidized and hardened equivalent, from a few inches to 2 feet or more in thickness. The footwall or east fissure is particularly well defined and sharp.

The blue clay carries not only rounded pebbles of ore, quartz, pyrite, and glance, but also others of granite, aplite, and rhyolite porphyry, where these rocks are near by and are cut by the fault. The rock alongside of this clay is often striated, in some places slickensided, and many of the major grooves run downward at an angle of about 42°. The west or hanging-wall fissure is well defined and clear cut, shows clays and friction breccias, and sharply cuts off the vein.

Evidence of movement may be seen along both walls and in the interfault mass. Parallel to the fault walls are many sympathetic or subsidiary fractures, some of which appear locally outside of the fault proper and have cut and slightly shifted the veins; others appear in the fault, bounding blocks of ore.

Within the fault walls is a mass of broken and crushed rock, which as a rule is more altered and softened than that outside of the fault and which contains detached irregular pieces and blocks of ore that once formed parts of veins but have been broken off and dragged from their places. These detached fragments have a disturbed orientation, being tilted and turned partly around. The large flat ore bodies appear to be a succession of blocks, a part of the veins broken and step-faulted by distributed displacement. They are never large and unbroken masses. The identity of the veins within the interfault mass is destroyed by the tilting and cracking. Moreover, the ground has been much shattered and serves as a water channel, so that granite and ore are altered and unlike the materials outside of the fault.

DIP AND DISPLACEMENT.

The average dip of the east wall of the Rarus, measured along the cut-off of the Windlass vein from the surface to the 900-foot level, is 52° 44′; the average dip of the west fault, from the surface to the 900-foot level, is 44° 49′.

The total displacement of the Rarus fault on the 500-foot level of the Michael Davitt appears to be 200 feet to the north and 230 feet vertical. The hinge point of the interfault blocks appears to be the 1,100-foot level of the Rarus. In the Rarus mine the country west of the fault has gone down 210 feet on the dip of the fault, and probably moved northward 195 feet horizontally. The slip is not normal to the strike, but inclines to it at 42°.

There is some doubt as to the amount of tilting of the hanging-wall block (i. e., the scissors movement along the fault) of the Rarus fault. In the Pennsylvania mine the displacement along the Rarus fault seems gradually to lessen. At the 600-foot levels it is well marked, is much less on the 700, still less on the 800, and practically lacking on the 1,200.

In the St. Lawrence mine the Rarus fault is steeper and has a greater throw in the upper levels than it has at a depth of 1,600 feet or more. On these deep levels the two bounding or wall fissures are no longer distinct, but the fault has split up into many slips, though in general the foot-wall fissure limiting the fault ground is well defined and persistent. The average dip is about 30°, but varies in each slip. The 1,600-foot level of the St. Lawrence shows six well-defined fissures composing the fault, and the same flat ore bodies are found here where the Anaconda lode is faulted by the Rarus as are found in the upper levels of the Rarus mine, notably the 450-foot, and in the workings of the Leonard mine, where the Rarus fault breaks through the Colusa, Gambetta, and Piccolo veins. The progressively western pitch of the ore bodies is, of course, due to the northwestern dip of the fault, combined with the southerly dip of the vein. In some of the cross sections constructed for use in court the ore bodies are marked as passing downward through the Rarus fault, without deflection, but in each case where development work has been done to prove the actual conditions, flat ore bodies have been found, so that there seems no reason to doubt that the explanation here given is approximately correct. On the other hand, it must be remembered that there are numerous northwest fissures which cut through the ground; further, in the Leonard mine there is an intermediate vein fissure, with a course of N. 45° E., which corresponds to the Rarus fault but has dips of about 45°. As the Rarus cuts all the veins of the camp, including postmineral faults like the Blue, Mountain View, and others, the resulting structure is very complex and an exact matching of the veins can not be obtained.

ORE BODIES.

The area between the two fault walls contains workable ore bodies of great value, not only in the Rarus ground, but notably northward in the Leonard-Colusa ground and in the deep levels of the St. Lawrence mine.

North of the Rarus mine the Rarus fault, in passing through the Leonard ground, undoubtedly cuts and displaces the veins. This is well shown in the upper levels, where in passing through the Colusa vein it has produced a flat ore body, due to a distributed faulting, by which the Colusa vein is spread out in a series of blocks arranged in steplike form. On this assumption it was reasoned that a similar flat ore body should be found in the immediately contiguous veins, and to prove this exploration work was started on the Piccolo Discovery. The work proved successful, the 600-foot crosscut encountering a streak of ore which was found to correspond in position and in shape to the flat ore body whose existence was demanded by the theory. The ore is solid enargite, but it is crushed and not hard like the ore of this character in unbroken veins. The block is, however, not brecciated; though mashed granite and clay, clearly fault matter, occur above and below it, the ore itself does not appear to be so badly broken.

South of the Rarus area, in the Silverbow area, the fault does not interrupt the continuity of the ore, though it shatters and step-faults the vein, flattening it on the dip and changing its course on its strike.

VEINS OF BUTTE FLAT.

DEVELOPMENT.

Between the productive copper area and the high mountain ridge of the continental divide on the east lies the Flat, a broad, nearly level valley bottom drained by Silverbow Creek. The copper veins are mined up to the western borders of this Flat and in the Silverbow mine out under it, but their eastward extension across it has not been established, though much prospecting has been done at many points. As early as 1896 the Atlantic shaft was sunk at a point almost due east of the Colusa mine and by 1900 a number of other shafts had been sunk in the same region. Those known as Butte & Boston shafts Nos. 5 and 7, together with the workings of the Ella mine, situated in the Flat east of Meaderville, showed that veins exist in this area, but did not reveal any that were profitable. The more extensive development of the Pittsburg & Montana Copper Co., which included two shafts 1,200 feet deep, with winzes down to 1,450 feet and over 25,000 feet of underground crosscutting and drifting, showed the existence of several veins with workable bodies of copper ore that do not extend upward to the surface. Other companies owning ground in the surrounding section have sunk deep shafts, especially along its eastern border, at the base of East Ridge, but though numerous small quartz-pyrite veins have been cut and a large number of fault fissures found, no large ore bodies of commercial value have been developed.

Owing to the thick mantle of débris filling the Flat, prospecting has been both difficult and costly. In the Atlantic shaft this "wash" is nearly 500 feet deep, a log being found 480 feet below the surface. The saturation of this débris by water has made shaft sinking extremely slow and troublesome. On the foot slopes of East Ridge conditions are not much better, as the wide north-south fault zones found there are filled by crushed and altered rock that requires close timbering, as the ground is loose and dangerous.

PITTSBURG & MONTANA PROPERTY.[1]

The Pittsburg & Montana property is the most important property of this area. In this mine the two upper levels of the south shaft show practically nothing of value. In the other workings several veins have been found, three of which carry well-defined shoots of shipping ore. The lodes are not continuously ore-bearing, a condition predicated by the workings on the Silverbow mine.

The veins developed in this property belong to the three systems, the Anaconda or quartz-pyrite system, a northeast fault-vein system, and the Blue or northwest system.

The Donner is a lean quartz-pyrite vein, having a course of N. 40° E., and a steep northerly dip (80° or about 50 feet in 200). It is developed by drifts and stopes from above the 1,000-foot level down to the 1,350-foot level, showing a mean of 3½ feet, with extremes of 1 to 6 feet in thickness. On the 1,350-foot level the vein is 12 inches thick at the winze, and 7 feet wide at the face of the drift. The ore shoot is 135 feet long, the vein being lean beyond the shoot. The ore contains enargite and glance, the shoot averaging 5 per cent copper and 13 ounces of silver as mined.

The Reed vein courses N. 65° W. and dips north. It is developed from the 500 to the 1,200 foot level, but is low grade.

The Rossell and Motherill veins are nearly parallel fault lodes 500 feet apart, which cut off the others. The Rossell courses N. 60° E., and dips steeply north, with an average thickness of 3 feet, varying from 1 to 11 feet along the drift. It has been stoped from 1,200 feet up, the ore shoot being 400 feet long on the 1,200-foot level. The Motherill vein runs N. 45° E. and varies from 2 to 6 feet in width, averaging 3 feet. It shows an ore body 150 feet long, developed from the 1,000-foot down to and below the 1,200-foot level.

ATLANTIC MINE.

The Atlantic shaft is between the East Ridge and the town of Meaderville. The shaft was sunk to a depth of 600 feet by the Boston & Montana Mining Co. in a search for the supposed eastward continuation of the veins of Anaconda Hill. The granite bedrock is covered by 400 feet of slide material and valley wash. On the 600-foot level a crosscut to the south 90 feet long shows three small veins, the most northerly of which has a general southeast course and stands nearly vertical; its maximum width is 4 feet. It has been drifted upon to the east for 75 feet and throughout was found to be a typical quartz vein, studded with irregular masses of chalcopyrite and pyrite. As much as 4 per cent copper and 15 ounces of silver to the ton have been found in portions of this vein. South of this vein the crosscut has been extended a short distance, but the two veins encountered are extremely small and without value. A crosscut has been extended 30 feet north, at which distance a vein 2 feet in width was encountered. This vein, like the more southerly ones, is a lean pyrite-quartz lode.

BUTTE & BOSTON NO. 7 MINE.

The Butte & Boston No. 7 shaft was sunk 410 feet by the Butte & Boston Co. in a search for the eastward extension of the copper veins. According to the mine foreman, the shaft was sunk through wash for 140 feet before reaching bedrock. At 200 feet down it cut a small

[1] Since this report was written important discoveries have made this mine a large and profitable producer.

vein of iron-stained quartz 6 to 15 inches wide, running N. 60° E. and dipping 50° N. This vein was explored by a west drift, which was closed at the time of visit. The vein has an aplite hanging wall, the rock being cracked and the fractures coated with red iron oxide. The footwall is silicified granite.

In the shaft, on the 400-foot level, which was being cut at the time of visit, the rock is fresh granite, cut by fractures running in all directions. The largest seen is a small clay seam 15 feet north of the shaft, dipping 60° S. and coursing N. 70° E. On the west side the rock is a pyritized granite, cut by a northward-dipping clay seam.

VEINS OF EAST RIDGE.

CHARACTER AND DEVELOPMENT.

The mountain ridge commonly called the East Ridge, which forms the eastern wall of Silverbow Flat, is seamed by many mineral veins, which are commonly believed to be the eastern continuations of the copper veins of Butte. The veins can not, however, be traced across the Flat, as this is covered by a deep layer of débris and mountain waste; moreover, the Continental fault, with its sympathetic fractures, has so displaced the ground on each side of it that no direct connection is probable. The evidence now available indicates that the Butte copper belt does extend eastward beneath the Flat, but that the great veins worked in the Anaconda and Rarus areas have lost their strength and are not definitely recognizable. The development work since 1900 has shown that numerous quartz-pyrite veins, carrying very low values in copper and seldom more than 2 feet thick, traverse the lowest foot slopes of the mountain ridge, and that these veins are cut by veins of the Blue Vein series and are truncated by broad and barren north-south fault zones. In the Pittsmont ground shoots of high-grade ore have been found; elsewhere the deep workings have not (up to 1906) developed ore enough to pay for working.

In the East Ridge proper, east of the Continental fault, the veins are unlike those of the copper belt, but greatly resemble those of the Butte silver district. They are quartz-filled fissures, carrying silver minerals and some copper ore. At the Homestake and Clinton mines considerable chalcocite was found, but it occurred in the central or open and vuggy part of a vein of comb quartz containing rhodochrosite and some tetrahedrite. Elsewhere development work on many veins has failed to show any extension of the Butte copper veins. Though the mineralization of the East Ridge has not as a whole proved remunerative, there is no sound reason to assert that this area contains no good properties. It may safely be said, however, that the veins show no evidence of becoming copper-bearing in depth. As the Continental fault depressed the Butte area proper, the veins of this East Ridge must be far more deeply eroded than those of Butte.

The entire East Ridge area has been staked out in mineral claims, and more or less prospecting has been done. The most extensive work appears to have been carried on along the lowest part of the ridge, which lies between the gulches which score the mountain front.

Many of the surface showings along these claims are more attractive than any on the great mines across the Flat. The granite is stained and impregnated with copper oxides and silicates over considerable areas near the Altona, Montgomery, and Bertha claims, on the ridges on either side of the Columbia Garden gulch. Veinlets and bunches of cuprite and chrysocolla occur, and small shipments of rich oxide ores have been made from several claims. It has been found, however, that this mineralization is due to alteration and leaching of small and mostly lean veins and, mainly, of the copper so generally distributed as chalcopyrite through the granite beneath the limit of oxidation. The lack of pyrite and the presence of chalcopyrite appear to be unfavorable conditions for large accumulations of copper ore, and this despite the fact that the dark and fresh granite contains an average of nearly 1 per cent copper.

The entire foothill area was actively prospected in 1896, but the lack of favorable results led to the gradual cessation of work until 10 years later, when the high price of copper, the Pittsmont discoveries, and the importance of the fault veins as ore producers all led to active prospecting work. Of the earlier work that on the Altona was the deepest and most important.

ROCKS.

The rocks resemble those of the Bluebird silver area rather than those of the Anaconda or Syndicate hills. They show large quantitites of aplite, with the usual associated darker transition to Butte quartz monzonite, and numerous quartz and pegmatite segregations, whose presence has given rise to false hopes, as the quartz is generally supposed to be vein quartz, but is really local, not mineralized, and similar in occurrence and origin to pegmatite.

Wherever aplitic granite occurs in this ridge, copper seams appear. The silver values are rather high, being 2 ounces of silver to 1 per cent of copper, whereas generally the proportion is three-fourths ounce of silver to 1 per cent of copper.

The aplite from near Columbia Gardens is the typical aplite of the Butte district, showing more or less alteration and no biotite. This rock is cracked and the fissures filled with malachite, with cuprite in the center. No replacement has taken place, and it is evident that the oxidized minerals form actual cavity fillings. This is readily understood, as in the western part of the Butte district the aplite of many of the masses crack into a network of fissures, similar to mud cracks, which are believed to be due to the strains developed in the weathering of the rock. The derivation, however, of this malachite and cuprite is difficult to explain, as it must come from the surface. The most reasonable hypothesis is that the chalcopyrite-bearing granite on the higher hillsides is decomposed and that solutions traveled along the base of the disintegrated mantle lying above the solid rock deposited their burden on encountering the cracks in the aplite. No reason, however, for precipitation in these cavities is apparent in the specimens, as there is no evidence of replacement of the rock and none of the presence of pyrite. It is, of course, possible that the seams represent oxidized, enriched, and subsequently reoxidized pyrite seams.

The rock from the Clinton mine consists mainly of aplite. The dump heap shows some granite, which is nearly normal in character, but has the porphyritic tendency and facies so often observed in the borders about aplitic masses. The biotite in the rock gives it a porphyritic appearance.

MINES.

SIX O'CLOCK MINE.

The Six o'Clock mine is situated on the foot slopes of the East Ridge, just below the Great Northern Railway. The old shaft was down 1,000 feet in 1907. At 400 feet down a crosscut south 100 feet long traversed several belts of altered granite, associated with which are numerous stringers and veinlets of manganese spar. Studies under the microscope show an apparent ratio between the amount of manganese and the ferromagnesian minerals, especially the biotite. On the 1,000-foot level crosscutting showed several veins, which have not been examined, but are said to be small east and west quartz-pyrite veins, cut by large northerly trending fault fissures.

NORTHWESTERN MINE.

The Northwestern mine is situated just east of the Butte quadrangle, at the mouth of the canyon which opens from Elk Park. When visited the shaft was only 300 feet deep, with a crosscut running 25 feet north and an equal distance south from its bottom. In sinking the shaft two east-west veins were cut, dipping steeply to the north. The granite is of a transition type, rich in ferromagnesian minerals and plagioclase and rather more coarsely crystalline than the common rock. It is comparatively fresh and unaltered, the zone of decomposition extending only a foot or so from the veins. Twenty feet north of the shaft, on the 300-foot level, a 6-inch vein was cut, which carried a large amount of pyrite and some chalcopyrite, fresh and massive. Several crystals of quartz an inch in diameter were easily broken from the mass and left a mold which showed every detail of their shape. The pyrite is everywhere distinguishable from the chalcopyrite, the lines of division between the two minerals being sharp and the contrast in color marked. The iron pyrite occurs in more or less crystalline masses in the vein and in the country rock inclosing the vein for as much as a foot, possibly 2 feet, away from the veins. This pyrite is closely associated with the ferromagnesian minerals of the granite; it is observed to occur along cleavages in the hornblende and biotite and in regular masses within these crystals; it may therefore be either a replacement of the ferromagnesian minerals or a reduction from them, as the minerals associated with the decomposed ferromagnesian minerals and the pyrite are those formed by the decomposition of the biotite, hornblende, and augite, it seems probable that the iron of the pyrite at one time belonged to the iron-bearing silicates.

On the surface of this mine two veins have been found. Both of these have an east-west course and a northerly dip; this last, however, is not persistent and in all probability averages vertical.

Nearly every joint plane or fracture surface in the granite—and there are many—carries some form of copper. In many this is chalcopyrite, though much native copper is found, everywhere in thin plates, dendritic in form and showing a very weak tendency to crystallize.

CLINTON MINE.

At the Clinton mine the vein is developed by a N. 80° W. drift. The vein is wet but only contains ore at intersections with N. 80° E. fissures. The canyon itself is eroded along a fault fissure.

HOMESTAKE MINE.

The Homestake mine has the greatest development of any of the East Ridge properties, but it has been full of water for many years. Good ore is said to occur on the 500-foot level 1,300 feet below the Clinton tunnel. The ore is tetrahedrite and glance and is found in well-defined quartz veins, whose general character more nearly accords with that of the silver than that of the copper veins.

The Homestake mine is situated nearly a mile east of the Northwestern mine. Development work has been carried on in a desultory way for a number of years; at first a tunnel was run into the side of the hill, and granite, considerably altered, together with numerous veins of copper ore was found; subsequently a shaft was sunk on the side of the hill 75 feet above the tunnel. This shaft is 550 feet deep. From the shaft three veins have been developed, all of which have a general northwest and southeast trend. They are not more than 200 feet apart. The middle vein is the best developed. It stands nearly vertical. At the bottom of the shaft it is 7 feet wide, and is composed of very white, hungry-looking quartz, which contains bunches of chalcopyrite, pyrite, and gray copper. Analysis of this ore yields 1 ounce of silver and $2 in gold per ton, together with 4 to 8 per cent of copper. A number of tons of ore taken from this mine showed close association with the country rock, that is to say, the heart of the vein is composed of very low-grade quartz, and the walls of the vein, both hanging and foot, yield a grade of ore which is valuable when concentrated. Studies of this ore under the microscope showed only small amounts of iron pyrite, together with some sphalerite, tetrahedrite, and quartz. The pyrite was apparently the first mineral to form; it is in crystals more or less rounded and is at times highly shattered. Closely associated with it are quartz inclusions. The sphalerite is rich golden yellow in color, and shows a full development of octahedral cleavages. It is of later origin than the iron pyrite and than much of the quartz. Gray copper (tetrahedrite) occurs plentifully, associated with chalcopyrite. In general it does not show crystalline outline, but, in the thin section studied, traces of a tetrahedron form were found. One such crystal is composed in greater part of tetrahedrite, covered by a crust on two sides and by chalcopyrite on the others, as if the chalcopyrite were a reduction from the tetrahedrite.

BULLWHACKER MINE.

The Bullwhacker vein shows well in the Bullwhacker discovery shaft, where the good ore is 5 to 8 feet wide and extends down 50 feet west of and against a north-south slip.

Above the 100-foot level the same ore body was stoped, carrying 3 to 4 per cent ore quite like that of the Bertha claim. On the 200-foot level the values are too low to work, and nothing was found on the 400-foot level. It appears that this ore body is a concentration of material leached out of the copper-bearing rocks and veins of the slope above the vein, and concentrated in this fault zone by absorption by the fault clays.

The same vein shows in the Maggie Fraction, where a shaft 30 feet deep at time of visit showed good oxide and silicate ore on a north-south fault at the bottom of the shaft. A drift east developed a lean east-west vein, 3 to 6 inches thick.

BERTHA GROUP.

The Bertha group of claims, embracing the Bertha Fractional claim, the Pacific, Copper Queen, Sarsfield, and Lillie claims, covers the gentle foot slopes of East Ridge, where it is cut through by Park Canyon, the deep cut by which the Great Northern Railway crosses the Continental Divide.

These claims are traversed by several quartz-pyrite veins, having a general easterly course, and by north-south fault fissures and zones belonging to the Continental fault series. One strong fault fissure in the Bertha claim can be traced at intervals in a northerly direction across the Copper Queen, Sarsfield, and Lillie claims. Southward this vein crosses the Bullwhacker, Maggie, and probably the Montgomery claims, but is disturbed by cross faults in the latter, and lost beneath rock débris or flood "wash."

BERTHA MINE.

The Bertha mine is situated on the foot slopes of East Ridge, north of the canyon leading to Columbia Garden. The workings show a wide fault vein, with a general north-south course, with workable ore 20 feet across. The development consists of a tunnel with a winze 50 feet deep, from the bottom of which drifts are run for 45 feet north and 115 feet south.

The ore body lies in the fault. It includes 20 to 25 feet of granite, cut by veinlets and stringers of copper silicates, oxides, and carbonates, etc., inclosed between well-defined walls. The wall rock, which is impregnated for 15 to 20 feet from the hanging wall, carries 1 to 2 per cent copper.

The ore body is developed for 140 feet in length and for 120 feet in depth. Shipments of nearly 1,800 tons from between the tunnel and winze levels gave 5.2 per cent copper. On the bottom the ore carries but 2 to 3 per cent, and the south drift is partly barren, showing that the ore is fringing out. Two east-west veins also outcrop. One of them, explored by drifts from the shaft, 200 feet below the surface, shows a vein 6 inches to 3 feet wide, with a narrow stringer of ore running 6 to 30 per cent copper.

The ore of the Bertha-Bullwhacker vein consists of crackled granite along a fault fissure, with numerous clay slips intercepting the rock. It consists of chrysocolla and tenorite, filling fractures and replacing the granite. The ore is acidic, carrying 80 per cent silica and about 5.1 per cent copper. On the 100-foot level the ore body has been stoped for a width of 20 feet. The bulk of the ore is not a true fault breccia, but may be more fittingly called a mashed granite with the spaces filled by waxy, solid chrysocolla. Part of the ore consists of block-jointed granite, in which the body of the rock has been altered and impregnated with chrysocolla and tenorite, both as films along fracture planes and as patches replacing portions of the rock. About 2½ feet of crushed fault matter is seen, but the bulk of the ore body gives no evidence of the fault and is not recognizable as true fault material. An east-west crosscut shows the character of the walls, and indicates that the impregnation of chrysocolla fades out gradually from the vein. The drift on the ore has a general course of S. 10° E.

LILLIE CLAIM.

This claim shows a broad surface capping of limonite and iron-stained rock that forms a "blowout" connected with a fault vein that may be the extension of the Bertha. The gossan extends downward very irregularly, but as the shaft on this property is not on the fault, but west of the vein, nothing is determinable. The iron stain is apparently the work of an old spring, now dry, and shows no evidence of being true gossan.

SARSFIELD CLAIM.

The Sarsfield shows the extension of the Bertha fault, and also another north-south fault vein carrying a little pay ore. The rock shows a peculiar transition form between granite and aplite. It is, in fact, almost a porphyry, with fresh biotite, uralitized hornblende, and accessory pyrite and molydenite, the latter forming a half-inch veinlet of quartz, marked by bands of molybdenite on each side.

PACIFIC CLAIM.

In the Pacific claim, which adjoins the Bertha on the east, two north-south fault fissures occur. The westernmost, or Pacific vein, appears to be parallel to and not far from the Bertha. It has been developed by a vertical shaft to a depth of 399 feet, with drifts on the vein. Both the Bertha and Pacific fault veins extend northward, probably crossing the Copper Queen and Sarsfield claims.

COLLEEN BAWN MINE.

A crosscut tunnel on the Colleen Bawn property intersects two small east-west quartz-pyrite veins, which have been developed by drifts 75 feet long. The veins are narrow and show little ore and have no commercial value.

EXEMPTION CLAIM.

Two small east-west veins on the Exemption claim are cut by a tunnel and by drifts at a depth of 100 feet in a shaft 130 feet deep. The vein seen showed 6 inches to 3 feet of vein matter, and in the shaft is said to carry a foot of 10 per cent ore. Shipments of selected ore are said to have aggregated 26 tons that carried 12.6 per cent copper, 38 tons that carried 3.1 per cent, and 1 ton that carried 48 per cent.

SINBAD MINE.

The Sinbad mine lies south of the Altona, near the second canyon south from Columbia Garden. When visited in 1905 it had a shaft about 500 feet deep, with levels at 410 feet and 490 feet. The upper level showed a N. 72° E. fault vein in rotten brown granite. The vein is soft, carries no values, and but little quartz.

MONTGOMERY CLAIM.

Considerable prospecting was done on the Montgomery claim in 1906–7. A shaft over 100 feet deep, with crosscuts north, south, and west, was sunk, showing a fault vein 18 to 24 inches thick, overlying a few inches of greenish granite, impregnated with copper.

A crosscut was driven 282 feet west through more than 100 feet of altered white granite, which gradually changed to less-altered granite with fresh biotite, cut by 1 to 2 inch seams of aplite, and with aplite in the breast. A fault cut 74 feet from the shaft ran almost due north and south and dipped 42° W. A drift running south 30 feet on this fault disclosed the cut-off end of an east-west vein on the hanging wall of the fault, and led to the discovery and working of a vein averaging 4 feet in width carrying 3 per cent copper.

A north-south crosscut, 164 feet long, cut a fault zone running N. 45° W. The footwall slip dips northeast in the crosscut, but farther west dips southwest, parallel to the hanging wall. Between the fissures the granite is broken, mashed, and altered and shows green spots, colored by chrysocolla and carrying 2 per cent copper.

MAGGIE MINE.

The Maggie mine, which is situated on the Maggie Fraction claim, showed, in 1906, a shaft 30 feet deep, containing a distinct ore body of oxide and chrysocolla ore similar to that of the Bertha. This ore is cut off by a strong north and south fault, marked by clay and fault pebbles.

An east-west vein, cut off by this fault, runs through the center of the drifts. The ore body is about 20 feet wide.

Although the Maggie shaft is not over 125 feet from the Montgomery tunnel (N. 92° E.) and is on the direct extension of the Bullwhacker vein, the tunnel shows only dry and barren disintegrated fault matter and granite. Throughout the claim quartz films and blebs of aplitic material are common; the quartz is probably largely magmatic, but is in part masked by silica released by sericitization of the rock.

ALTONA MINE.

The Altona mine is situated on the slopes of the first canyon south of Horse (or Columbia Garden) Canyon. The shaft is 360 feet deep, and has a very heavy inflow of water, so that when the mine was pumped out the springs of the neighborhood dried up. The mine, at 200 and 360 foot workings, has developed an east-west quartz vein, cut and displaced by north-south faults. This, the Altona vein, has a true east-west course and dips 55° to 60° N. It varies from 6 inches to 3 feet in thickness and carries a 3-inch to 30-inch streak of ore, with 1½ per cent to 4 per cent copper. It has a persistent clay selvage which carries 1 to 3 inches of breccia, which cuts out the ore to the east. The vein is cut 92 feet north of the shaft, and is continuously exposed for 230 feet. Ninety feet east of the north crosscut a cross fault cuts off the vein, which is recovered 25 feet to the north, but is again thrown by a second parallel fault, 30 feet east of the first. These two faults are 10 and 15 feet thick respectively, run N. 10° E., and dip 65° and 70° W. They outcrop northward, an inclined shaft going down on one for 25 feet or more on the Macarona claim. The vein is recovered about 200 feet east of the faults.

On the 360-foot level the Altona vein is cut 230 feet north of the shaft, and is developed by a short drift. It is from 2½ to 3 feet wide, but carries less than one-half of 1 per cent copper and only low values in silver.

Another small vein less than a foot thick, cut by a south crosscut on the 360-foot level, carries 6 inches of 9 per cent ore, but is cut off eastward by the fault found on the 200-foot level. Numerous northeast and northwest clay-filled fault fissures are encountered.

The granite in the vicinity of the Altona mine differs from the normal rock of the district, appearing to be a transition form to aplite. In the specimens obtained from this mine, both from the surface and the deep levels, no pyrite was observed, but chalcopyrite is abundant both as dendritic masses on fracture surfaces generally, and in the deeper levels as particles disseminated through the rock and especially abundant in connection with the fresh or but slightly altered ferromagnesian minerals. Specimens of the ore from this mine show a banded quartz-pyrite vein filling 6 inches thick, separated from the granitic wall rock by films of molybdenite, which material also impregnates the wall rock for one-fourth to 1 inch; accompanying this impregnation is a marked sericitization for an inch or more from the wall. The central portion of the vein shows comb quartz, with the points of the crystals coated by glance. This structure is characteristic of the Clinton and Homestake ores, and indicates that the Altona does not differ markedly from the other veins of this portion of the district.

IDA MINE.

The Ida mine adjoins the Altona on the south, covering both sides of a small gulch debouching westward into the Flat. The property is developed by two shafts, on opposite sides of the creek. The southern shaft was 110 feet deep when this property was visited in 1906, with levels at a depth of 40 feet beneath the surface, running 36 feet west and 32 feet east. The shaft and drifts are in aplite rich in molybdenite, resembling the aplite of the Altona mine. The ore shows tetrahedrite and chalcocite, secondarily enriching a quartz-pyrite vein filling carrying accessory galena and sphalerite; it is therefore a typical silver-vein ore.

The mine workings disclose a small vein, averaging less than 8 inches thick, running northeast and dipping northwest at a very steep angle (80°). The vein filling is banded rhodonite, with streaks of ore—a normal silver vein. A second parallel streak, 2 inches thick, carries the quartz-pyrite molybdenite ore noted above, enriched by glance, etc.

These veinlets are cut off and dislocated by an east-west fault 4 inches thick, filled with clay and dipping 60° S. This fault shows in the shaft.

SCHWEITZER-MONITOR TUNNEL.

The Schweitzer-Monitor tunnel is in Elk Park Canyon, midway between the Homestake and the Northwestern mine, on the north side of the gulch. It runs north for 1,500 feet. The first 80 feet cuts aplite; succeeding this for approximately 200 feet is granite of the basic variety; the next 6 feet is composed of iron pyrite and decomposed granite; then from 286 to 400 feet the tunnel is in granite; next comes a 60-foot zone of intensely altered granite, containing many veins and veinlets, some of which carried as much as 5 per cent copper. As is common in veins of this sort, iron pyrite is abundant. For 750 feet to 800 feet from the mouth of the tunnel granite was encountered; then a small vein; next 300 feet of granite; then a vein 8 to 10 feet in width; then 100 feet of granite; then a 3 to 4 foot vein, and finally granite to the breast of the tunnel, 1,500 feet in all. The veins are all parallel or nearly so, and their average trend is east-west.

The first 30 feet of the tunnel follows a 3-foot quartz vein running N. 80° W. and dipping 64° S., with a 10-inch band of fault clay on the north wall. The second seam is a quartz-pyrite vein 2 feet thick, running N. 82° W. and dipping 82° S. The line between aplite and granite is indistinct. In the granite 80 feet from the aplite a vertical east-west 4 to 6 inch quartz-pyrite vein is cut, and a few feet farther a 4-inch streak of quartz and rhodochrosite. At 730 feet from the portal a big northeast vein is crosscut. It is 11 feet wide, runs N. 65° E., dips 70° S., and looks fairly promising. Thirty-five feet farther in, an east-west vein (N. 80° E.), 5 to 6 feet wide, is cut. This vein carries a 10-inch streak of ore that assays 13.3 per cent copper and 3.4 ounces per ton in silver; it dips 70° S. Beyond these veins the granite is hard and blocky to the face of the tunnel. A lean northwest vein, cut at 320 feet from the breast, is 5 feet wide and dips 65° N.

Though two veins have been cut, no drifting has been done to determine their value. It will be noted that the trend is similar to that of Butte.

COLUMBIA GARDEN.

The fault knobs back of Columbia Garden stand up in front of long, flat-topped spur ridges, largely of brecciated material, showing quartz and decomposed silicified granite. Where fresh granite occurs it appears broken and shattered. Some aplite is also seen. The Homestake and Clinton ore bodies occur in this shattered rock. No rounded pebbles or extensive bodies of clay or breccia are, however, seen, and it is believed that the fault is a compound one of a distributed type, or possibly a very close sheeting. The breccia at the west end of the tunnel is slide rock and shows no definite, well-defined outcrop.

Back of Columbia Garden the Mountain Lion ledge shows a course of N. 65° E., and the rock is stained by manganese. Above the mine the granite is sheeted into thin slabs, the course of the joints being N. 10° E. and the dip 80° S. A secondary summit south of the main top of the ridge is composed of aplite blocks, with flat veins of pegmatite having a dip of 19° W. and a course of N. 50° E. On the main summit, however, the sheeting is S. 10° W. and the dip 80° W.; the entire course is N. 30° W., with a dip of 70° S. A very promiment, closely sheeted area shows fractures running N. 10° W. breaking the rock into thin vertical plates.

The veins on the summit of the ridge between Elk Park and the Flat have a general east-west course. The Major Burke vein, which is exposed in the first gulch south of Elk Park, has a course of N. 70° W. On the ridge southeast of the Major Burke mine the vein runs N. 70° E.

The veins are typical silver-bearing fissure veins, showing manganese and comb quartz, and like the veins of the Rainbow lode, they carry but little replacement quartz. The veins follow a direction of early fissuring, marked by large dikelike masses of aplite.

CHAPTER XI.—THE SILVER LODES.

PRODUCTIVE STATUS.

The silver lodes of the Butte district have been extensively and profitably worked, but their importance has been overshadowed by the immense production of the copper lodes. From 1881 to 1890 the four principal producers of the district yielded 28,704,310 ounces of silver, but in 1896 the practical demonetization of silver, together with the change in character of the ores in depth, led to a sudden and almost complete stoppage of mining, and since that date the silver lodes have not been regularly worked. At present (1906) the silver production of the district from the silver lodes, excluding the metal recovered as a by-product of copper smelting, is comparatively small. Lessees are at work on many properties, and when rich ore bodies are found, as occasionally happens, the discovery stimulates a renewal of exploration work on many of the properties, especially those adjacent to that on which the find has been made. As a whole, however, the industry is decadent and the great mills and mining plants are idle.

AREA AND SUBDIVISIONS.

The silver-bearing area is much larger than the copper-bearing area, which it laps round on the north and west, silver lodes occurring as far north as the boundary of the Butte special quadrangle and as far west as the borders of the Silver Bow lake-bed district. In this large area the veins occur in bunches or clusters, and are therefore best discussed in six different groups, each of which takes its name from its most prominent mine or from its locality. These groups are (1) Lexington, (2) Rainbow, (3) Northern, (4) Missoula Gulch, (5) Western or Aplite, and (6) Southern and Eastern.

LEXINGTON GROUP.

VEINS.

The Lexington group lies just north of the copper area, between the Syndicate lode area and the lodes of the Rainbow group. The Lexington mine comprises five claims, developed by extensive underground workings from a shaft 1,450 feet deep. The veins of this group must be arbitrarily distinguished from those of the Rainbow group inasmuch as there is no intervening barren ground. The veins have been traced continuously from Missoula Gulch eastward to the West Greyrock mine, a distance of 5,500 feet.

Though the group includes numerous veins, they do not seem to be closely related. They do, however, as a whole, follow a course similar to that of the Rainbow lode, but lack the latter's minor distortions. Their course varies from N. 75° E. at the west end to nearly east and west in the center, and to southeast or S. 65° E. at the east end.

BLUE WING LODE.

The Blue Wing lode is the northernmost member of the Lexington group. It consists of two veins, separated by 50 to 100 feet of granite, which are cut in the workings of the Lexington, Paymaster, and Blue Wing mines. The northernmost vein of the lode splits between the 100 and 200 foot levels, forming two veins or branches 20 feet apart. The dip is nearly vertical and the veins rarely exceed 5 feet in width. The southern vein of this lode lies parallel to the northern one, and is a single fissure vein varying in width up to 20 feet, and containing exceptionally rich but very irregularly distributed silver and gold ores. At a depth of 300 to 600 feet the space between these two veins contains a number of smaller veins, which it is not necessary to distinguish.

LEXINGTON MINE.

The workings of the Lexington mine show three principal veins, the Allie Brown (Atlantic) on the north, the Wappello, and the La Plata (South) vein.

ALLIE BROWN VEIN.

The Allie Brown outcrops about 400 feet north of the Lexington shaft and about 200 feet north of the Wappello. It is a persistent well-defined vein, with a course slightly north of west and a nearly vertical or slightly southerly dip. To the west it extends into the Blue Wing claim, splitting into two veins which diverge until they are 75 feet apart, continue separate for about 500 feet, and reunite westward. To the east the vein extends to the Corra mine. The average width is 5 feet, with lenticular expansions to 20 feet, in places inclosing lens-shaped horses of altered granite.

WAPPELLO LODE.

The Wappello lode consists of a number of close, parallel veins, one of which, called the Main vein, is persistent throughout the workings of the Lexington mine, but near the surface to the north splits into a number of small veins which diverge downward. These spur veins are not persistent, but where they die out many of them are replaced by other small lenses of vein matter. Westward the Wappello is encountered in the Eveline workings, where it is cut by numerous very small fault fissures running parallel to it and dipping north; their maximum throw is 20 feet. Eastward the main vein splits into a number of smaller fractures, which are nearly parallel to the main fracture. These lesser veins are worked in the Sisters, Flag, Josephine, and West Greyrock mines, where they have yielded notable amounts of copper, mostly as chalcopyrite, from the surface downward for some 200 to 300 feet.

The Wappello has an average width of 5 feet, but locally broadens to several times this width. The ore is solid and frozen to the vein walls. The dip is southward at an angle of 55° to 70°. The West Greyrock lode is parallel to the Wappello, but dips south at a smaller angle. The two south veins of the West Greyrock mine unite westward to form this vein.

LA PLATA LODE.

The La Plata lode is the most southerly member of this Lexington group. It consists of a number of short connecting veins which may be traced on the surface from Missoula Gulch to Main Street. It is nearly parallel to the Wappello, but differs from it in having clay selvages, 4 to 5 inches thick, between vein matter and wall rock, and is wet and difficult to keep open. (See Pl. XLI, *B*.)

COST OF MINING.

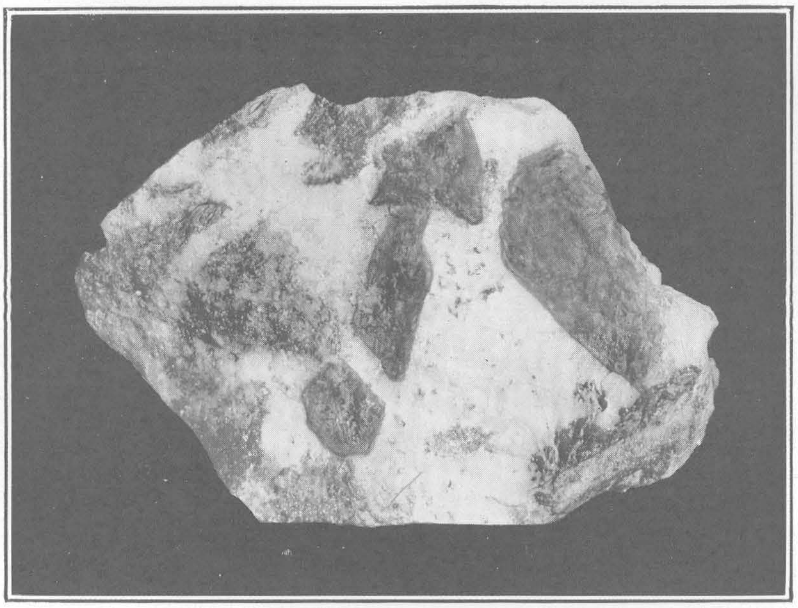
The following data, obtained from the books of the Lexington mine, help to explain the abandonment of silver mining in the Butte district:

Table showing production of Lexington mine.

Years.	Gross product.	Cost of mining per ton.	Cost of transportation per ton.	Cost of reduction per ton.	Total value per ton.	Net return per ton.
	Tons.					
1897	2,240	$15.79		$8.00	$27.96	+4.17
1899	1,443	15.57		7.50	23.29	+0.22
1901	2,815	9.30	$0.76	7.10	19.47	+2.37
1902	3,091	11.46	.83	7.12	16.41	−3.00

ORES.

The average copper output of the entire mine is 5.3 per cent The ore runs about 1 ounce of gold to 100 ounces of silver, though of late years it has increased to 2 or 3 parts to 100. The high-grade chalcopyrite ore averaged about 19.8 per cent copper, 43.3 ounces of silver, and a trace in gold. The gold values appear to be greatest in ore showing brilliant facets of fine



A. BRECCIATED SULPHIDE ORE EMBEDDED IN LATER QUARTZ.
Lexington mine. One-half natural size See page 241.

B. VEIN STRUCTURE, LA PLATA MINE, FIFTH LEVEL, SOUTH VEIN.

secondary quartz, which are regarded by Mr. Ruger, the manager, as a sure indication of high-grade ore, and this is the ore which is now being searched for by the leaser. The copper ore consists of chalcopyrite mottled with quartz and showing considerable zinc.

The Allie Brown and the Wappello veins are mineralogically almost identical. They appear as remarkably uniform open fissures in the granite from 1 to 5 feet in width, rarely larger, which have been filled by vein material. The veins consist of quartz, iron pyrite, sphalerite, galena, chalcoyprite, argentite, and some form of gold, presumably a sulphide. Associated with these are the silicate of manganese, rhodonite, and the carbonate of manganese, rhodochrosite, which are typical of the silver lodes. Both are very abundant, and serve quite generally to distinguish the silver from the copper veins. The metallic sulphides occur in bunches or spots throughout a matrix of quartz and manganese minerals. In certain places the heavy sulphides form almost the entire vein, but this is uncommon. (See Pl. XLI, *A*.) Rhodonite, the silicate of manganese, is much more abundant than the carbonate, rhodochrosite. It is easily recognizable in the hand specimen by the greater hardness and by its nonoccurrence in large crystals. It is very fine grained, massive, and tough, and has the general appearance of an opaque rose quartz or jasper. All the carbonate of manganese, rhodochrosite, is crystalline, with conspicuous rhombic cleavage; it gives off CO_2 feebly when treated with dilute hydrochloric acid. The workings have failed to develop any sulphide of manganese, and none of the evidence indicates conclusively that these manganese minerals are alterations from the sulphide. They may be, therefore, a final stage of deposition from solutions which pass through the same channels that the earlier and more strongly mineralizing solutions traversed. No definite order of formation of the sulphides of the heavy metals can be traced, for both megascopic and microscopic study show an apparently indiscriminate arrangement. Crystals of pyrite carry inclusions of the more valuable sulphide, argentite, and pyrite also has been found inclosed with crystals of this same sulphide.

Several epochs of deposition probably occurred, as the veins are in many places beautifully banded. One specimen from the 300-foot level of the Wappello vein, found frozen to the hanging wall, consisted of a crystalline band of quartz, dotted abundantly with crystals of fine iron pyrite and chalcopyrite; a somewhat smaller and less fully defined band composed almost entirely of the sulphides of the heavy metals; a band of almost pure rhodonite; and finally a cap of quartz, presenting in the heart of the vein an open cavity lined with the typical hexagonal prisms and pyramids of quartz. These quartz crystals are interesting because they are coated with little clusters of a rhombic mineral, which is probably rhodochrosite. The succession of the vein from the outer wall to the heart is identical with that just described. Frequently the vein is found banded in a similar way, but with no order of deposition. Plate VII, *A* (p. 72) shows a specimen, 9 inches long and 4 inches wide, in which the line of contact of the vein material with the granite is well marked, though there is no selvage. The vein is composed of alternating bands of more or less pure quartz, the darker portions being the less pure, the impurity consisting of the sulphides of the heavy metals already described.

Associated with the formation of the veins there has been much movement. A specimen taken from the hanging wall of the Wappello vein on the 300-foot level, near the once famous Butte & Boston raise, shows a fine-grained rock, consisting of rounded and angular fragments of quartz, feldspar, and vein materials. The rock is thoroughly impregnated with iron pyrite. Microscopically it reveals fragments of quartz and feldspar, which are widely separated by a mass of unrecognizable material having a strong resemblance to the microfelsitic groundmass of rhyolite. None of the heavier silicate minerals, such as hornblende or biotite, appear in the slide; and if these were ever present they are now represented by traces of chlorite. Iron pyrite in well-defined crystals, unbroken and unworn, is abundant. A slide of a granitic fragment of this breccia showed all the characteristics of decomposing granite; biotite had turned to muscovite, the feldspar, which was nearly all orthoclase, having decomposed to kaolin and epidote. This alteration of the feldspars begins along the cleavage cracks or in the heart of the crystal, the outlines of the crystals always remaining intact. The quartz is fresh and normal. Both slides reveal certain amounts of micrographic intergrowths of quartz and feldspar. The presence of fragments of vein quartz and fragments of granite in the same specimens indicates that this breccia was formed after a period of mineralization. The condition of the pyrite, the matrix of the breccia, and the fact that the rock is now solid and compact indicate subsequent mineralization.

A specimen taken from one of the intermediate levels of the mine consists of a number of angular bowlders of ore, cemented by almost pure crystalline quartz. It is a striking illustration of the intermittent character of the mineralization which formed the vein deposit.

On the 500-foot level an interesting condition has been found. Some disturbance of the vein has taken place since its deposition, and as a result the vein minerals, principally the galena and sphalerite, have arranged themselves in a series of narrow, parallel veinlets, separated by narrow bands of highly altered country rock. This arrangement is particularly interesting because the galena forms numberless series of twins, almost identical in appearance and characteristics with those described by Cross[1] from Bellevue, Idaho. The adjacent country rock is highly altered. The heavier silicates have been removed almost entirely; the feldspars have been reduced in varying degrees to zeolites, sericite, or kaolin; the quartz has been attacked by the mineralizing solutions. Both the quartz and the feldspar appear under the microscope in extremely irregular crystals, the process of this change being seen in the pitted faces of otherwise fresh crystals. In some specimens the accessory minerals, zircon, apatite, and titanite, have either been removed or rendered unrecognizable. This change in the country rock extends for varying distances from the veins. It is rarely ever less than a foot, and it may be as much as 25 feet. Associated with these changes is the impregnation of the country rock with iron pyrite, which occurs near the veins wherever the minerals of the granite have been altered by the vein solutions. It occurs largely in association with the heavy silicates, generally in a series of minute crystals parallel to their cleavages. Pyrite is also seen in larger masses with less definite crystalline boundaries, replacing the whole of what was once a crystal of biotite or hornblende. It has also been observed with more or less frequency associated with feldspars and even with quartz. The changes in the rocks and veins, which have been brought about by normal weathering, apart from the mineralizing solutions, have extended into the country rock to depths of not over 50 feet, and in country rock associated with veins to as much as 200 feet. The veins are oxidized for about 100 feet, below which any oxidation is the result of either mine workings or natural channels produced by recent movement in the country rock.

The La Plata (South) vein is characterized by a small amount of the manganese minerals, a very high per cent of zinc and galena, and a peculiar occurrence of veinlets of zinc and galena. Nearly all of these are 2 or 3 inches wide, in groups of perhaps five, separated by bands of highly altered country rock. The vein is further characterized by a large amount of clay and fault material, showing conclusively that much more movement has taken place along the plane of this vein than in either of the other veins. Some evidence goes to show that the minerals occurring in this vein are secondary in origin. They may have been introduced from other veins through chemical processes associated with oxidation.

In brief, the phenomena seen in the Lexington mine include (1) a highly sheeted granitic country rock, much decomposed and altered along fracture planes and planes of jointing, containing many large masses of pegmatite; (2) a series of aplite dikes, varying in width, inclination, and regularity; (3) a series of nearly east-west veins, dipping nearly vertically or to the south at a very high angle, and carrying quartz, silicate and carbonate of manganese, the sulphides of the metals iron, silver, zinc, and copper; (4) alteration and oxidation of these minerals, extending as much as 200 feet from the surface, and producing psilomelane, wad, goslarite and other minerals; (5) movement parallel to the course of the veins, but dipping in the reverse direction, producing local displacement and fracture; (6) movement parallel to the plane of the veins, producing vein breccias; (7) movement occurring after the first mineraliza-

[1] Cross, Whitman, Proc. Colorado Sci. Soc., vol. 2, 1887, pp. 171-174.

tion and previous to the final mineralization; (8) increased percentage of copper in the lower levels, especially in the lowest level; (9) heavy percentage of zinc in the more southerly vein; and (10) banded structure in the ores.

RAINBOW GROUP.

The Rainbow group, which takes its name from the great Rainbow lode, includes other veins which outcrop on the hill slopes north of Walkerville, where they attain their greatest and most important development. From the central portion, where the strikes vary but a few degrees from east and west, the veins have been traced eastward to the banks of Silverbow Creek, curving gradually, until they trend S. 60° E. Westward the veins extend along Oro Fino and Beefstraight gulches, where their course changes to south of west.

VEIN SYSTEMS.

In the vicinity of Walkerville the group includes three distinct vein clusters—(1) the Valdemere, a system of nearly parallel southeast to east veins; (2) a system of northeast cross fissures; (3) the Rainbow lode. The latter crosses the veins of the Valdemere system in a direction somewhat north of east, dividing it into northwestern and southeastern portions.

VALDEMERE SYSTEM.

The southeastern division or the Valdemere system includes the Valdemere, Moose, Magnolia, Hawkeye, Garfield, and Curry, which lie at nearly uniform distances of 200 feet apart, and strike N. 75° to 80° W. Their dip is uniformly 75° to 80° S. Those near the Rainbow have thus far proved the richest. The Valdemere and Moose have been very productive, the latter having been worked even during the low prices of silver. The Hawkeye vein has also been productive. All these veins have been disturbed by secondary cross faulting, as is well seen in the Belle of Butte mine, where four cross faults were noted, the largest fault displacing the vein 60 feet southward on the east.

The northwest portion of the Valdemere group includes the Silver Safe, Moulton, Amy, and Goldsmith mines. These veins are less uniform both in strike and in dip than those first mentioned. The dip in the Silver Safe mine is 45° S. at the surface, steepening to 60° at 200 feet in depth. The Moulton and Amy veins have normal southerly dips, but the Goldsmith dips 80° N. for a distance of 200 feet below the surface, and then changes to a southerly dip. The strike of the veins changes westward and finally bows around to the south. The veins have an average width of 4 feet, with extreme variations of 1 to 7 feet.

NORTHEAST SYSTEM.

The series of northeast cross veins is particularly well exposed just east of the Magna Charta shaft, where they connect the Valdemere vein with the Rainbow lode. They dip south at a comparatively low angle. Their average width is about that of the southeast veins.

RAINBOW LODE.

DEVELOPMENT.

The Rainbow lode, which is the largest and most productive silver lode of the district, received its name from its crescentic course.

The outcrop of the lode shows a great number of ledges of quartz stained a deep black by oxides of manganese. Its course is marked by numerous prospect pits and open cuts, by which the veins are readily traced for several thousand feet. Where these veins merge together in about the center of the lode they have been developed in the Alice mine, to the east of which lie the Fraction, Magna Charta, Valdemere, and the Poser, and to the west the Moulton, Amy-Silversmith, Goldsmith, and Rising Star. These veins can be traced eastward as far as the alluvial bottom of Silverbow Creek, and westward to the point where they are hidden by the overlapping rhyolitic rocks. They traverse normal Butte quartz monzonite, which shows much less alteration in the vicinity of the silver veins than in the copper-bearing portion of the district. Dikes of aplite and small areas of pegmatitic granite are also found. Plate XV, *A* (p. 170), shows the waste dump at the Moulton mine. The great size of the dump indicates the extent of the mine workings.

MINES.

ALICE MINE.

The principal development of the Rainbow lode is on the group of claims worked by the Alice Gold & Silver Mining Co., and collectively known as the Alice mine.

In this part of the Rainbow lode the bold outcrops consist of heavily stained and blackened quartz, porous and honeycombed in places (the cavities indicating the former presence of pyritic material), in layers and parallel masses, differing somewhat in composition and hardness. The more compact quartz rises 20 feet or more above the surface, but the softer layers have been worn down to the general surface of the ground.

The Rainbow lode has been the great ore producer of the mine, and is remarkable among the silver veins for the great width to which mineralization has extended, reaching in some places nearly 100 feet. It consists generally of two distinct fissures, known as the north and south veins, respectively, which stand nearly vertical, the north vein tending to incline a few degrees north, and the south vein as much south. The veins are separated by a varying width of granite, impregnated in many places with vein materials and cut by small veins to such an extent as to constitute one great ore body, with streaks of richer and poorer ore.

Numerous breccia zones carrying fragments of ore are accompanied by secondary fault fissures and clay seams. These zones are generally parallel to the primary veins in strike, but commonly diverge a little in dip.

The vertical throw on the secondary fissures, as far as determinable, is quite small, but the direction of the striations on the abundant slickensided surfaces indicates lateral movement. These features show a reopening of the vein and a sliding of one portion on the other.

The largest and richest ore bodies were found in the oxidized zone, quite near the surface, and generally accompanied by the breccia zone. Down to the 100-foot level the ore is all oxidized; on the 200-foot level a mixture of oxides and sulphides is found; and in places along the breccia zones oxidation extends even deeper. Rich sulphide ores were found at considerable depth, but decrease in amount with depth. In general a decrease in silver is accompanied by an increase in zinc; this seriously interfered with amalgamation, so that before the 1,000-foot level was reached the ore was no longer remunerative. The shaft was sunk to nearly 1,500 feet, and considerable drifting done in search of new ore bodies, but the lower workings were soon abandoned and allowed to fill with water.

In the oxidized zone, associated with cerusite and other oxidation products, some carbonates and a little oxide of copper were found, and in the mine drifts some chalcanthite was seen on the walls, indicating the presence of a small percentage of copper in the ore; but no accumulation of copper ore of merchantable value has been found.

The ore below the oxidized zone consists of white quartz carrying iron pyrite, galena, sphalerite, and argentite, with much rhodonite and some rhodochrosite. These minerals being in many places arranged in parallel bands or crusts. The quartz is subcrystalline or at places is in distinct crystals, showing that it filled open cavities. The rhodonite and rhodochrosite occur locally in large masses or in bands or layers of pale to deep-pink color, in some places dotted with metallic sulphides and again forming with secondary quartz the cement in breccia zones. Silver sulphide occurs as films upon cleavage planes and in cracks in massive pyrite; near the water level it has decomposed and formed filaments and wires of silver, some of which are several inches in length. Generally, however, they are very fine and lie curled and matted over the ore surface like a mass of wool. A few flakes and scales of silver also occur. The silver contains a small amount of gold; in the bullion from oxidized ore, which averaged $74.22 per ton in value, 87.26 per cent of the value was in silver and 12.74 per cent in gold; in the bullion from roasted ore, representing the average yield of sulphide ores, with a value of $56.95 per ton, 92.93 per cent was in silver and only 7.07 per cent gold. Up to 1879 the mine had yielded $837,539.

On the 200-foot level of the Alice mine but 135 feet below the surface, the Rainbow lode, east of the shaft, is 80 feet wide, and contains three pay streaks; and the south vein consists of two closely adjoining fissures. West of the shaft the north and south veins come together, forming a thin lode 2 to 3 feet wide, but they separate again and are 40 feet apart at the Moulton line. The north vein dips 70° to 80° N., and the south vein as much south. The breccia or secondary fault plane is less marked than in the level above and occupies a different relative position. Similar conditions obtain on the 300 and 400 foot levels, but on the latter several secondary fault planes cross the lode at somewhat steeper angles than do the original veins; they have distinct striations on their walls which dip 24° SW.

The granite horses include considerable bodies of rhodochrosite and some veins, 1 to 2 feet wide, of rhodonite and quartz. Though the individual veins are as a rule distinctly filled fissures, in some places they grade through partly replaced granite to normal country rock. Specimens examined under the microscope show that quartz and feldspar have been attacked and secondary quartz and sericite formed, and that the ferromagnesian minerals have been replaced by pyrite and sphalerite.

A measured section across the vein at one point gave the following divisions:

Section across Rainbow lode in Alice mine.

	Ft.	in.
Hanging wall, granite.		
Clay gouge, with quartz fragments	4	
Hard quartzose ore	4	
Clay seam		1
Black quartz, with ore and clay seams	4	
Clay seam		1
Rich ore, quartz and massive rhodochrosite, with sulphides	1	6
Granite, with veinlets of ore, forming horse	6	2
Massive pyritous ore, carrying native silver	2	4
Massive sulphide ore, galena, sphalerite, and pyrite, with filaments of native silver	2	
Massive quartz, with a little pyrite, and veinlets containing native silver	3	
Massive quartz, with patches of ore	3	
Shattered quartz, white, but carrying disseminated sulphides	3	
Low-grade ore, with white quartz	5	
Clay seam		2
Crushed and soft ore	3	
Footwall granite, with small veins of quartz, fading out in country rock.		

On the 500-foot level east of the shaft there are two streaks of rich ore, with 30 feet of impregnated granite between.

The Hawkeye vein, which is 240 feet south of the Rainbow lode on the 200-foot level, strikes about S. 80° E., and dips 80° S., shallowing to 65° S., in depth. It has yielded considerable high-grade ore, being in places as much as 15 feet in width. In the lower levels it is a strong vein of low-grade ore, consisting mainly of quartz and rhodonite.

The Garfield vein at 550 feet and the Curry vein at 625 feet south of the Hawkeye are strong veins, generally parallel in dip and strike with the latter and from 2 to 3 feet in width, but have not been important producers. Their ore is oxidized to a depth of 200 feet or more.

The paragenesis of the ores of the Alice mine is the same that obtains in the other silver veins. The vein minerals are, in the order of their abundance, quartz, iron pyrite, rhodonite, galena, sphalerite, rhodochrosite, and argentite. A study of thin sections of the ore shows that quartz belongs to many generations and may be both the oldest or the youngest mineral formed. The iron pyrite is probably of at least two generations, but is usually younger than part of the quartz, and in part at least younger than the argentite. The argentite is generally without crystal outline, much of it occurring within iron pyrite. The pyrite occurs in well-defined cubes and dodecahedrons, both in the quartz and in the altered country rock. Sphalerite and galena are of later age than pyrite. They occur in irregular masses lying along cleavage planes and joints and also in thin films along fractures in the ferromagnesian minerals. Rhodonite occurs both crystallized in rhombs and in massive form. Rhodochrosite occurs also as an alteration product from the rhodonite; it can hardly be distinguished from calcite when of pale color; little of it occurs crystallized.

MAGNA CHARTA MINE.

East of the Alice mine the continuation of the Rainbow lode is worked in the Magna Charta mine, a small fraction 200 feet wide separating the two properties. In this mine the Rainbow lode shows five principal veins, commonly called the North, Tunnel or McGinty, South, Magnolia, and Copper, corresponding to those worked in the Alice mine. West of the shaft these veins have an almost due east-west course, but east of the shaft they turn markedly to the north. The mineral content of all of them is entirely similar to that of the other silver properties; they have been oxidized for a little more than 100 feet below the surface.

The north vein shows an uncommonly well-developed series of branches and spurs. It dips steeply north and the branches from it also dip north but at a lesser angle; as they lie in the footwall country they rejoin the vein before any great depth is reached. At the shaft, however, the North vein splits in depth, and the north portion is the larger and more persistent, though the south branch contains the higher-grade ore. The Tunnel vein and the South vein are closely allied. The former is less persistent and is not seen below the 300-foot level. The two veins are traced eastward to the Valdemere shaft, but are not continuously developed.

The Magnolia vein is remarkable for its persistence in depth and in outcrop; it is not split and shows no unusual features. The Copper vein is interesting because it carries bunches of chalcopyrite ore which have been worked in recent years.

MOOSE MINE.

In this mine three veins are developed. One of these is the Valdemere vein, which extends eastward from the Valdemere mine into the Moose, though in the absence of continuous drifts between the two properties the identity of the two is not absolutely established. This vein has a steep dip, which varies from north to south in different parts of its course. The second vein lies 150 feet south of the Valdemere, and, like the former, has an exceedingly steep dip, which varies from north at the surface to south in the deeper levels. This vein splits westward, the two branches dipping to the south and uniting below the 300-foot level. This second vein is probably the eastern extension of the Magnolia vein cut in the Magna Charta. A third vein is cut at a distance of 300 feet south of the shaft. It is vertical and extends westward, and is probably the eastern extension of the Belle of Butte vein running into the Amador mine. The Moose mine has been worked almost continuously for the last decade, even while the other silver properties of the district were idle. These veins are well-defined fault fissures, but the quartz is largely a filling and not a replacement of the country rock. It is well banded and contains the usual pink manganese minerals.

The Valdemere vein shows in the Moose workings a tendency to split, the ends overlapping and connecting by curved strain cracks carrying ore. On the second level the vein near the shaft is a mere seam of quartz and rhodonite, carrying 5 inches of ore for a few feet westward; 100 feet or so from the shaft the vein has been stoped for a distance of 260 feet, until it apparently ends in a small slip; a short parallel ledge, 10 feet to the north and separated from the vein by north-dipping clay seams, carries a body of good ore; the main lode is continued by a ledge parallel to the main drift, showing in the stopes 3½ feet of zincky quartz-pyrite ore. Eastward the Valdemere changes to a mere clay seam in crushed granite, showing a foot of ore for a few feet but being mostly barren. On the third level this vein has been developed for several hundred feet west of the shaft, the drift and stopes showing the vein to dip 75° N. and to vary from a foot or two up to 15 feet. The ore shoot at the west end shows a width of 8 feet, mostly a mixture of quartz, with pyrite and sphalerite, carrying silver. Generally, however, the vein consists of numerous stringers an inch or two in width, with many spur slips running off to the north to the parallel north vein of the lode. The north branch of the vein shows a width of 4 to 5 feet and dips 75° N. The south branch ends in a 6-inch seam of poor ore and has walls of hard and but little altered granite, the northern one cut by many ½-inch stringers of rhodochrosite running northwest up to the north branch.

The Magnolia, the middle of the three veins worked in the Moose, has been most extensively developed on the third level. It has a curved, somewhat irregular course, in contrast to the straighter course of the copper veins, and at one place splits and passes around a large horse of granite. It is developed but slightly on the 200-foot level, as the ore is low grade, but is worked for a total distance of 1,200 feet on the 300-foot level (6,124-foot elevation), showing a width of 2 to 5 feet and an average width of 15 inches of ore, with good bunches where splits occur. The walls are smooth, showing in places slickensides dipping at 25° W. The vein is cut, but not shifted, by a N. 40° W. fissure dipping north, having clay walls and a 10-inch seam of black stained quartz.

To the east the vein becomes double, a south branch showing 6 to 12 inches of ore. Throughout its course the vein has clay gouge, usually on both walls, and dips north. The ledge is 2½ feet wide at the east face and consists of rhodonite, with little or no quartz. The hanging-wall granite is crushed in many places and shows joints dipping at 45° NE.

BELLE OF BUTTE MINE.

The southern vein in the Belle of Butte mine varies up to 3 feet in thickness, with a few inches of ore, and dips 75° S. It has been stoped from the surface to nearly 30 feet below the 300-foot level. It contains ore in short shoots and also a persistent but narrow streak of rhodonite varying from 3 inches to 1 foot in thickness. The cross cuts show normal Butte quartz monzonite cut by a few northwest clay slips, some of which carry fault breccia and rhodochrosite with alteration of the wall rock.

AMY-SILVERSMITH MINE.

West of the Moulton mine the Rainbow lode is worked in the Moulton claim of the Amy-Silversmith mine to a depth of 500 feet or more. Three veins have been developed, of which the north and south veins have been the most productive, and the middle vein has contained pay ore in the eastern end. The north vein dips about 80° N., becoming vertical in depth, and then dips south. This vein varies from 1 to 3 feet in width and is chiefly notable for the uniformity and persistence of the ore shoots; the ore, however, is of rather low grade and the bunches of high-grade material found in the other veins are lacking. The middle and south veins, which lie south of the shaft, are not well defined in depth and do not carry pay ore. In part at least they are represented by fractured planes, marked by clay walls and slightly mineralized material, opening in places into masses of quartz and rhodochrosite too low in grade to warrant exploration.

East of the Amy shaft the middle vein has been cut and drifted upon continuously to the Moulton shaft. The south vein is very persistent and has been drifted on to the limits of the ground both east and west. This south vein has shown extremely rich ore in pockets and bunches, separated by stretches of brecciated material and inclosed in well-defined walls. It shows postmineral brecciation, the vein filling consisting of well-banded layers of quartz, rhodonite, and iron sulphide, with silver minerals, the bands being from one-sixteenth to one-half inch in thickness. Later movement has sheeted the granitic breccia alongside the vein into plates varying from 1 to 4 inches in width, and these plates are now cemented by veins of quartz, which show scattered crystals of iron pyrite and argentite. This records an intermittent opening of the veins and is in line with the evidence found in the Lexington mine.

GOLDSMITH MINE.

West of the Amy-Silversmith mine the Rainbow lode is worked in the Goldsmith, in which two veins have been developed, the southern of which has been the more productive. This south vein has a width of 8 inches to 3 feet, is persistent throughout the length of the claim, dips about 80° S., and is but little disturbed by postmineral movements. The north vein lies north of the shaft; it dips north for 120 feet below the surface, at which depth it is faulted, and is assumed to be continued by a steeply southward dipping vein 1 to 3 feet wide. At the east end of the claim the level driven on the north vein is connected with the Amy-Silversmith; at this point a northeast fault with a northwest dip produces a throw of 100 feet to the south. A similar displacement is observed on the south vein at the west end of the workings. The ore extracted from the Goldsmith north vein has been extremely rich, varying from $100 to $200 per ton in gold, with an unusually high percentage of silver, but in general the average for the mine is not higher than that from the other mines of this lode.

NORTHERN MINES.

The Wabash group lies at the extreme northern end of the Butte district, west and north of the Rainbow group. In this portion of the district the outcrops are more prominent than in any other portion, but although the veins are so conspicuous in outcrop and abundant in number their exploration has been disappointing, inasmuch as workable ores occur only in small amount and extend only to comparatively shallow depths. It is, indeed, doubtful if any of the mines in this portion of the district have returned the cost of equipment.

WABASH MINE.

The Wabash lode outcrop is one of the best defined and strongest in the neighborhood. The lode lies just south of the Black lode. Its course is about east and west. At the point where it has been developed by mine workings the vein splits into three branches, which join at a depth of 200 feet, on the west at a distance of 150 feet, and on the east at a distance of 100 feet from the shaft. The mine has not been worked in recent years, and the workings have not been examined since 1900 or thereabouts, as the mine has been under water. Oxidized ore extends downward for 100 feet. In general the vein belongs to the silver series and has the same general character as that already given.

The Black lode, which is on the Wabash claim, has an outcrop of black stained quartz that is readily traceable by its color and by the prominence of its outcrop, which rises 10 feet above the surface and has a width of 2 to 3 feet. The vein dips 80° S. and the outcrop forms a curved line.

SPRINGFIELD MINE.

The Springfield mine is situated north of the Wabash, its nearest neighbor. The workings show but one vein, which runs east and west, dips 80° S., and is about 3 feet wide. The vein filling consists of quartz with but little manganese, and carries small pockets and streaks of iron pyrite, together with a little sphalerite, and very small amounts of chalcopyrite and galena. Ruby silver and argentite occur as tiny black and red specks impregnating the quartz. The vein matter is everywhere shattered and separated from the hanging wall by a persistent clay seam an inch or two thick. A second vein parallel to the first and 100 feet north of it has been cut on the 80-foot level. This second vein is composed entirely of quartz and iron pyrite, is well banded, and shows included lenses of granite. The walls of both veins are well defined, and the country rock is fresh and unaltered except for a width of 3 or 4 inches next to the wall. Ruby silver (proustite), found in fracture planes in the vein filling, is probably of secondary formation and is believed to result from the oxidation of tennantite.

SNOWDRIFT-GLENGARRY.

The Snowdrift and Glengarry mines are situated on the south side of Oro Fino Gulch, near its head. Though once extensively worked, these mines are at present abandoned, and the information obtained in 1896 is all that is available. At that time the property was opened by a shaft near the boundary line between the two claims. The vein is well marked for 1,500 feet, and can be traced at intervals with fair identification for 7,000 feet. Many spur and parallel veins accompany the main vein, but they are less persistent and rarely contain pay ore. The vein dips about 70° N., and when visited had been developed to a depth of but 75 feet, with east and west drifts at this depth. A fault fissure with a N. 45° E. course and a dip of 60° NW., belonging to the Rarus series, cuts through the vein and displaces it for 25 to 40 feet. East of this fault the vein consists of quartz and rhodonite containing disseminated pyrite, with gray copper and small amounts of gold and silver, the manner of occurrence being entirely similar to that observed in the Rainbow lode, with the common oxidation products, limonite, psilomelane, and some calcite. In the development of this lode the rich ore, running 100 ounces or more in silver, occurs in small lenses or pockets. The vein filling contains small amounts of galena and is almost free from sphalerite. The gold value is, however, low, and for this reason the ore has not been as extensively sought as that in less prominent veins.

SILVER LICK MINE.

The Silver Lick mine is situated on the hill next north of the Moulton. The vein has a general east-west course, and a dip of 80°. Its average width of 3 feet is extremely constant, but increases to 15 feet at the west end of the 200-foot level. The mine is developed by an inclined shaft 250 feet deep. The vein is a filled fissure containing quartz and iron pyrite, with rhodonite and complex sulphides of silver, the ore shipped averaging about 35 ounces in silver and $1 or more in gold to the ton.

MISSOULA GULCH GROUP.

The mines of the Missoula Gulch group lie west or slightly north of the west end of the Anaconda-Parrot lode.

LATE ACQUISITION MINE.

The Late Acquisition is generally regarded as a silver mine, although it lies on the borders of the copper belt, and up to 1906 had not been sufficiently developed to prove that copper minerals do not occur in the deep levels. The mine is situated immediately north of the Gagnon, and has been developed by three shafts to a depth of 150 feet only. The workings reveal the presence of one vein 1 to 3 feet wide, striking east and west, and dipping 78° S. Oxidation has extended downward for 80 feet, below which the unaltered ore resembles that of the other silver mines, except that it contains more galena and somewhat less zinc sulphide than do the silver veins of the Lexington group. Rhodochrosite and rhodonite are both abundant, occurring in places as pockets of extremely rich ore, which are, however, small and not persistent vertically.

MOUNT MORIAH MINE.

The western extension of the Late Acquisition vein was formerly worked in the Mount Moriah mine, on which a number of shafts were sunk to depths of 100 to 200 feet. These workings have been inaccessible for many years, so that the conditions underground are not known. The vein is wider on this claim than it is to the east, but has broken up or branched into a number of smaller parallel veins, and the ore bodies so far mined (1906) have not been so rich as those in the Late Acquisition mine. At the extreme west end of the claim recent workings along the bed of Missoula Gulch have encountered several pockets of rich ore along fault planes in dull dark quartz stained by iron and zinc but free from manganese.

ANSELMO MINE.

The Anselmo claim, next south of the Mount Moriah, has been opened to 150 feet below the surface by means of an incline following an east-west course, dipping 45° S. and gradually flattening to 30° near the bottom. A crosscut was driven south from this shaft for 150 feet. The vein, which is only fairly productive, varies in width from 1 foot to 4 feet. In the crosscut three small veins have been cut, none of which were found to be persistent nor large, consisting for the most part of an association of broken vein material and clay walls, developed by post-mineral movement. Probably the ores are the result of mechanical, and possibly of chemical, concentration of the vein minerals.

CALEDONIA AND JASPER MINES.

West of the Gagnon mine a great many small silver veins, none of them extending more than 300 feet either vertically or laterally, carry rich ore in small pockets. In width they vary from 1 inch to 3 feet, but their marketable ore is small. This ore is similar to the ores of the other silver veins, except that the amount of manganese and sphalerite is somewhat less. The Caledonia and Jasper mines, located on these properties, are worked intermittently by leasers and show no extensive development.

SILVER KING MINE.

The Silver King mine shows a strong and well-defined quartz vein, too zincky and too low in value to pay for working, whose outcrop, though quite strong and easily traceable over the bare slope on the east side of Missoula Gulch below the Gagnon claims, shows almost no quartz. The vein that is worked appears to be an offshoot or spur from this vein, and is believed to run northwestward into the Gagnon vein. The vein, which shows no outcrop nor surface indication, was discovered while digging the foundations for a house.

The vein splits as it passes eastward, one branch passing out of the Silver King claim into that of the Plymouth. Surface developments and levels driven 8 or 10 feet beneath the surface traced both branches of this vein for several hundred feet. The hanging wall is remarkably smooth and regular, and in places shows slickensides. It marks the outer of a series of three or four planes sheeting the granite. This granite on the hanging-wall side is nearly fresh, very hard, dark in color, and is unmistakably the normal and almost typical Butte quartz monzonite of the district. The footwall, on the other hand, is irregular and rolling, and the granite is more or less decomposed to a soft and clayey material or to a whitish granite impregnated with mineral. The vein dips 60° to 65°. Its width varies from 3 to 6 feet, owing to the irregular footwall. The pay streak runs across from the hanging wall to the footwall and is marked in the oxidized zone by its rusty color and the presence of manganese. In the deeper workings it is recognizable only by scattered quartz streaks and by the presence of well-defined minerals.

The ledge is remarkable for its richness and for the amount of gold which it carries. The ore runs as high as 333 ounces in silver, and $294 in gold; as a rule, however, the ratio is $3 in gold to each 10 ounces of silver. The ore is not only remarkable for its richness, but for the fact that a large amount of it, though of very high value, is nothing but a granite, carrying minute particles and bunches of ore scattered through it; much of the ore looks like an ordinary decomposed granite. It contains a little quartz, it is true, but this quartz is more in the nature of a leader; that is, it marks the occurrence of the ore on its under side rather than being an ore itself. Most of the footwall ore, however, is dark-colored, decidedly quartzy, and easily distinguishable by its toughness from the granite itself. The quartz streak on the hanging shows very well on the 250-foot level, east face, where it is lean and carries no values. A cross fault running diagonally across the face, but more in the nature of a strike fault, seems to terminate the ore abruptly.

Westward a strong, well-defined, very zincky vein, with much clay, comes into the Silver King vein. West of the junction no pay ore has been found. This zinc vein has been explored for some distance on the 250-foot level and has so far failed to show up any ore shoot of value. The vein matter is soft and clayey, and it is with difficulty that the level has been kept open.

The Silver King vein, on the contrary, needs but little timbering, and though not dry is not clayey. The dip of the vein is south, and the dip of the cross fault is also southward, but at a less steep angle. The Silver King vein strikingly contrasts with the veins of the silver mines farther north, such as the Moulton, Alice, and Lexington. In these last the ore occurs as minute black spots, few of them large enough to be distinctly recognizable, scattered through a quartz which is quite clearly a vein filling. In the Silver King, on the other hand, the vein filling is more in the nature of a replacement, or in the ordinary language of the miner, an impregnation. By this it is not meant that the interstices of the rock have been filled with mineral, but rather that portions of the rock have been replaced by mineral. This distinction must be emphasized because many authors use the term replacement only where the entire rock has been replaced, and in this case the granite texture, and, indeed, the granite nature of the rock is not only apparent, but is very striking. The rich ore, which occurs in lenses in the granite, is composed very largely of dark and amorphous-looking quartz, having none of the characteristics of filling quartz. On the contrary, the quartz stringers which accompany the vein are crystalline and show comb structure, and are undoubtedly the filling of open cavities.

The yield of the Silver King vein has been rather phenomenal; and there was probably something like $150,000 worth of ore in sight at time of visit (1905).

WESTERN GROUP.

NETTIE AND PHILADELPHIA MINES.

The Nettie and Philadelphia mines were worked for many years by the Colorado Mining & Smelting Co., which also controlled the Gagnon mine. They are situated about a mile southwest from Big Butte and 2 miles from the city courthouse. Both are typical silver mines, in which the veins have been reopened by faulting, with much crushing and the formation of large amounts of soft fault material, largely a clay or granite so thoroughly decomposed that when wet it runs badly and causes difficulty in mining.

VEINS.

GENERAL CHARACTER.

The veins have a general east-west course and show in well-defined outcrops. They are developed by three shafts, the easternmost known as the Nettie, the middle as the West Nettie, and the west as the Philadelphia. The first shaft is 300 feet deep; the second, which lies 700 feet to the southwest of the first, has an inclined shaft 54°, 450 feet long, equivalent to a vertical depth of 370 feet.

The mine workings reveal the presence of three veins. The Nettie (or north) vein varies from 6 to 8 feet in width, and consists of quartz, separated from the country rock by thick seams of gouge or fault clay, the country rock being decomposed aplite, altered for a distance of 12 to 20 inches outward from the vein walls.

The Philadelphia vein, which is the southernmost of the three, carries the principal workings. The drifts, which are largely to the west from the No. 2 shaft, extend for 300 feet to a rhyolite dike. The vein has an average width of 5 feet and carries exceptionally good ore.

The three veins developed in the Nettie mine are all in aplite and are cut across by a dike of rhyolite just north of the Nettie No. 1 shaft. This dike has a northwest and southeast course, is approximately 200 feet thick, and splits in the lowest level of the No. 3 shaft into two branches separated by 140 feet of aplite. This rhyolite invariably cuts off the veins. It is not mineralized except where oxidized iron and manganese minerals have formed by recent surface waters, and even these products contain no precious metals. (See fig. 107.)

In the earlier workings of the mines the Nettie (north) vein was the principal one developed. Later, when the inclined shaft was sunk, the Philadelphia (south) vein was opened up, and, as good values were encountered, a third shaft was driven at the east end of the claim.

NETTIE VEIN.

The Nettie vein has not been developed west of the rhyolite dike. It has an average width of 3 feet. Ore shoots on the 300 and 200 foot levels are separated by 7 feet of barren clay and mashed granite. These two shoots are roughly heart-shaped, that on the 200-foot level being 100 feet in lateral extension, 90 feet in vertical extension, and having a maximum thickness of 10 feet. This shoot occurs directly south of the main shaft. A similar shoot on the 300-foot level is 100 feet long, 70 feet high, and has a maximum thickness of not more than 10 feet. East of these shoots there is a barren zone 300 feet in length, then two persistent and well-defined ore shoots which stand vertically or have a slight pitch to the east. The more westerly, which lies just west of the Hibernia shaft, is 140 feet wide, and has been stoped from the surface down to the 400-foot level of the Philadelphia shaft, a distance of 470 feet. The more easterly shoot extends from the surface downward and joins the west shoot on the 400-foot level of the Philadelphia shaft. It is in places 400 feet long. Beyond these ore shoots the vein abuts directly against and is cut off by the rhyolite dike.

MIDDLE VEIN.

The Middle vein has been somewhat developed at the east end of the Nettie, where it has been most productive, and at the extension of the vein into the Hibernia claim. The vein is lean in the workings from the Nettie shaft, but becomes richer, developing an important ore body on the line separating the Hibernia and Nettie claims. The vein is developed on the 100, 200, and 300 foot levels of the Nettie shaft. It is a comparatively narrow vein, nowhere rich, which becomes lean at a depth of 300 feet, where it is merely a narrow veinlet composed

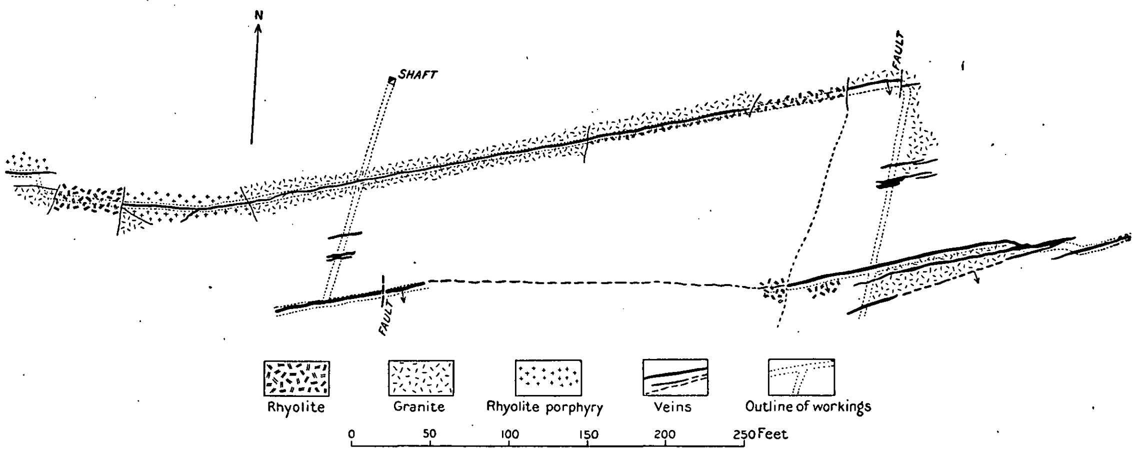


FIGURE 107.—Plan of workings of Britannia mine, showing silver veins cut but not displaced by rhyolite dike.

of valueless quartz impregnated with iron pyrite. In the upper course it carries small bunches and pockets of pay ore, especially in the west end near the rhyolite dike. This vein is probably encountered in the workings of the No. 2 shaft 100 feet north of the Philadelphia vein, though this correlation is not proved.

PHILADELPHIA VEIN.

On the Philadelphia vein the workings show a long ore shoot extending the entire length of the development work from the No. 2 shaft. This vein is thicker than either of the other veins, attaining a width of 25 feet in places. It has been better developed than either of the other two veins, except for an interval between shafts Nos. 1 and 2 in which the rhyolite dike cuts off the vein.

FRACTURES.

The mine workings show at least three periods of movement. The first produced a series of parallel joint planes sheeting the aplite, and along these joint planes mineralization took place, forming the veins. Subsequent to this a series of northwest-southeast fault fractures were formed, faulting the veins and forming lines of weakness, along which the rhyolite dike was injected. These fractures appear to have been due to the volcanic outbreak of the Butte, and must have been in the nature of a sudden shock, as the aplite is not sheeted, nor is there a dislocation of the veins parallel to this plane of movement. The last period of fracturing resulted in displacement, producing three well-defined, persistent faults, which cross the veins at right angles and throw their eastward extensions up to 150 feet northward. These faults run north and south and dip 45° E.; the most easterly shows a series of minor breaks or sympathetic fractures, with slightly steeper dip and distributed displacement, this being well shown on the east workings of the 550-foot level of the Philadelphia shaft.

The veins are remarkably persistent from one end of the mines to the other; they dip from 45° to 60° S.; they occur in aplite and vary in width from 1 inch to 25 feet. The vein filling, like that of all the silver veins of the camp, consists of quartz with associated silicate and carbonate of manganese, and the usual sulphides, galena, sphalerite, pyrite, and probably argentite and proustite. The Nettie vein has a persistent and conspicuous outcrop, but is not workable below a depth of 300 feet. The Middle vein has a well-defined and strong outcrop, and has been worked to a depth of 500 feet, but has not proven particularly profitable. The Philadelphia (south) vein has an ill-defined outcrop, but has proved very productive in the lower levels. It narrows westward and widens eastward.

ORES.

In the veins of the Nettie and Philadelphia property oxidation is complete to a depth of 200 feet or more, and extends along fault planes and fractures to the lowest levels. Its products consist of manganese and iron oxides and silver chloride. Gold, though present, is not visible, and native silver is not abundant. Manganese is extremely abundant, especially in the upper levels, and it is forming in the deeper levels as the result of percolation of surface waters downward along the strike faults. The primary ores consist of pyrite and complex silver sulphides, embedded in a matrix of quartz, rhodonite, and rhodochrosite. A diminution in manganese is noted with depth, the 550-foot level showing a predominant quartz gangue. The ore contains sulphides of zinc, lead, iron, and silver. A typical cross section on the Middle vein shows a smooth hanging wall, devoid of clay selvage, with a streak 2 feet in width of nearly solid metallic sulphides resting upon a 4-foot band of quartz ore cut by innumerable veinlets from one-fourth to one-half inch thick, running approximately parallel to the vein walls and composed of rhodonite and rhodochrosite. The footwall streak is a fault fissure 6 inches thick, composed of fine-grained ore and aplite in a clay matrix.

The South vein, which dips 45° S., is 11 feet 3 inches wide on the 550-foot level. Where revealed by a crosscut on this level it shows a solid and fresh aplite hanging wall, with a 5-inch seam of clay separating the country rock from a band 2 feet thick of low-grade quartz ore containing metallic sulphides. This rests, in turn, upon a band 6 feet 9 inches thick of high-grade sulphide ore containing relatively small amounts of quartz; and this in turn is underlain by a 10-inch band of barren white quartz frozen to the aplite footwall. In some places the ore forms small tongues which extend into the aplite, the mineralization gradually fading out. In general, the richest ore occurs nearest the hanging wall, and the footwall streaks are lean or barren. The banding of the vein is largely a true ribbon structure, due to postmineral fracturing, but there is also original crustification.

MOODY & SANKEY, IOWA, AND KOSSUTH MINES.

The Moody & Sankey, Iowa, and Kossuth mines, located near the western limit of the Butte quadrangle, are situated on the crest of the knolls of granite which mark the limits of the lake-bed depression. To the north and east rhyolite covers the granite; westward the lake beds cover the bedrock; to the south an aplite mass is found. The area in which the veins occur is thus an island-like mass of granite, in which sixteen veins outcrop. Only six of these veins are, however, shown on the map, the others being too small or lacking in persistence to warrant it. The veins have a general east-west course, turning slightly north of east, and dip from 70° S. to 90°.

The Kossuth shaft develops, to a depth of 90 feet, a typical silver vein whose features differ in no way from those already described.

The Moody & Sankey shaft was 270 feet deep at the time of examination, but has been filled with water for many years. The veins exposed in the upper levels vary from 1 to 3 feet in width, and consist of completely oxidized ores, composed chiefly of manganese oxide, lying on the hanging and foot walls of the veins with impregnated quartz between.

The Iowa shaft, near the east end of this granite area, develops a vein 16 inches wide that lies on a contact between a granite footwall and an aplite hanging wall. The vein has an east-west course, dips 80° S., and is developed to a depth of 80 feet. A parallel dike of aplite is encountered 20 feet north of the vein.

In general, the veins of this vicinity show pronounced oxidation to a depth of at least 100 feet. The most abundant minerals are psilomelane, wad, and pyrolusite, with less abundant malachite, the silver values occurring as cerargyrite. Psilomelane occurs in radiating aggregates of crystals and massive botryoidal forms. Pyrolusite is abundant as a crystalline coating on fracture planes on the vein. Wad is much more abundant than either of the other minerals, and is, of course, massive. Malachite occurs only as minute needle-like crystals, filling cavities in the manganese oxides. Cerargyrite forms a thin coating which discolors the surface of the other minerals.

KIT CARSON MINE.

The Kit Carson mine, located in the gulch east of the Nettie, has four veins, which outcrop on the crest of the hill immediately north of the shaft. These veins have an east-west course, and dip 70° S. They have been developed to a depth of but 100 feet. The workings lie north of the shaft, the crosscut developing an east-west fault. The vein materials consist of abundant chalcopyrite, carrying crystals and mossy aggregates of native silver on fracture surfaces. This is the only vein encountered in the silver area where chalcopyrite exceeds iron pyrite in abundance. Galena is present in small amounts, and sphalerite is abundant. Stringers encountered in the veins show very high values in gold and silver.

SOUTHERN AND EASTERN GROUP.

ELLA MINE.

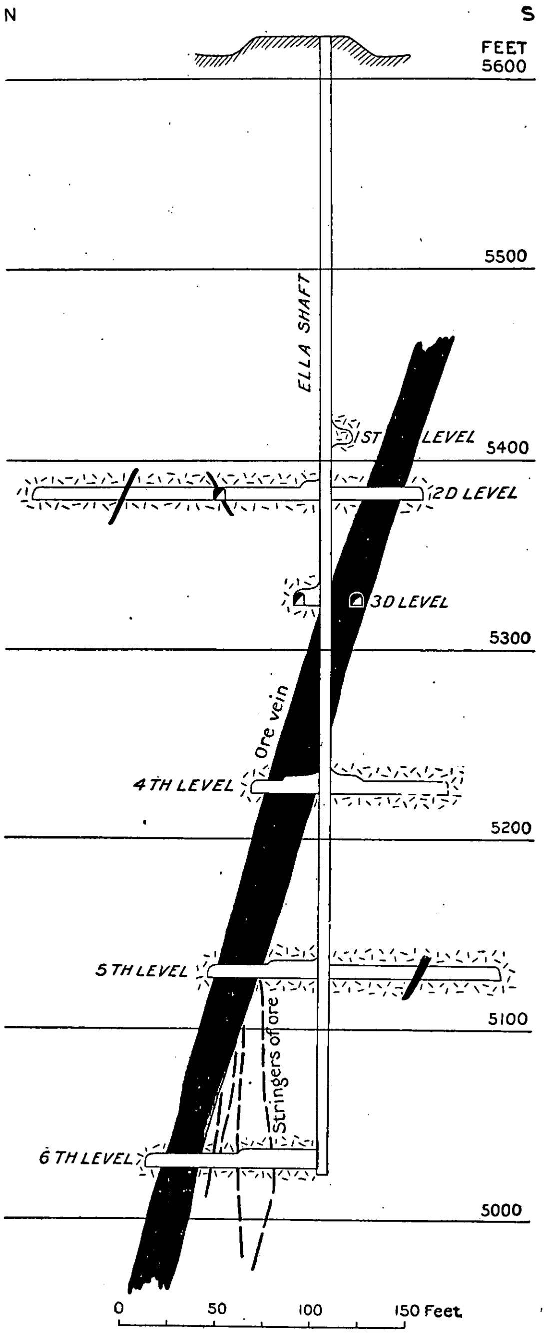


FIGURE 108.—Vertical section through Ella mine.

Although the Ella mine lies along the direct easterly continuation of the veins worked in the West Colusa and Leonard mines, its veins are typical silver lodes. The mine is situated in the flat valley bottom of Silverbow Creek, east of the Leonard mine. When examined it was developed to a depth of 600 feet, and showed a well-defined silver-quartz vein, continuously exposed from the second to the sixth levels (fig. 108). The vein has a width of 15 to 25 feet, of which 4 feet may be regarded as ore.

The vein filling consists of well-banded or "crustified" quartz, rhodonite, and rhodochrosite, showing in places as much as 6 to 10 feet of solid pink manganese ore, without quartz and devoid of banding. A quartz band 3 to 12 inches thick generally lies next to the selvage.

This ore carries from 1 to 20 ounces in silver, with only traces of copper and gold, showing a progressive decrease in silver values downward. The walls are well defined, with clay selvages, but show no evidence of movement, the clay gouge being without pebbles or crushed granite and being probably due mainly to alteration. (See fig. 109.) The wall rock is but slightly mineralized for a few inches, being mainly hard, fresh granite, much of which shows veinlets of pink manganese. On the third level 6 feet of clay is seen on the foot wall. On the second level the vein has been developed by drifting for a distance of about 400 feet, but has not been stoped, as the values were low. On the third level the rather irregular workings are mainly within the vein.

The general strike of the vein is N. 65° E. and the dip 70° N. The vein is defined by fault slips, but is not a typical fault vein. A sample taken across a width of 3½ feet gave only traces of copper and gold and 9 ounces in silver. The fourth level exposes a vein having a width of about 20 feet, marked by considerable pink manganese and quartz, and carrying 3½ to 4 feet of ore that averages 40 ounces in silver. The ore consists mainly of pink manganese, with some colorless quartz mixed through it.

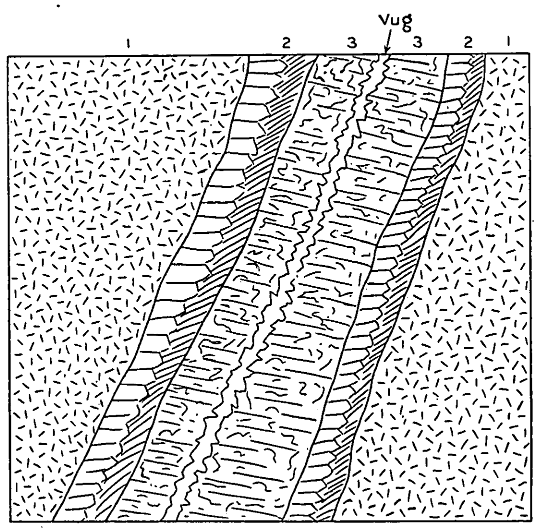


FIGURE 109.—Section of Ella vein. 1, Granite; 2, rhodochrosite; 3, quartz.

On the second level a crosscut driven north from the shaft cuts a parallel vein, consisting of quartz, with pyrite, zinc, and galena, which has a width of 1 to 2 feet and dips 60° S. The granite walls are impregnated with zinc and galena, and a sample cut for a width of 1 foot yielded 1.4 ounces in silver, with mere traces in copper. A second vein cut in this north crosscut at a distance of 100 feet north of the shaft showed 2 to 4 feet of vein matter, mostly quartz. The vein dips 65° NE. and trends N. 70° W. It carries no copper and low values in silver. Near the breast of this north crosscut a clay slip occurs, and a quartz veinlet running N. 70° E. and dipping 40° N. cuts through fresh granite.

On the fifth level the main vein lies north of the shaft, and is exposed not only by the crosscut but by a drift to the west. A 13-foot sample cut across the vein in the crosscut showed 2½ ounces of silver. A south crosscut from the 500-foot station (5,126 feet above sea level), 50 feet from the shaft, showed a banded quartz and rhodonite vein 3 or 4 feet wide (fig. 109), trending N. 85° E. and dipping 65° N. This vein carried low values in silver, with neither copper nor gold. The adjacent rock is fresh and blocky granite, showing a few veinlets of pink manganese. At the 600-foot level the main ledge north of the shaft has a width of 13 feet and an average silver content of less than 2 ounces. The vein walls here dip 80° N. and the granite lying south of the vein is cut by stringers of pink manganese.

ANCIENT OR EMMA MINE (BLACK CHIEF).

The big manganese outcrop of the Ancient (Emma) vein crosses South Washington Street two squares south of Silver Street. It is one of the most prominent silver veins of the district. Its outcrop consists mainly of black-stained quartz, with decomposed clayey material forming parallel streaks on each wall. The outcrop is between 40 and 50 feet wide, as seen in cuts made in the excavation of the streets. In the prospect pits it shows the usual sulphide ore, the mineral occurring in streaks and films in white quartz and being itself cut by later filling of secondary quartz. The vein has a pronounced southward dip. In the large ridge the outcrop shows occasional slickenside surfaces which cut across the vein. The main outcrop ends in a high knob which overlooks Missoula Gulch; a smaller outcrop continues across the gulch and becomes lost under the placer-ground flat, though still farther west, about a half mile beyond the gulch, a similar reef occurs that may be the same vein. Granite shows in the prospect shaft near Missoula Gulch immediately north of the lode, and granite also occurs across the gulch, where it is covered by 3 to 5 feet of clayey placer gravel alongside of a dike of rhyolite porphyry 125 feet wide. The prospect shaft on the summit of the hill formed by the vein has cut through the footwall, and the dump shows fresh undecomposed granite and some quartz porphyry.

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