COPPER.

NOTES ON COPPER DEPOSITS IN CHAFFEE, FREMONT, AND JEFFERSON COUNTIES, COLO.

By Waldemar Lindgren.

INTRODUCTION.

Colorado is not an important copper-producing State. The annual production rarely reaches 10,000,000 pounds, and was only 7,427,253 pounds in 1906. Eighteen counties contributed to this output, but only two—Lake (Leadville district) and San Juan—yielded notable amounts. The Leadville output was somewhat over 2,000,000 pounds, which was really obtained as a by-product; that from San Juan County slightly exceeded 1,500,000 pounds. The copper ores, properly so called, of Colorado comprised only 31,431 short tons, of which one-half came from San Juan County. It may be said that Colorado does not contain a single copper mine of prominence.

Of the counties mentioned in the title Chaffee produced 349,466 pounds of copper from 6,249 tons of copper ores in 1906; the yield of Fremont and Jefferson counties is negligible. Although the copper deposits in these counties are not of great commercial importance, they are in some respects unusual, and from the standpoint of genetic problems merit some discussion. Nearly all the gold- and silver-bearing deposits of Colorado, and the copper deposits as well, occur in close connection with igneous rocks of Tertiary age. They have clearly been formed during late geological epochs—chiefly during the early or late Tertiary—and their deposition closely followed the eruption of the igneous rock with which they are associated.

There is evidence, however, of a far older epoch of ore deposition, antedating, in fact, the whole of Paleozoic and Mesozoic time, and best designated as pre-Cambrian. The existence of such deposits has been shown in South Dakota,[a] Wyoming,[b] New Mexico,[c] and Arizona,[d] and it is the purpose of this paper to describe six or seven such occurrences in Chaffee, Fremont, and Jefferson counties, Colo.

Copper deposits of still another class occur as disseminations in certain sedimentary beds in New Mexico, Texas, and Arizona; also in western Colorado. These deposits are generally of low grade, but the question of their origin has given rise to much discussion, which has lately been summarized by S. F. Emmons.[e] An occurrence of this kind in Fremont County will be described, for the reason that it seems to throw light on the genesis of these concentrations of copper.

PRE-CAMBRIAN COPPER DEPOSITS IN CHAFFEE AND FREMONT COUNTIES.

TOPOGRAPHY.

The larger part of Fremont County is occupied by the Front Range and the irregular plateau to the west of it. The southwestern part of the county contains the north end of the Sangre de Cristo Range. Through the central part of it flows Arkansas River in a deep and picturesque canyon.

The western part of Chaffee County, adjoining Fremont County on the northwest, is occupied by the high snowy peaks of the Sawatch Range, and the eastern part contains a complex of moderately elevated ridges, which forms part of the general plateau south of South Park. Arkansas River traverses the county from north to south in a series of open valleys, of which that surrounding Salida is the most attractive. A short distance south of Salida the river enters the canyon, from which it emerges just above Canon City. In the western part of Chaffee County are the La Plata, Cottonwood, Alpine, Chalk Creek, Monarch, and Garfield mining districts, of whose geological features but little is known. In the southeastern part of the county near Salida are the mining camps Turret, Sedalia, and Cleora. (See fig. 9.)

[a] Irving, J. D., and Emmons, S. F., Economic resources of the northern Black Hills: Prof. Paper U. S. Geol. Survey No. 26, 1904.

[b] Spencer, A. C., The copper deposits of the Encampment district, Wyoming: Prof. Paper U. S. Geol. Survey No. 25, 1904.

[c] Lindgren, W., and Graton, L. C., A reconnaissance of the mineral deposits of New Mexico: Bull. U. S. Geol. Survey No. 285, 1906, p. 81.

[d] Reid, J. A., A sketch of the geology and ore deposits of the Cherry Creek district, Arizona: Economic Geology, vol. 1, No. 5, 1906, p. 417. Graton, L. C., Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, p. 389.

[e] Copper in the red beds of the Colorado Plateau region: Bull. U. S. Geol. Survey No. 260, 1904, pp. 221–232.

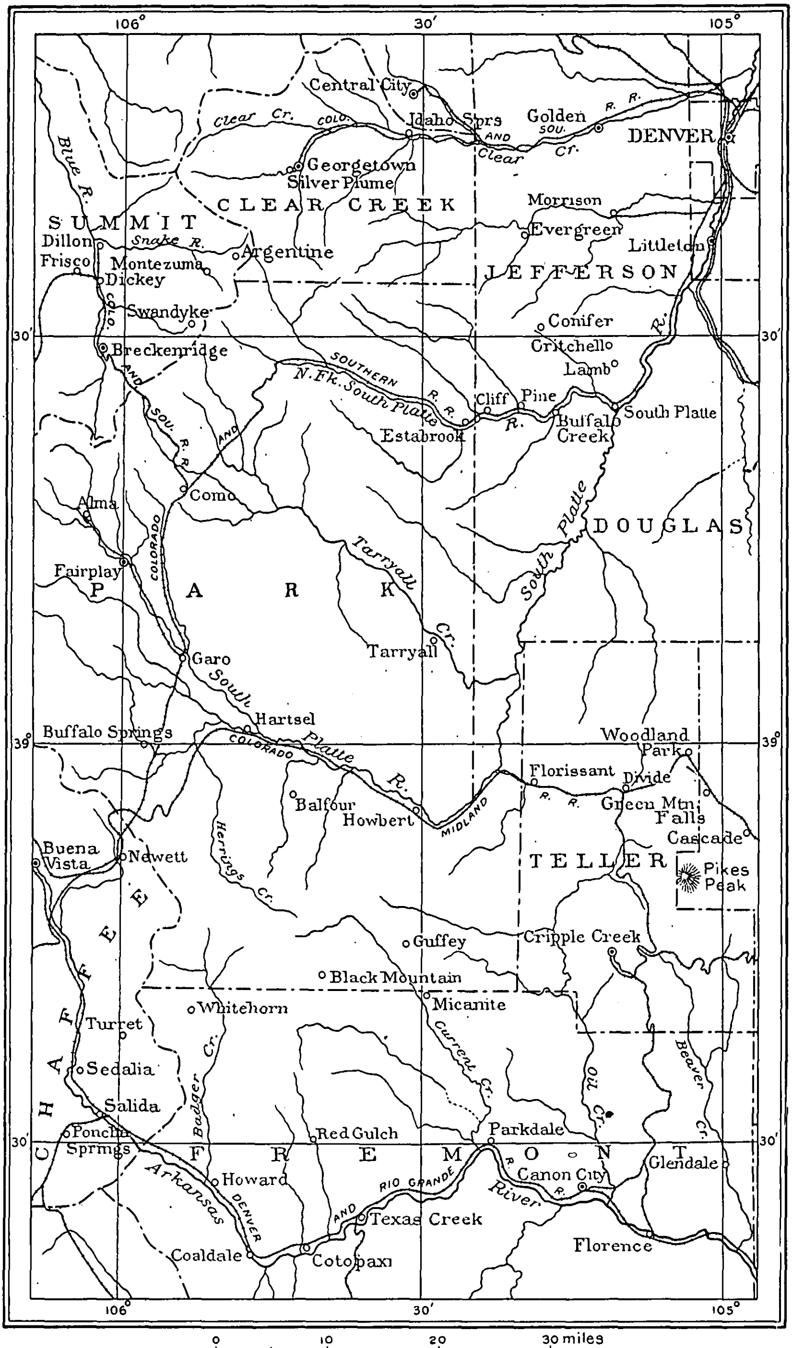

Fig. 9.—Map of central part of Colorado, showing location of copper deposits in Chaffee, Fremont, and Jefferson counties.

GEOLOGY.

Fremont County contains large areas of pre-Cambrian rocks, and their granites, gneisses, schists, and pegmatites are well exposed along the canyon of the Arkansas. In the western part of the county a belt of limestones and red beds crosses the canyon, and this belt occupies some areas north of the river in Chaffee and Fremont counties. The age of the lower beds is not well established, and the areas are outlined with imperfect accuracy on the Hayden map of Colorado. A bed of quartzite lies at the base, being succeeded by a thick series of limestones, which in turn are covered by red beds of Carboniferous or Triassic age. It is doubtful whether any Cambrian beds are present in this vicinity, but as they appear elsewhere in conformable development underneath the upper Paleozoic, the rocks underneath the great unconformity may with confidence be referred to as pre-Cambrian.

Near Cotopaxi gneissoid granites predominate, and these rocks with micaceous schists and intruded pegmatites make up the bulk of the pre-Cambrian area. At Salida, however, a series of greenstone schists have been described by Whitman Cross,[a] who states that they extend with general east-west strike from a point a few miles below Salida to a point about 5 miles north of that place. The rocks are determined as amphibolitic schists ranging into coarse-grained altered dioritic rocks (metadiorites) in the lower part of the series near Salida. Locally they are developed as chloritic, micaceous, and staurolitic schists, many of which contain garnets. They are cut by dikes of pegmatite and granite.

The pre-Cambrian complex is well exposed along the road from Salida to the small mining camp of Turret, 14 miles to the northeast. For 8 miles this road ascends in a steep gulch along which for the entire distance massive, very coarse grained dioritic rocks are exposed, in some places slightly sheared, and everywhere much jointed. Locally these rocks are epidotized, and traces of copper are seen in places. Under the microscope the structure is decidedly ophitic, and the rocks were doubtless originally diabases or gabbros, although the augite is now wholly converted into pale-green hornblende with small specks of pyrite and chalcopyrite. At an elevation of 8,500 feet, or 1,500 feet above Salida at the first divide, a block of nearly horizontal limestones covers these rocks for about 1½ miles; at the northern edge of this block the limestones are underlain by very coarse, white gneissoid granite with coarse mica, cut by pegmatite dikes with feldspar crystals a foot long. Turret, a couple of miles farther north, lies in a shallow gulch cut in white granite, containing chiefly quartz, microcline, biotite, and a little albite. From Turret another road

[a] On a series of peculiar schists near Salida, Colo.: Proc. Colorado Sci. Soc., vol. 4, 1891–93, pp. 286–293.

descends to the Arkansas through Browns Canyon in reddish gneissoid granite, forming conspicuous turret-like outcrops. At the river the schists become very micaceous and are injected by pegmatite dikes.

Cross believed that the schists were derived from a metadiorite, probably a surface flow. It seems more likely that we have here a large pre-Cambrian mass of gabbro or diabase, which is intrusive in sedimentary metamorphic rocks, and which in part has been made schistose by pressure.

ORE DEPOSITS.

INTRODUCTION.

The deposits in this vicinity contain chiefly copper, and the following are described or mentioned below: The Sedalia mine, the Independence and Copper King mines, and the prospects at Cleora and Cotopaxi. The Independence and Copper King mines are located near Turret, and there are at that camp two other mines, the Gold Bug and the Vivandiere, which, however, are on gold-bearing fissure veins of an entirely different type from those which form the main subject of this description. The Gold Bug mine is on a quartz-filled fissure following a dike of fine-grained porphyry. The strike is east and west, and the greatest depth attained is 500 feet. The richest ore is said to carry about 2 ounces of gold and 6 ounces of silver per ton, besides 9 per cent of copper. The Vivandiere is probably located on the same vein a short distance to the east, and is developed by a shaft 600 feet in depth. Both properties are intermittent producers. Beyond doubt they are much more recent than the copper deposits described below. It is said that similar auriferous veins are found at Whitehorn, 10 miles farther east in Fremont County.

SEDALIA MINE.

Location, history, and production.—The Sedalia mine is situated in the first foothills rising on the east side of Salida Valley, 2 miles east of Arkansas River and 4 miles north of Salida. It is said to have been discovered about twenty-four years ago and has been worked intermittently since that time. At present it is owned by the Shawmut Consolidated Copper Company. It was an active producer in 1907; the ore was shipped to various smelters, but lately it has been taken chiefly by the Canon City zinc-lead paint plant of the United States Smelting Company, which utilizes the zinc for paint and smelts the residues for copper matte. No exact data of production are available, but the Shawmut Company states that probably in all from 60,000 to 75,000 tons of ore have been shipped, containing from 5 per cent upward of copper and from $1 to $2.50

in gold and silver per ton. It is really one of the few important copper mines of Colorado. During the last two years the mine has shipped about 400 tons per month.

Developments.—The deposit is developed by three tunnels. The lowest, No. 3, is 100 feet higher than the first outcrops of schists above the sandy valley bottom and at an elevation of approximately 7,475 feet, or 475 feet above Salida. No. 2 tunnel is on the steep slope, 321 feet above No. 3, and the uppermost tunnel, No. 1, is 100 feet above No. 2. There are two levels 60 and 100 feet below No. 2. No. 3 tunnel runs in a direction a little north of east for about 1,300 feet. The total developments probably aggregate 5,000 feet.

A leaching plant was built on the sandy valley bottom 1 mile west of the mine, but as it was not successful it is now being turned into a concentrating plant for the primary sulphide ores recently found. The surface ores contain both sulphides and carbonates, and for this reason direct leaching is not applicable to them. An incline carries the ore from No. 2 to the level of the valley, whence it is transported on a tramway to the railroad spur at the concentrator.

Geology.—Seen from a distance the rocky, reddish-gray slope with scattered junipers seems to rise abruptly from the valley. The prevailing rocks are schists. Both north and south of the mine heavy dikes of light-colored pegmatite cut conspicuously through the schists, which strike almost due east and west and dip from 50° to 70° S. Cross, in the paper already cited, states that the succession consists of "fine mica schists, locally staurolitic, actinolite and chlorite schists, with garnet developed in various forms." The best exposures are found in the long No. 3 tunnel, which penetrates below the level of oxidation. For the first 1,000 feet the tunnel penetrates a hard dark-gray and blocky gneissoid rock in which the schistosity is obscured by joints striking north and south or N. 65° W., and dipping respectively 80° W. and 40° NE. This hard gneiss, which contains softer bars of schist richer in biotite, continues up to a place where the plane of the ore deposit intersects the tunnel. No ore is visible here, but the rock is softer, with some slips and copper stains. Beyond this point the rock is a mica schist with smooth planes of schistosity dipping 52° S. In this rock the crosscut continues for 300 feet, and the schist is intersected by many small dikes of white pegmatite, probably apophyses of the larger dike shown in the upper workings.

The gneiss in the first part of the tunnel is dark gray and imperfectly schistose, and consists chiefly of a fine-grained mixture of quartz and brownish-green biotite, fibrous crystals of sillimanite, abundant small grains of corundum, and pale-red garnets up to 1 centimeter or more in diameter. The garnets and the sillimanite give a pseudoporphyritic appearance to the rock; the quartz appears in allotriomorphic grains and the general structure is that intimate intergrowth characteristic of many crystalline schists which Grubenmann designates as diablastic.

The steep hillside between tunnels No. 3 and No. 2 shows the weathered forms of the gray gneissoid schist, in places containing streaks of chloritic schists with very large crystals of garnet, some of them several inches in diameter. These garnets appear near the contact of the big pegmatite dike, but as they are also noted elsewhere in the series it is doubtful whether they are the effects of contact metamorphism. Above the dike, up to the croppings of the ore deposit, the rocks are mixed and consist of amphibolite rocks, chloritic schists, dark quartz schists, and garnet schists. In the foot wall of the croppings appears fissile mica schist similar to that noted from the lowest tunnel level. Toward the east the mica schist occurs on both sides of the deposit. On the highest spur and 200 feet south of the ore body is a fine-grained aplitic dike rock, which contains bunches of amphibolitic rocks.

The principal pegmatite dike is 50 feet wide and outcrops in the vicinity of tunnel No. 2. As shown by the workings, it dips 70° N., consequently in an opposite direction to the schists. Only small stringers of pegmatite are noted in the lowest tunnel. The rock is coarse grained; the specimens examined consist of white microcline, quartz, and greenish-white muscovite, the foils of which reach 1 inch or more in diameter.

The ore deposit.—Cross, in the paper cited, referred briefly, but correctly, to the copper deposit of the Sedalia mine as "a thick bed of actinolite schist richly impregnated with copper minerals." The ore body lies conformable with the schists and is practically a flat lens, 800 feet long and at most 150 feet thick, of amphibolitic rocks of varying types. The outcrops of the ore body can be followed for many hundred feet east and west on a ridge 600 feet above the valley, and show chiefly as soft whitish rocks locally stained by copper or lead. These rocks, to a considerable extent, are made up of talc, asbestos, and partly weathered amphibolite. On the first level the ores have been followed for about 400 feet. On the second level the deposit extends for over 800 feet. There are two smaller levels 60 and 100 feet below level 2. Below that level, however, the 50-foot pegmatite dike mentioned above as dipping in a direction opposite to that of the deposit and the schists cuts off the ore body. In one place toward the east of the body the workings are said to have crossed the dike, but only low-grade and very hard ore was found beyond it. Thus practically all of the ore shipped has been taken from that part of the deposit which lies above the pegmatite dike, and tunnel No. 2 shows the character of these ores very well. They are all at least partly oxidized, and it is evident that the copper has spread through a considerable width of rock outside of its original home. In one place the mass of amphibolite is about 150 feet thick. Some of the stopes are 50 feet wide. The prevailing rocks are amphibolite of varying grain, chloritic schist, and a dark-gray quartz rock. Much low-grade copper ore, said to average 2 per cent, still remains in the workings. The ore generally consists of a mixture of limonite, malachite, cuprite, and chalcocite, with remaining unaltered grains of chalcopyrite, which evidently is the original mineral; this ore is contained in a gangue of chloritic schist or amphibolite. There is no well-defined zone of chalcocite. A little zinc blende, galena, and cerusite occur in places. The ore carries a very small amount of gold and silver. A new basic lead-copper sulphate, having the formula $PbSO_4.CuSO_4.CuO$, was found in the croppings. It appears as a dull lemon-yellow powder.

The first attempts to find the ore deposit on the level of the lowest (No. 3) tunnel were not successful, as indicated under the description of the rocks (p. 162). Recent exploration, however, resulted in the finding of a considerable body of sulphide ore 40 feet above and a little to the north of the tunnel. This ore body also lies on the contact of the biotite schist and the garnet gneiss, almost directly underneath the croppings, following the southerly dip of the schists, which seems to be a little steeper between levels 2 and 3 than it is above level 2. The ore is here about 300 feet vertically below the surface. The find had just been opened last year, and so far as could be seen from the scanty exposures, the body is about 50 feet wide, although the workable part has only one-half of that width. The rocks are fresh and their study gives a far better insight into the relations than is possible in the oxidized ores of the upper workings.

The foot wall was exposed in only one place, and is the fissile biotite schist referred to above. Next lie irregular masses of a dark-green fine-grained amphibolite composed of bluish-green and colorless amphiboles, the two colors in places combined in one prism, and of grains of labradorite, possibly also other feldspars, and some disseminated particles of magnetite. The structure is diablastic and typical of a crystalline schist. Mixed with the amphibolite are streaks and bunches of an almost black quartz schist, which besides a quartz mosaic contains slender prisms of a pale-greenish or grayish-blue amphibole with scarcely measurable extinction and a few grains of magnetite and chalcopyrite. Then follows several feet of heavy, dark zinc-blende ore, which under the microscope shows reddish-brown sphalerite and a little chalcopyrite intimately intergrown with about equal quantities of prisms of bluish-green and colorless amphibole. The bulk of the ore is massive, and contains both zinc blende and chalcopyrite, with about 10 per cent of magnetite and some pyrite; as broken it is said to contain about 20 per cent of zinc. Under the microscope the ore shows irregular masses of reddish garnet penetrated by prisms of colorless monoclinic amphibole, which also, intergrown in the manner of the crystalline schists, makes up the bulk of the rock. These two minerals contain grains of chalcopyrite, pyrite, magnetite, and zinc blende in relations indicating simultaneous formation with the minerals of the crystalline schists. There are also small grains of a dark-green spinel and a little feldspar, apparently labradorite or anorthite.

Toward the hanging-wall side the ore gradually becomes poorer and changes into the normal garnet gneiss described under "Geology." In places it is chloritic and contains large dodecahedra of garnet. In the garnet gneiss the same bluish-gray amphibole referred to in a previous paragraph was observed. It is evidently closely related to glaucophane.

The following minerals occur at the Sedalia mine: Chalcopyrite, pyrite, sphalerite, galena, chalcocite, malachite, azurite, cerusite, a new basic lead-copper sulphate, magnetite, spinel (zinc spinel?), corundum, quartz, garnet, hornblende, biotite, glaucophane?, staurolite, labradorite, asbestos, talc, chlorite.

Summary and genesis.—For the origin of the Sedalia deposit the following hypothesis is suggested:

The series of micaceous schists at the Sedalia mine is probably of sedimentary origin. A large mass of diabase or gabbro was intruded into these rocks in pre-Cambrian time, between the Sedalia mine and Salida; the magma contained copper, and some of the dikes intruded into the folded sediments surrounding the igneous massif were products of differentiation rich in copper sulphides. The Sedalia ore deposit is probably such a dike, and the ores originally consolidated from a magma. The dike followed approximately, but not strictly, the planes of stratification. Renewed dynamometamorphism following the intrusion accentuated the conversion of the sediments into crystalline schists, and changed peripheral parts and dikes of the intrusion into amphibolites. The ore minerals were recrystallized and migrated in part through the wall rocks, the contacts being made indistinct by the pressure and rearrangement of minerals.

In its present form the deposit is assuredly a product of pre-Cambrian dynamometamorphism, and to judge from the position of the covering of Paleozoic crust blocks near Turret the portion now worked was at least 1,500 feet below the surface upon which the Cambrian and Carboniferous sediments were deposited. It was probably much farther below the surface of the earth at the time of the intrusion. The intrusion and regional metamorphism of the diabase or gabbro was followed by enormous intrusions of granites, which seem to be barren of mineral deposits. Pressure continued after the consolidation of these rocks, and they were made partly schistose.

The last feature in the pre-Cambrian intrusions was the pegmatite dikes. These are likewise barren and one of them has cut the Sedalia deposit in two.

Active oxidation has converted the upper 200 feet of the deposit into copper carbonates and chalcocite, mixed with residual sulphides, but even in the lowest levels, 300 feet below the surface, there are indications of incipient oxidation. The water level is at present below the lowest (No. 3) tunnel. There is no well-defined chalcocite zone. In the upper 200 feet of the deposit the zinc blende has been oxidized and almost wholly removed as soluble sulphate.

COPPER DEPOSITS AT TURRET.

A short distance west of the Turret mining camp (see p. 160) the granite becomes more micaceous and somewhat schistose. At the Independence mine, 1 mile west of Turret, at an elevation of 8,500 feet, the strike is N. 55° W. and the dip 30° NE. The schists here consist of a coarse brown "augen" gneiss; there is also some quartz-biotite-garnet schist like that at the Sedalia camp. Streaks of very coarse amphibolite embedded in this gneiss or schist contain partly oxidized chalcopyrite. The explorations have been carried down 200 feet along the dip. The mine was not entered, but the owner, Mr. P. S. Plympton, states that the width of the ore body is 30 feet, with a richer streak 5 feet wide. Molybdenite is stated to occur in this deposit. A considerable tonnage of copper ore, low in gold and silver, was hauled down to the railroad in 1907 and sold to smelters, where it is used for purposes of flux in matte concentration.

The Copper King is another deposit of very similar character situated between Turret and the Independence mine.

COPPER PROSPECTS AT CLEORA.

The Cleora district is situated 4 miles south of Salida along Arkansas River. Many prospects have been located here, but no important deposits are reported. The ore is chalcopyrite, occurring in amphibolite schist, and the occurrence is probably similar to those described above.

COTOPAXI MINE.

The little settlement of Cotopaxi is located 24 miles southeast of Salida, in the canyon of Arkansas River, at an elevation of 6,373 feet, or about 600 feet below Salida. The old Cotopaxi mine is located in a small gulch half a mile northwest of the railroad station. It has been idle for many years and the underground workings were closed in 1907, but it was at one time a considerable shipper of copper ore. The lowest tunnel has an elevation of about 6,650 feet. There are three tunnels, 40, 90, and 120 feet above the bottom of the gulch.

The prevailing rocks in this part of the canyon consist of reddish granite or gneissoid granite with imperfect schistosity. Bunches of irregular pegmatite dikes are also present. Approximately 1,500 feet above the river on the north side the Paleozoic rocks rest flat upon the eroded pre-Cambrian complex. The deposit occurs in granite gneiss, with irregular strike and dip. The strike is chiefly northeast and southwest, the dip about 45° NW. There are no extensive outcrops of the deposit, which appears to have come to the surface only at one place close to the highest tunnel. As the underground relations could not be seen, the following notes are based on the character of the rocks as shown on the dump. The ore minerals are massive chalcopyrite, and dark-brown zinc blende, in intimate intergrowth. There are also a few grains of galena. The gangue consists of quartz with large amounts of biotite, reddish garnets, and dark-green amphibole. Some of the material on the dump is a soft schist composed only of mica and garnet with a few grains of chalcopyrite. There are also almost pegmatitic rocks consisting of quartz, labradorite, and dark-green zinc spinel, with a little chalcopyrite and galena. The zinc spinel (gahnite) is abundant in places, and the locality is mentioned by Dana. The deposit is probably a lenticular mass of an igneous basic ore-bearing rock, now greatly metamorphosed and conformable to the schistosity of the gneiss.

The similarity to the Sedalia deposit is unmistakable, and there seems to be little doubt that the Cotopaxi mine should be classed with the pre-Cambrian copper deposits. If this is correct the ores lie about 1,500 feet below the eroded surface on which the Paleozoic sediments were deposited. Probably they were formed at a far greater depth below the surface.

PRE-CAMBRIAN COPPER DEPOSITS IN JEFFERSON COUNTY.

LOCATION AND GEOLOGY.

Jefferson County contains a part of the Front Range just west of Denver. Between Golden, on Clear Creek, and Evergreen, on Bear Creek, are several copper prospects on some of which considerable development work has been done. The only mine which has any production to its credit is the Malachite property.

As is well known, the Front Range is in this region almost wholly built up of granite and gneissoid rocks. The geology has been briefly described and mapped in a recent paper by James Underhill.[a] Several kinds of granite and gneisses, as well as belts of diorite, are described. The conclusion of this author is that the whole series is of igneous origin, and that the rocks were possibly formed at a later

[a] Areal geology of lower Clear Creek: Proc. Colorado Sci. Soc., vol. 8, 1906, pp. 103–122.

period than has generally been supposed, perhaps as late as the Devonian. It is difficult to accept these results entirely. The general fact of a great unconformity at the base of the Cambrian seems fully proved throughout Colorado, and also the fact that there were no post-Cambrian epochs of dynamometamorphism in this region. The age of the gneiss complex of the Front Range, aside from some later intrusions, is pre-Cambrian beyond question. The correctness of recognizing as separate intrusions some of the granites outlined by Underhill seems at least open to discussion, and the igneous origin of some of the gneisses seems likewise doubtful. Three principal features are likely to impress the observer of the geology of this region—first, the great masses of biotite schist, compressed, folded, and contorted in the most extreme manner; second, the tremendous injection of granite and pegmatitic material to which this schist has been subjected; third, the great areas of somewhat gneissoid granite. The biotite schist bears all the earmarks of a highly metamorphosed sedimentary series, soaked in granitic and pegmatitic magmas.

Belts of amphibolite are inclosed in the schists a few miles east of Evergreen and continue in a northwesterly direction for at least a few miles. At the F. M. D. prospect the belt is at least 1,000 feet wide; the schistosity strikes due northwest and dips 75° SW. This amphibolite contains in places pegmatite dikes, showing that the rock is older than the pegmatite intrusions. In one or two places where good exposures are available dark, fine-grained diorites or diabases are seen to cut this amphibolite in sharply defined narrow dikes.

ORE DEPOSITS.

In general the copper deposits are in or near the amphibolites. At the Despatch property, 2 miles below Evergreen, the prevailing rock is granite, but there is also some schist. The shaft is reported to be 140 feet deep and two "veins" containing copper are said to have been encountered.

The F. M. D. property lies on a tributary to Bear Creek about 5 miles northwest of Evergreen, at an elevation of 6,800 feet. A vertical shaft 350 feet deep has been sunk here and three "veins" of copper-bearing ore are said to have been cut. Work is suspended and the shaft is partly filled with water. The country rock is a dark-green amphibolitic schist which contains pyrite and chalcopyrite. The rock consists of intimately intergrown prisms of ragged green hornblende and foils of biotite. In and between these minerals lies a mosaic of labradorite. Accessories are apatite and magnetite, the latter intergrown with pyrite and chalcopyrite. The rock is probably a metamorphosed diabase. Coarse-grained masses of a pale-green labradorite (?) feldspar, quartz, and biotite occur in the schist, perhaps as a dike, and contain pyrite and chalcopyrite. Fractures in this rock are coated by secondary pyrite and an unusual mineral in small aggregates of rhombohedra of brilliant luster. According to an analysis by Dr. E. C. Sullivan, this mineral is a rare zinciferous siderite containing 11.6 per cent of zinc oxide and allied to the subspecies monheimite. The pyritic deposit at the F. M. D. mine seems to trend east and west, toward the Malachite mine and obliquely to the schistosity, and it perhaps represents a dike somewhat later than the mass of the amphibolite. The continuity of the pyritic ores between the two deposits is, however, not proved. A small prospect shaft a quarter of a mile west of the Malachite, toward the F. M. D., shows amphibolite schist with streaks of chalcopyrite and pyrite containing a little garnet and epidote. Barren pegmatite dikes cut this amphibolite.

The Malachite mine is situated on a high ridge near the northerly divide of Bear Creek, 1¼ miles east of the F. M. D., at an elevation of 7,000 feet. Many years ago this mine produced a considerable amount of oxidized ores, and intermittent small shipments have been made since then. The value of the total production is estimated by the former owners to be $35,000. These ores were taken out from a shaft 150 feet in depth. A tunnel 300 feet in length has been driven in a northerly direction to tap the lower workings at the bottom of this shaft, and at the time of visit this tunnel was being reopened.

The entire length of the tunnel is in contorted biotite and amphibole schist intersected by pegmatite dikes. The deposit opened by the old shaft does not appear to be directly continued on the tunnel level, but immediately beyond the shaft the tunnel had just intersected an irregular mass of sulphides about 10 feet in width. Of the position of this ore with reference to the upper workings nothing definite can be said, as these workings were not accessible. The ore is massive and consists of coarse masses of chalcopyrite, zinc blende, and pyrrhotite, said to contain some nickel. It contains very little gold and silver. Sharply defined but small octahedra of pyrite are embedded in the pyrrhotite. The minerals occurring with the ores are augite, a pale-green feldspar in grains up to 1 centimeter in diameter, and small grains of quartz. The thin section reveals the fact that the feldspar is labradorite in broad plates; a pale-green augite is abundantly intergrown with the feldspar in gabbro structure. A few grains of apatite and titanite form the accessory minerals. The feldspar is in part sericitized and the augite is locally converted to greenish-brown hornblende. The abundant ore minerals in the sections are pyrrhotite, chalcopyrite, and dark-brown zinc blende, all three genetically equivalent and intergrown with augite and feldspar in a manner to indicate simultaneous crystallization. The sulphides include these minerals, and vice versa; the included augite is sharply defined with curved contact lines. The inevitable conclusion is that the ores form part of a gabbroitic dike rock and that they have crystallized from a molten magma.

A few of the ores are surrounded by a colorless or pale-yellow epidote and a little quartz, which probably resulted from secondary action in the consolidated rock.

The Malachite ore deposit is, then, a gabbro dike containing magmatic sulphides later than the main mass of schists, but probably earlier than the pegmatite. The proof of pre-Cambrian age is not quite as strong as at the Sedalia mine. Marked points of resemblance will easily be perceived between all these copper deposits so far described, and it seems justifiable to regard them all as differentiation products of a basic magma, in places changed and rearranged by dynamometamorphism.

The Augusta lode on Cub Creek, half a mile above Evergreen, is a very different deposit. Ore containing copper and silver was shipped from it several years ago and work has been resumed at intervals. The principal development consists of a shaft 130 feet deep. The lode is a sharply defined quartz-fluorite vein, occurring in red granite; its strike is north-northwest and its dip 70° WSW. Yellow zinc blende and chalcocite are the ore minerals. The vein shows distinct crustification, and is evidently very much younger than the deposits described above.

COPPER DEPOSITS IN THE "RED BEDS" OF FREMONT COUNTY.

LOCATION.

The Red Gulch copper district is situated in Fremont County about 9 miles due north of Cotopaxi station on the Denver and Rio Grande Railroad. The elevation at this station is 6,373 feet, and the high plateau at the Red Gulch camp has an elevation of about 8,000 feet.

GEOLOGY.

The Arkansas River canyon is here cut in pre-Cambrian gneiss and schist. On the north side of the river and about 1,500 feet above it a block of Paleozoic limestones gently inclined eastward rests upon the eroded pre-Cambrian surface. The road to the copper camp ascends steeply for a few miles in Bernard Creek, enters the limestone area, crosses eastward over into Red Gulch, the next tributary to the Arkansas from the north, and here enters the "Red Beds," which overlie the limestones and like them dip about 20° E. Following Red Gulch, the road continues northward for 3 or 4 miles in a wide, open valley, a sort of high plateau, in which the creek runs with slight fall. At the camp is a small settlement called Copperfield, and half a mile farther north another named Springfield. Immediately east of Red Gulch, and in places following the creek bed, a great north-south fault brings up the pre-Cambrian gneissoid granites above the "Red Beds," and these rocks form the whole eastern slope of the valley, which rises about 1,000 feet above the watercourse. On the western side the ridge of Paleozoic limestones is seen in the distance.

The series of sedimentary rocks exposed along Red Gulch is approximately as follows. The examination extended over only one day and was in the nature of a rapid reconnaissance.

Approximate section of "Red Beds" at Red Gulch, Colorado.

Top.	Feet.
1. Gray limestone, partly silicified	250
2. Red or green shale	20
3. Red conglomerate	20
4. Red or green shale	30
5. Conglomerate	40
6. Dark-green shales	200

The main body of Carboniferous limestones lies at an undetermined distance below No. 6. The original color of the shales and conglomerates is apparently dark green, but oxidation rapidly turns them to a deep brownish-red color. Water is scarce and evidently contains a large amount of sulphates. The age of these beds is doubtful. The limestones contain some imperfect round crinoid stems, and more careful search would probably reveal better fossils. The series probably belongs in the upper Paleozoic column.

Within a distance of a few hundred to 1,000 feet from the great fault the beds begin to dip more steeply, and at the fault they have at many places assumed a vertical position. A few smaller transverse east-west faults were noted. The only rock intrusive in the "Red Beds" is a thoroughly oxidized east-west dike, a fourth of a mile north of Springfield, which is said to contain a little silver. It has no apparent connection with the copper deposits.

COPPER DEPOSITS.

At several horizons the "Red Beds" of Red Gulch contain copper ores—chalcocite, malachite, and azurite—and the deposits are of the type made familiar by many occurrences in New Mexico, Arizona, and western Colorado. Their existence has been known for many years, but active exploration began only in 1907, and several companies are now operating in the camp. Two cars of high-grade ore and several cars of low-grade material are said to have been shipped in 1907, principally from the Red Gulch and Copper Prince mines.

The Copper Prince property lies a short distance northwest of Copperfield and covers a slope of heavy red conglomerate of well-washed pre-Cambrian rocks. Bunches of oxidized copper ores and chalcocite are found in the pits sunk in the conglomerate, apparently without exception associated with coaly material representing fossil wood. In a coaly shale bed below the conglomerate, exposed in a small shaft, chalcocite occurred more abundantly.

The Colorado Copper Company has sunk a shaft on the hill about 1,000 feet east of the creek at Copperfield and 150 feet above it; the depth attained in September, 1907, was about 250 feet. The water is kept in check by bailing. The sediments between the creek and the shaft dip eastward at moderate angles and consist of red shale with one intercalated bed of conglomerate. Near the shaft they dip at a steeper angle and the shales turn into reddish-brown limestone. At the granite contact about 100 feet east of the shaft the strata stand vertically or dip a few degrees from the vertical to the west. The fault is clearly marked, but no ore appears to follow it. Copper stains appear in various places, especially in a belt of quartzitic rock which lies near the contact, but it was not claimed that large ore bodies had been found.

The most interesting developments are at Springfield, half a mile north of Copperfield. The Red Gulch Gold and Copper Mining Company is operating at this place just east of the creek and has sunk a shaft 150 feet deep on an incline of 70° from the horizontal. Some rich chalcocite ore has been shipped. The fault lies here within a few hundred feet of the creek. On the west side are gently dipping shales and conglomerates, which near the shaft of the company gradually assume a dip of 70°. The ore follows a bed of carbonaceous shale 4 feet wide. In the foot wall lies a heavy red conglomerate; the hanging wall consists of about 50 feet of red shales with some intercalated conglomerate. The dip here becomes nearly vertical. The shales are capped by about 200 feet of gray, partly silicified limestone, which adjoins the great fault bringing up the pre-Cambrian granitic complex. The dark-gray, soft ore-bearing shale contains seams of a compact bituminous coal up to an inch or more in thickness, and in places abundantly disseminated chalcocite. The copper mineral appears to follow the coal seams very closely, and specimens show a peculiar ore of intimately intergrown chalcocite and coal. It is stated that the coal itself contains copper. Polished sections show that this is due to very minute veinlets of the copper sulphide in the coal. According to a determination by Doctor Hillebrand the coal contains some vanadium. The analysis gave 0.114 V_2O_3. The chalcocite also occurs in smooth nodules in the shale, usually 1 or 2 inches in diameter. Sections of these nodules show that the bedding planes of the shale continue through them and the inference is plain that they replace coaly shale material. The only associated mineral thus far found is barite, narrow seams of which cut both ore and coal. The pure chalcocite is said to contain at most 10 ounces of silver per ton. No ore occurs in the red shale, nor in the conglomerate or the limestone. The fault plane is likewise barren.

Half a mile north of Springfield are the Acme and Queen Princess properties. These are located on a gently dipping cupriferous dark-gray or dark-green shale, probably the lower part of No. 6 in the section (p. 171). At the Queen Princess two ore-bearing deposits, 12 feet apart, have been opened. The surface shows but little copper, but about 15 inches from the outcrops green stains and narrow seams of sooty chalcocite appear. The ore is apparently of low grade. The shale of the Red Gulch mine lies probably 200 feet above this horizon, but no copper is reported from it at this place.

CONCLUSIONS.

The copper deposits of this district are in the main similar to those in the "Red Beds" of New Mexico and Arizona and share with them certain disadvantages of exploitation, being generally of low grade and presenting difficulties of concentration, or leaching. Whether any property contains payable ore bodies can be determined only by careful sampling and close consideration of problems of transportation and reduction. As far as known to the writer the bodies of low-grade disseminated ore in the "Red Beds" have not been profitably handled anywhere, in spite of many attempts. On the other hand, the finding of rich chalcocite shipping ore in the coaly shale is a more promising feature, encouraging further exploration in favorable places.

GENESIS.

In view of the extended discussion of the genesis of the copper deposits in the "Red Beds," the data obtained in this camp are of more than passing interest. The earlier view that the copper ores were formed simultaneously with the accumulation of the strata in which they occur has lately been disputed, and theories explaining their origin by ascending thermal solutions or by precipitation from circulating surface waters have been advanced. The primary ore of the Red Gulch district is unquestionably chalcocite. Its connection with the beds containing carbon is equally unquestionable. Sections of the ore occurring in the Red Gulch mine show that the chalcocite is deposited by replacement of this coal, which of course would exercise a strong reducing action. If this theory is accepted it follows that the solution must have contained copper sulphate. The presence of barite and the known gypsiferous character of the "Red

Beds" indicate that sulphate solutions would be abundant in them. The reaction probably took place according to the following formula, in which it can be shown that chalcocite and carbon would be exchanged almost volume for volume: $4CuSO_4+5C+2H_2O=2Cu_2S+2H_2SO_4+5CO_2$.

This reaction would not appear to necessitate ascending or heated waters, but could proceed at ordinary temperatures in circulating surface waters. It has been shown in preceding pages that the pre-Cambrian rocks which furnish the material for the "Red Beds" contain old copper deposits. The degradation of these pre-Cambrian deposits would distribute through the "Red Beds" an appreciable amount of copper salts, partly soluble, partly sulphides. When surface waters containing oxygen searched these beds copper would naturally be dissolved as a sulphate, and its precipitation as chalcocite would follow wherever agents of reduction, such as carbon, were available.

NOTES ON THE FORT HALL MINING DISTRICT, IDAHO.

By F. B. Weeks and V. C. Heikes.

INTRODUCTION.

The Fort Hall mining district is located in Bannock County, southern Idaho, near the city of Pocatello and along the Oregon Short Line Railroad. The present paper contains the results of a brief reconnaissance undertaken in October, 1907.

The mining district was established June 17, 1902, and its area comprises all of the ceded portion of the Fort Hall Indian Reservation lying within Bannock County. It extends approximately 26 miles north and south and 30 miles east and west, comprising an area of about 750 square miles. Pocatello lies in the northwestern part of the district.

TOPOGRAPHY AND DRAINAGE.

Portions of three mountain ranges are included within the district—the Pocatello Range in the western, the Bannock Range in the central, and the Portneuf Range in the eastern part. These ranges trend north and south and are fairly well defined. The upper and the lower Portneuf valleys and the Marsh Creek valley are the principal depressions. (See fig. 10.)

The Portneuf Range extends from the valley of Ross Fork on the north to Cache Valley on the south. On the east is a wide valley known as Portneuf Valley, and on the west it is separated from the Bannock Range by the south fork of Ross Fork, Rapid River, and a portion of Portneuf River. It is about 40 miles long and its average width is 12 to 15 miles. The principal peaks are Mount Putnam and Bonneville Peak, the latter having the greater elevation—9,200 feet. Portneuf River has cut a deep canyon across the southern part of the range nearly at right angles to its trend. South of this canyon the range is formed of several parallel ridges of less elevation, but much wider in mass than the northern part of the uplift.

The Bannock Range is bounded on the north by the valley of Ross Fork and extends southward to the headwaters of Malade Creek.

Portneuf River cuts through the range at right angles to its trend about 10 miles north of its canyon through the Portneuf Range. The northern portion of the Bannock Range is formed of the Tertiary and basalt hills south of Ross Fork, the hills west of Mount Putnam, and the ridge which faces the lower valley of the Portneuf. South of the Portneuf Canyon the range extends to the headwaters of Marsh and Malade creeks.

The Pocatello Range extends from the Snake River plains southward to the headwaters of Bannock and Malade creeks and is formed of a broad mass of hills and ridges.

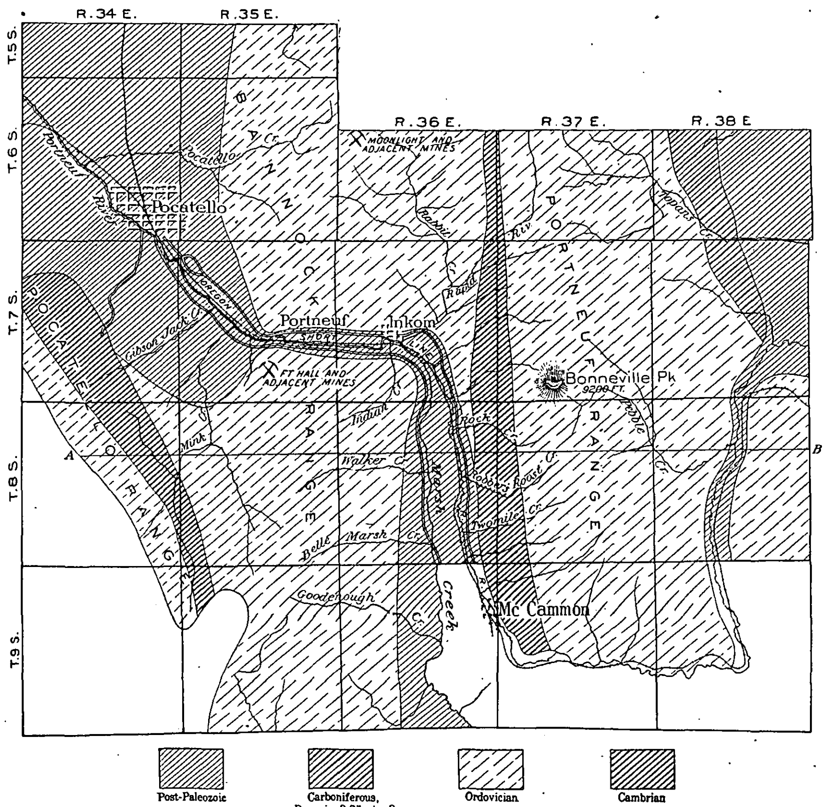

FIG. 10.—Geologic sketch map of Fort Hall mining district, Idaho.

Portneuf River and its tributaries drain the three ranges above described. This stream forms one of the principal southern branches of Snake River. Its course is very irregular. It rises in the hills north of Portneuf Valley, which form the divide separating the Great Basin from the Pacific drainage, and flows southward for about 35 miles, penetrating the eastern portion of the Portneuf Range; turns abruptly to the west and cuts directly through the range; thence flows northwestward and northward for about 10 miles, paralleling the valley of Marsh Creek, from which it is separated by a basalt flow from 1 to 2 miles wide; turns again abruptly to the west and cuts through the Bannock Range a short distance below the mouth of Marsh Creek; and thence flows northwestward into Snake River. Before reaching the Snake the Portneuf receives the waters of Ross Fork from the east and Bannock Creek from the south.

The basaltic flows through which the Portneuf has cut a channel of considerable depth and which form benches reaching back to the foot of the mountain slopes are prominent features of the valley of this stream.

GEOLOGY.

STRATIGRAPHY.

The sedimentary strata exposed in the Fort Hall mining district extend from the upper Cambrian to the lower Carboniferous. They outcrop principally along the higher portions of the ridges and have been folded into a series of anticlines and synclines. The lower slopes are usually covered by débris and the Portneuf Valley is filled by basalt flows.

CAMBRIAN AND ORDOVICIAN.

Only the upper beds of the Cambrian system are exposed in this area, in the Pocatello Range and along the western slope of the Portneuf Range. They form the northern extension of the strata exposed along the eastern side of Malade Valley, and their age has been determined by fossils collected and identified by Charles D. Walcott.[a] The strata comprise siliceous and cherty limestones and are conformably overlain by Ordovician sandstones. The Ordovician rocks cover the greater part of the district. They are mainly quartzites, conglomerates, and shales, with a series of limestones 50 to 75 feet thick in the upper part. The total thickness is approximately 3,000 feet. They represent the horizon of the Ogden quartzite of the Wasatch Range and by change in character of sediments probably include the limestones of Ordovician age, which occur above and below the Ogden quartzite in that region.

DEVONIAN, SILURIAN, AND CARBONIFEROUS.

Field work by the senior author in 1905 in the northern part of the Wasatch Range has shown that Devonian and Silurian strata occur in that region. It is possible that strata of the same age may be present on the eastern slope of the Portneuf Range beneath the known Carboniferous limestones.[b]

[a] Personal communication; also Sixth Ann. Rept. U. S. Geol. Survey Terr., 1873, pp. 203–204.

[b] Eleventh Ann. Rept. U. S. Geol. and Geog. Survey Terr., 1879, pp. 329–330.

Carboniferous rocks occur only in the northeastern corner of the district. They consist of limestones of Mississippian age, as shown by fossils collected by the Hayden Survey.[a]

STRUCTURE.

An anticlinal fold, formed by Cambrian and Ordovician strata, follows approximately the trend of the Pocatello Range. West and a little south of the canyon of Portneuf River through the Bannock Range this fold is broken, probably by a thrust fault. Southeast of Pocatello the valley of the Portneuf occupies a syncline which, south of the bend of the river, is broken by a fault of considerable displacement.

The Bannock Range is formed by an anticlinal fold that follows its general trend. This structure is well shown on the ridge north of the Portneuf Canyon. South of this canyon the ridge shows only the eastern side of the fold. In the tunnel of the Fort Hall copper mine the lower part of this fold is shown to be broken by a fault.

Between the Portneuf and Bannock ranges the valley of Portneuf River occupies a synclinal basin. The strata rise in a low anticline along the western slope of the Portneuf Range, exposing the Cambrian limestones in a rather narrow north-south belt extending across the district. The main ridge is an eastward-dipping monocline of Ordovician strata which merges into a low syncline in the southern part of the upper Portneuf Valley.

An east-west structure section across the district is shown in fig. 11.

IGNEOUS ROCKS.

With the exception of the basaltic flows, igneous rocks are of rare occurrence in the Fort Hall district. On the north side of the canyon of the Portneuf through the Bannock Range is exposed a grayish-green rock, which under the microscope is seen to be of igneous origin. The structure of the rock indicates that it was probably poured out through a vent or fissure as a sheet of lava. In its present outcrop it appears as more or less regularly defined beds. South of the river it is not found in any of the underground workings, so far as known, but it may, nevertheless, underlie the main ridge at no great depth. To the north and east of the river it rises on the upward pitch of the Bannock anticline and forms the surface rock over a considerable area on the western side of a second anticline that is developed in the region known locally as Moonlight.

In the hand specimen the rock is of medium grain and rather compact, but shows distinct amygdaloidal texture. It is as a rule somewhat schistose and has probably been subjected to the action of the

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[a] Sixth Ann. Rept. U. S. Geol. Survey Terr., 1873, p. 206; Eleventh Ann. Rept., 1879, p. 563.

dynamic forces which have affected the associated sedimentary rocks. Under the microscope it appears greatly decomposed, but still preserves its character as an amygdaloidal diabase. Its most prominent characteristic is the occurrence of many elongated amygdules filled with coarse calcite and rimmed by hematite. Portions of the rock mass are very strongly schistose and stained with copper carbonates. Others, more massive, contain specks of chalcopyrite and pyrrhotite. A deep-green chlorite is the most abundant mineral, but remains of augite still show in places, as well as locally preserved triclinic feldspars of lathlike form.

ORE DEPOSITS.

OCCURRENCE.

Prospecting work has been done at several points since this portion of the Fort Hall Reservation was thrown open to the public, but the most important mining operations have been carried on by the Pocatello Gold and Copper Company, owning the Moonlight group of claims in the northern part of the district, and the Fort Hall Mining Company in the southern part. (See fig. 10.) The valuable metals of the ores are copper, silver, and gold. The occurrence of lead is limited to small quartz veins in the limestone, and a little of this metal is also associated with the copper minerals in the Fort Hall prospects. Some manganese oxide and iron ore are found in parts of the district, but no attempt has been made to ship the material.

The Moonlight property is located at the head of Rabbit Creek, about 9 miles east of Pocatello, and has been

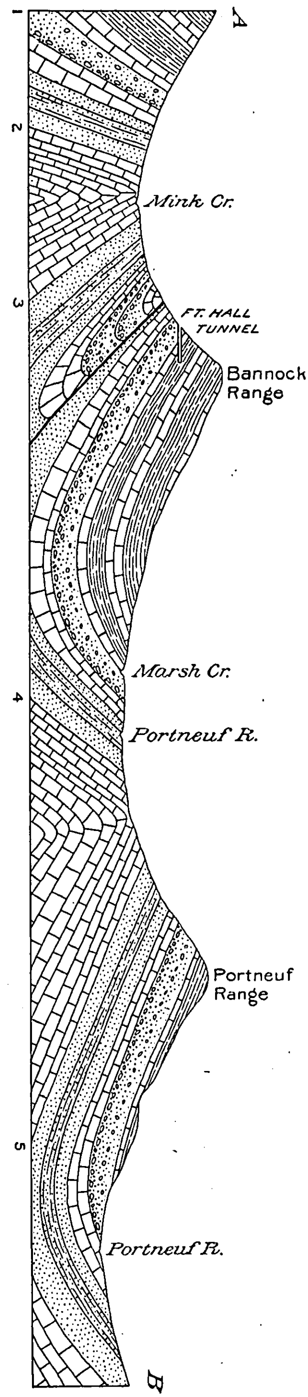

FIG. 11.—Structure section along line *A–B*, fig. 10. 1 to 2 and 3 to 4, Ordovician; 2 to 3 and 4 to 5, Cambrian.

worked steadily since the opening of the reservation in 1902. Soon after the opening the Pocatello Gold and Copper Mining Company (Limited) was incorporated to operate the property. During 1904 two carloads of copper ore of a good grade were shipped to the smelters. The development consists of a crosscut tunnel 830 feet long driven westward, at the end of which is an upraise opened for 90 feet for the purpose of connecting with known ore bodies. This part of the work was abandoned, however, and attention was given to taking out the ore near the surface. Two tunnels have been driven near the top of the hill, 275 feet and 75 feet long. The ore deposits occur in the conglomerate as opened in the workings near the top of the hill. The minerals, bornite and copper glance, associated with some carbonate of copper near the surface, are found in small kidneys and in fractures or fissures in the conglomerate. These have a north-south trend and dip about 40° E.

The Fort Hall Mining Company owns property located about 1½ miles west of Portneuf siding, on the Oregon Short Line, and 8 miles southeast of Pocatello. The development consists of a crosscut tunnel driven for 3,890 feet to the east through several different formations of the sedimentary rocks. These rocks have a westerly dip at the mouth, but at 1,200 feet in the dip is eastward. Near the end of this tunnel a crosscut is being driven and the sinking of a winze has been commenced.

Adjoining the Fort Hall property are claims owned by the Papoose Mining Company. The development consists of a 400-foot tunnel driven in black shale toward the west. This rock is apparently the same formation as that in which the Fort Hall Company terminates its tunnel, and the Papoose management expects to cut the Fort Hall mineral zone by extending its tunnel a few hundred feet farther. There are numerous other prospects in the district on which some development work has been done, especially on the east side of the ridge south of Portneuf River.

GEOLOGY.

The ore deposits of the Fort Hall district occur in conglomerates and shales of Ordovician age. These rocks are exposed in the anticlinal fold which forms the Bannock Range and in another fold of similar character which occupies the area between this range and the Portneuf Range, locally known as the Moonlight region. A few hundred feet beneath the strata in which the ores occur is an intercalated mass of diabase, which probably is a surface flow of Ordovician age, and which appears to have been an important factor in the ore deposition.

In the Moonlight area the ore occurs in a dark-colored conglomerate, which lies 500 to 600 feet above the shale series which contains the ore of the Fort Hall mine. The stresses that produced sharply compressed folds in the shales were relieved by fracturing and the formation of fissures in the conglomerate in which the ores were deposited.

In the vicinity of the Fort Hall mine the ore occurs in a gray calcareous shale which is No. 11 of the section in the Fort Hall tunnel, given below. This ore-bearing zone comprises approximately 125 feet of crumpled and contorted layers of shale and thin-bedded limestones. The Fort Hall tunnel shows the following section, the thickness having been measured along the tunnel level:

General section of the Fort Hall tunnel.

	Feet.
1. Brown conglomerate made up of granite and quartz bowlders, ranging in size from small pebbles to bowlders 12 inches in diameter in a brown cementing material, dipping 40° W	400
2. Brownish-gray quartzitic sandstone made up of subangular grains in a sericitic matrix	420
3. Gray slates, thinly laminated and contorted, the ends of the beds thrust upward against a white quartz vein, which marks a plane of thrust faulting. Throughout the shales there are nearly vertical white quartz veins ranging from 1 to 3 inches in width. Small nodules of chalcopyrite and iron pyrite are disseminated in white quartz	465
4. Grayish-green compact dolomitic shale, composed of angular quartz grains, sericite, and aggregates of dolomite. At the contact of the shale and conglomerate the dip is 20° E	325
5. Conglomerate, fractured and brecciated. Open fissure, with much water at contact of conglomerate in 10-inch quartz vein	245
6. Quartzitic sandstones dipping 40° to 54° E	275
7. Brown conglomerate composed of large quartzite bowlders in a brown quartzy cementing material. Probably mineralized zone of the Moonlight area	800
8. Varicolored calcareous shale	50
9. Fine-grained gray sandstone, dipping 20° to 40° E	300
10. White and gray siliceous and calcareous shale containing quartz seams	275
11. Laminated gray shale and thin-bedded limestone in beds from 1 to 3 inches thick. Dip 26° to 40° E. *Zone of ore deposition*	125
12. Compact gray to black calcareous shale	210
	3,890

CHARACTER OF ORE.

In the Moonlight area the principal minerals occurring in the fissures in the conglomerate are bornite and copper glance, associated with carbonate of copper near the surface. In the southern part of the district, in the Fort Hall and adjacent mines, the most abundant mineral is chalcopyrite, occurring as veinlets in the sharply compressed folds. There is also some pyrite. A small amount of galena is contained in the limestone strata. The company reported that a general sample from the ore zone 125 feet in width along the tunnel level was tested to determine the proper methods of milling the product. A ratio of concentration of 11.05 tons of crude ore to 1 of concentrates gave the following results: Copper, 12.3 per cent; gold, 0.13 ounce per ton; silver, 4.30 ounces per ton; iron, 26.4 per cent; silica, 16.1 per cent; and lead, 0.8 per cent. The gangue consists of quartz with some calcite. A specimen consisting of chalcopyrite and quartz in about equal quantities contained, according to an analysis made by the Bureau of the Mint, 0.05 ounce of gold and 0.75 ounce of silver per ton.

The copper-bearing shale zone contains innumerable, mostly nonpersistent veins and veinlets filled with quartz, calcite, and chalcopyrite, with smaller amounts of pyrite. These veinlets are bent, corrugated, and contorted. The shale itself is a normal clay shale with sericite in minute flakes and aggregates of dolomite. Next to the seams of quartz and chalcopyrite sericite is developed more abundantly over a distance of a few millimeters. The banded limestones intercalated with shales contain seams of metasomatically developed cubes of pyrite and also some albite which has the appearance of being authigenetic.

FORM OF THE DEPOSITS.

At the Moonlight property, as stated above, the bornite and chalcopyrite occur in small masses along fractures in the Ordovician conglomerate. At the Fort Hall property the ore body appears on the surface as a broad belt of limonite-stained rock which can be traced by irregular outcrops for a considerable distance and which contains little or no copper. There are no developments of note in this surface zone, but the tunnel intersects a bed of cupriferous shale (No. 11 in above section) approximately 800 feet below the croppings (measured vertically) and in a position which indicates that it corresponds stratigraphically with them. Measured along the dip this would indicate a distance of about 1,600 feet from the outcrops to the tunnel level. The thickness of the ore-bearing bed would be about 80 feet.

From present knowledge it is doubtful whether the ore bodies shown are of sufficient value to warrant the expenditure of the large amount of capital required for their extraction and reduction. At the Fort Hall and adjacent mines deposition of minerals of economic value has taken place irregularly through a zone of sedimentary strata of considerable width and a large amount of very low grade ore must be handled. Local conditions affecting the cost of mining and milling operations should be most carefully considered in connection with plans for the mining of these ores. Some enrichment may possibly have taken place in the lower part of the zone of oxidation between the barren croppings and the poor ore of the tunnel level.

ORIGIN OF THE ORES.

Chalcopyrite ores low in gold and silver occurring in fissured zones in sedimentary rocks and not apparently associated with igneous rocks are unusual for the Cordilleran province and therefore of interest in any study of the origin and formations of ore deposits in general. The occurrence of a flow of diabase intercalated in the sediments within a comparatively short distance below the ore bodies and the presence of disseminated copper minerals in it suggest the hypothesis that the diabase is the original source from which the ore minerals in the sedimentary strata were derived.

The amygdaloid diabase probably represents an Ordovician lava flow from some deeper-seated source. The succeeding sediments were laid down upon it. After the beginning of the crustal movements by which the strata were elevated and folded into the present mountain ranges, the ores may have been leached from this diabase and deposited higher up by ascending more or less heated surface waters. Where the circulation of these waters through the interstices or along the planes of stratification or plication in the shales was arrested a deposition of minerals held in solution took place.

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