THE MOUNTAIN CITY MINING DISTRICT, ELKO COUNTY, NEVADA

by

T.B. Nolan.[1]

(circa 1933)

1/ published by permission of the Director, U.S. Geological Survey.

TABLE OF CONTENTS

THE MOUNTAIN CITY MINING DISTRICT, ELKO COUNTY, NEVADA.

By THOMAS B. NOLAN*

INTRODUCTION

The Mountain City (Cope) mining district is situated in the Centennial or Bull Run Range in the northwestern part of Elko County, Nevada, about 100 miles by road north of Elko (Figure 1). The town of Mountain City, which

---

Figure 1. Index map showing location of the Mountain City district.

---

is the post-office and supply point, is on the east fork of the Owyhee River, near the northeast corner of T. 45 N., R. 53 W. The district is most readily reached by auto from Elko, either by way of Deep Creek or by way of North Fork. The former route is somewhat longer but is of necessity followed by heavily loaded vehicles since the bridges on the North Fork road are too weak to be used by other than passenger automobiles. Roads into Mountain City from the north have been planned but in 1932 were in such poor condition that they were but little used.

The Mountain City district is an old one. Emmons[1/] writes that "the

---

1/ Emmons, W. H., A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada: U. S. Geol. Survey Bull. 408, p. 80, 1910.

---

first discoveries were made in 1869 by Jesse Cope and others who were on their way from Silver City, Idaho, to the White Pine district, Nevada, and from this circumstance the Mountain City region is called the Cope mining district. In the seventies there was considerable activity in mining and three silver mills were in operation. These were small amalgamation mills of the Washoe pattern, equipped with stamps, pans, and settlers. It is said that over $1,000,000 in silver was recovered prior to 1881, mainly from surface and shallow workings. Since 1881 considerable prospecting has been done, but the production of ore has been small. In late years three gold mills

* Published by permission of the Director, U. S. Geological Survey.

have been built and are still in good condition, but they were not running in the summer of 1908, when the camp was visited." From 1908 until 1932 mining activity in the district was at a low ebb. The Silver Banner Mining Company constructed a 50-ton mill at the old Nelson Mine in 1921 and did some development work at both the Nelson and Mountain City Mines in the succeeding years, but the production from this work was negligible.

The present interest in the region resulted from the discovery by Mr. S.F. Hunt in November, 1931, of unusually rich copper ore on the Rio Tinto claims. A Salt Lake weekly has given the following account of the discovery:

"In 1919 he (Hunt) was attracted to the area by an extensive gossan outcrop. He located the ground and a short time after succeeded in interesting V.P. Strange, local contractor, in the prospect. In 1922 Mr. Hunt started development of the property on a small scale and the work continued until 1930 when his backers were forced to give up the project. At this time a shaft was down 73 feet.

"His stoic determination and faith in the property was manifested when he continued to seek funds and finally made a deal with Ogden C. Chase, local broker, to continue development of the property. Mr. Chase agreed to furnish $50,000 for the work, but when the ore was struck only $7,000 had been spent.

"The depression worked a hardship upon Mr. Chase and he had difficulty in raising the funds, so he instituted a new and unique method of financing. Mr. Chase gave the stock away with the agreement that stockholders would pay 5 cents per share in assessments. The fifth assessment had been levied when the ore was encountered and the stock has since advanced to around 20 cents a share."1/

1/ Western Mineral Survey and Utah Statesman, vol. 13, No. 30, July 22, 1932.

The discovery resulted in so many inquiries to the Nevada State Bureau of Mines that that organization requested a brief survey of the district as a part of the work to be done in 1932 by the Geological Survey in cooperation with the Bureau. The examination of the district was made by the writer during the period August 15-24, and the Rio Tinto Mine was visited a second time in September, (in order to examine the underground workings, which were inaccessible at the time of the first visit.)

The writer is greatly indebted to the officials of the Rio Tinto Mine, particularly R.C. Dugdale, superintendent, M.B. Kildale, geologist, and E.C. Stephens, engineer, for their hospitality and assistance. (They gave access to a geologic and topographic map of the vicinity of the mine, prepared by D.C. Gilbert, which has been incorporated in Plate 1 of this report, and much of the geologic material here presented in part is based upon conversations held with them. The Davidson brothers of Mountain City also assisted the work in a number of ways).

PREVIOUS GEOLOGIC WORK.

Relatively little geologic work has been done in this portion of Nevada. The Mountain City district lies north of the route followed by the Fortieth Parallel Survey and the relatively brief period of importance of the ore deposits in the quartz veins, together with the inaccessibility of the region has caused it to be generally neglected by geologists. Previous to the discovery of the Rio Tinto Mine, the only published information known to the writer is that by W.H. Emmons, based upon a short visit for the Geological Survey in 1908.1/ In 1932 two visits

1/ Emmons, W.H., A reconnaissance of some mining camps in Elko, Lander, and Eureka Counties, Nevada: U.S. Geol. Survey Bull. 408, pp. 80-84, 1910.

to the district were made by members of the Nevada State Mining Bureau, and their observations have been made available by press notices, which have in turn been republished by some of the western mining journals.2/ Polished sections of ore from

2/ Nevada State Bureau of Mines Memorandum for the Press, June 30, 1932.

Smith, A.M., Mountain City Mining District: Nevada State Bureau of Mines Memorandum for the Press, Oct. 12, 1932.

Reprinted by the Mining Journal (Arizona), vol. 16, Nov. 30, 1932, pp. 5-6, under title of "The Mountain City mining district of Nevada," and by the Mining Review (Salt Lake), vol. 34, Oct. 25, 1932, pp. 6-8, under title of "Mountain City district's mines of copper, gold, and silver."

the Rio Tinto Mine have been described by Crawford and Frobes.1/ Short news

[1] Crawford, A.L., and Frobes, D.C., Microscopic characteristics of the Rio Tinto, Nevada, copper deposits: The Mines Magazine (Colorado School of Mines Alumni Association), vol. 22, pp. 7-9, August, 1932.

notes regarding the Rio Tinto Mine have appeared in a number of the technical periodicals.

GEOLOGY

The Centennial Range, within which the Mountain City district is situated, is a northeasterly trending mountain mass that lies between the east and south forks of the Owyhee River. Its highest summits rise 3,000 to 4,000 feet above the river valleys on either side of the range but on the whole the range is less rugged than the Independence Range which adjoins it on the south.

According to Emmons[2], the mountainous area is underlain by a thick series

[2] Emmons, W. H., op. cit., pp. 67-69.

of Paleozoic sedimentary rocks, which are intruded in a number of places by granodiroite, and are overlain by rhyolitic flows and pyroclastics. South of Mountain City he reports that a thick quartzite is the lowest formation exposed and that this is overlain by several thousand feet of limestone. The limestone grades upward into black shale, which in turn is succeeded by a thickness of limestones and shales. Where the limestone adjoins the granodiorite intrusives it has been locally converted to a lime-silicate rock.

The larger areas of the volcanic rocks appear to be restricted to either topographic basins or to regions of subdued relief bordering the higher parts of the range. Locally, however, as at Mountain City, the contact between the volcanics and the older rocks shows that dissection of these areas of subdued relief had commenced before the eruption of the lavas and pyroclastics.

In the region around Mountain City, covered by Plate 1, about two-thirds

Plate 1. Geologic map and cross section of the vicinity of Mountain City, Nevada.

of the mapped area is underlain by more or less metamorphosed rocks, largely of sedimentary origin, that are in part at least of Carboniferous age. These are chiefly quartzites and schists but near the middle of the exposed sequence an horizon of limestone, overlain locally by amphibolitized andesitic rocks, is exposed. The sequence has been divided into five formations for the purposes of mapping. These beds are cut by a number of small faults, but are free from important folding; all of them dip to the north at moderate to steep angles.

In the northern part of the area the bedded rocks are intruded by a coarse-grained quartz monzonite which extends far beyond the limits of Plate 1. Near the borders of the intrusion, finer-grained aplitic rocks of similar composition are abundant. The age of this intrusion is unknown, but it was probably emplaced some time between late Jurassic and early Tertiary.

A series of rhyolitic lavas and pyroclastics are much younger than either the bedded or the granitic rocks. They were erupted over a topography that appears to have been characterized by steep walled valleys, but the present exposures represent only a small part of the original beds, the remainder having been removed by erosion.

Terrace gravels are found along the borders of the Owyhee River, whose flood plain is covered by alluvium.

GEOLOGIC FORMATIONS

"Footwall" quartzite.- Along the southern portion of the area mapped, quartzitic rocks are exposed that have been mapped by local geologists under the name of "Footwall"[1/] quartzite. The typical rock is a light colored, medium-grained quartzite which weathers to shades of light brown or tan and shows little variation in texture or composition. The formation is much more resistant to erosion than the adjacent Rio Tinto formation and underlies the high ridge southwest of the Rio Tinto mine. Exposures of the quartzite are commonly so well jointed that in many places it is difficult to determine bedding planes in the uniform siliceous rock.

The contact between the quartzite and the Rio Tinto formation, which adjoins its exposures to the north, is covered throughout the area mapped, but the thinning of the latter formation westward and discordances in strike shown west and southwest of the Rio Tinto Mine show clearly that the two are not conformable.

[1/] Since the true relations of the formation to the other rocks of sedimentary origin are unknown, the descriptive name, in quotation marks, is retained here.

It is believed, however, as shown on pages 32-3, that the contact is a reverse fault along which the "footwall" quartzite has been thrust up against the Rio Tinto formation. The age of the quartzite was not directly determined, but according to this interpretation of the faulting, it must originally have underlain the Rio Tinto formation and must be Carboniferous or older.

Rio Tinto formation.- The Rio Tinto formation, named by D. C. Gilbert [1]

---

[1] Manuscript map.

FROM THE Rio Tinto mine, is exposed in a nearly east-west band that ranges from half a mine to nearly a mile in width along the southern border of the area mapped. It is composed in large part of fine-grained quartz-sericite schist, although locally fine-grained dark quartzite and dense black cherts are conspicuous members. It is rather easily eroded and exposures are as a result few in number. The greater part of the surface underlain by the formation is covered either by talus from the "footwall" quartzite, terrace gravels, or wash composed of small fragments of the more resistant members of the formation. The formation is important economically since it forms the wall rock in the Rio Tinto Mine, and in other places is silicified in a manner not unlike that found near the Rio Tinto.

The dominant fine-grained quartz-sericite schist, which is exposed chiefly in trenches and prospect pits, is commonly pale gray in color. This color may be the result of bleaching in the softer rocks by surface waters, as some partially silicified rocks that crop out on the surface (notably about 600 feet north northwest of the southeast corner of the SW¼, sec. 11) are black. The quartz is mostly a fine-grained aggregate, though commonly the original bedding planes are indicated by alternations of slightly coarser and slightly finer-grained layers. Most sections show in addition a few larger quartz grains, but even these are less than 0.1 mm. in diameter. Oriented sericite shreds occur in thin seams that wrap around the larger quartz grains and are for the most part parallel to the bedding but locally may trend at a low angle to them. Where sericite is unusually abundant it is not as well oriented. Locally tourmaline, green hornblende, and other minerals are found in small quantities.

Quartzite is the next most important constituent of the formation. Southeast of the Rio Tinto mine it forms a belt nearly a quarter of a mile wide, which was traced to the eastern border of the area mapped. This belt is offset by several minor faults and about half a mile southeast of the Rio Tinto mine is apparently terminated westward by a fault striking north northwest. The quartzite may continue for a short distance farther west beneath tauls but it must be terminated by the fault that forms the contact between the "footwall" quartzite and the Rio Tinto formation. The rock in this belt is a rather unfform, fine-grained dark grayish-black quartzite. The individual sub-rounded quartz grains are from 0.1 to 0.4 millimeters in diameter and are commonly set in a matrix of sparse sericite and fine-grained quartz. There are, in addition, thin horizons or lenses of similar quartzite interbedded with the quartz sericite schist,--one of these is found at the surface close to the ore zone of the Rio Tinto mine.

Small fragments of dense black chert are found in many places in the wash that covers most of the formation. In a few places the rock crops out, but these exposures are commonly the result of cementation of the numerous joints by quartz veinlets. Under the microscope, the rock is seen to be an almost opaque fine-grained aggregate, dotted by rounded areas which are filled with granular lighter colored quartz. These are almost certainly, according to K. E. Lohman, 1/ poorly

---

1/ Personal communication.

---

preserved radiolaria.

Still another variety of rock was found in a prospect pit about 1500 feet west southwest of the Rio Tinto shaft. This appears to have been originally a fine-grained porphyry, but it is now composed largely of sericite, finely divided carbonate, and brown iron oxide. The rock occurs as a band 2 to 6 inches in width essentially parallel to the schistosity of the enclosing quartz-sericite schist. In thin section, much of the sericite is aggregated to form tiny tabular areas that resemble old feldspar crystals, and the carbonate surrounds areas that appear to have been formerly occupied by crystals of hornblende.

The contact between the Rio Tinto formation and the overlying Banner limestone is poorly exposed. An irrigation ditch on the west side of the Owyhee River south of the bridge west of Banner Hill provides some information about the contact, however. At this place, the two formations are essentially conformable in strike and dip and may be gradational, since the limestone contains a number of quartizitic beds near the base. Similar quartzitic beds crop out near the base of the limestone westward as far as the Nelson Ranch. About half a mile west of the Ranch, outcrops of conglomerate are found just north of Mill Creek at about the horizon of the contact, so there may have been some disturbance before the deposition of the limestone.

The total thickness of the Rio Tinto formation is not known since the base of the formation was not seen. Accurate measurements of the portion that is exposed are impossible because of the few outcrops, but at least 4,000 feet of beds must be present in the area mapped.

No fossils except the indeterminate radiolaria found in the black cherts were collected, and the age of the formation is therefore in doubt. The overlying Banner limestone is of Carboniferous (probably Upper Mississippian) age. If the contact between the Rio Tinto formation and the limestone is gradational, the Rio Tinto formation may also be Mississippian, but if there is a lack of continuity between them, as is perhaps suggested by the conglomerate west of the Nelson Ranch, it may be considerably older.

Banner limestone.- The Banner limestone, named by D. C. Gilbert [1] from

---

[1] Manuscript map.

ITS OCCURRENCE ON Banner Hill, south of the Silver Banner mine, crops out as a band which is more than a quarter of a mile in width on Banner Hill but which wedges out a short distance west of the Nelson Ranch. The formation on the whole is much more resistant to erosion than either the underlying or overlying formations, and crops out prominently on Banner Hill and locally on the relatively steep slopes north of Mill Creek.

The greater part of the formation is made up of thick-bedded grayish blue limestone. Bedding planes are only locally recognizable, and in a few places partially silicified corals may be found. The insoluble residue of one typical specimen tested, amounted to nearly 50 percent of the rock and consisted chiefly of quartz and tremolite. The quartzite beds near the base of the formation are notably calcareous and in some places contain abundant disseminated diopside. The quartzite beds are fine-grained, much jointed rocks that are pale gray on fresh fracture, and pale brownish on weathered surfaces. The conglomerate found west of the Nelson Ranch and which appears to be along the projection of the base of the quartzitic zone is a gray schistose rock with pebbles, chiefly of white quartzite, up to 1 cm. in diameter. Pebbles of an epidotized rock and of feldspar are less abundant. The matrix contains considerable biotite, together with some sericite, quartz and epidote.

On Banner Hill, there is a considerable development of lime silicate minerals in a wide zone adjacent to the quartz monzonite contact. These rocks were not examined closely during this survey but Emmons mentions the occurrence of "tremolite, actinolite, epidote, white mica, garnet, and other silicates of contact-metamorphic origin." 1/

1/ Emmons, W. H., op. cit., p. 80.

The Banner limestone is 500 to 600 feet thick over most of its extent along the north side of Mill Creek. It appears to wedge out west of the Nelson Ranch and to have its stratigraphic position taken by the Nelson amphibolite. On Banner Hill the thickness appears to be greater, but this may in part be due to the inclusion of higher beds within the area of more intense metamorphism.

Several poor collections of fossils made by M. B. Kildale and E. C. Stephens of the Rio Tinto Company and by the writer suggest an upper Mississippian age for the formation, according to G. H. Girty. His report is as follows:

"The collection consists of two blocks of limestone, one of them containing numerous corallites of a compound coral, and the other containing several specimens of a simple coral. On breaking up the latter, another fossil probably a Productus was brought to light. The rock has been much altered, the corals have been replaced by silica, and the details of the structure are more or less indeterminate. The compound coral appears to represent a species of Lithostrotion, the simple coral a species of Campophyllum or Cyathophyllum, and the other fossil, as just remarked, to represent a species of Productus. It would be easy to overestimate the evidence of the two corals but if circumstantial evidence is taken into consideration, I believe that they indicate an upper Mississippian age and would belong in the Brazer limestone, if the use of that formation name were extended to Nevada. If the other fossil is actually a Productus, as it seems to be, the stratigraphic evidence is considerably strengthened for at the very least the geologic age could hardly be anything but Carboniferous."

<u>Nelson amphibolite</u>.- The Nelson amphibolite is named from the Nelson ranch ~~formation~~, a short distance west of which are found the only good outcrops of the formation. The rock represents a much altered andesite, which was originally introduced either as a flow interbedded with the sedimentary rocks, or as a sill intruded between them. The amphibolite was recognized only on the west side of the Owyhee River where it occurs as a narrow band between the Banner limestone and the Mountain City formation. Throughout most of this distance the exposures consist only of small fragments of float. The formation may be present above the limestone on Banner Hill east of the Owyhee River, but it was not definitely recognized there because of the metamorphism.

The amphibolite is a dark gray green to gray rock without app rent schistosity b but locally showing a faint fibrous texture. In many specimens the rock is obscurely porphyritic with poorly defined feldspar phenocrysts up to 3 mm. in diameter. In the wider westerly outcrops the phenocrysts are both more abundant and larger, being commonly 5-6 mm. in diameter. These larger phenocrysts have a dull greenish cast due to epidotization of the feldspar crystals.

In thin section, the original textures of the rock are seen to have been largely obliterated by the development of acicular green pleochroic amphibole, with which is associated titanite and sparse biotite. The original andesine phenocrysts have for the most part escaped amphibolitization but are commonly altered to epidote or less commonly sericite. The matrix is now almost completely composed of amphibole but locally remnants of small plagioclase laths have been preserved. Chlorite is uncommon. A specimen collected from the dump of one of the tunnels on Banner Hill may represent a metamorphosed phase of the amphibolite. A thin section of this rock showed pyroxene replacing the sheafs of green amphibole, and disappearance of the plagioclase phenocrysts, which may now be represented by aggregates of small feldspar crystals. Microscopic garnet and large apatite crystals are also present.

The relations of the amphibolite to the adjacent sedimentary rocks were not definitely ascertained. It appears to occupy the stratigraphic position of the Banner limestone west of the Nelson ranch but this does not necessarily mean that the igneous rock is responsible for the disappearance of the limestone, since the limestone may have originally lensed out in this direction. This latter view is perhaps indicated by the presence of notably calcareous schists in the basal horizons of the

Mountain City formation near the western border of the area mapped. Throughout most of the outcrop of the amphibolite it appears to be concordant to both the Banner limestone below and the Mountain City formation above, and thus to be wither a sill or an interbedded flow. With the information available it is difficult to determine which of these is the correct interpretation.

The amphibolite is believed to be of approximately the same age as the remainder of the sedimentary sequence even if it should prove to be a sill, since it has apparently had essentially the same metamorphic history as the sediments. It is clearly older than the quartz monzonite intrusion, which is undeformed.

Mountain City formation.- The Mountain City formation was named by D.C. Gilbert[1] from its occurrence at the Mountain City Mine in the SE. $\frac{1}{4}$ of sec. 2, R.53 E., T. 45 N. It was recognized only west of the Owyhee River, where it occurs as a westerly trending band from half a mile to nearly a mile in width. The formation is rather easily eroded and in several places is concealed beneath either terrace gravels or younger volcanic rocks.

The greater part of the formation consists of dark siliceous schists, which are in part calcareous, and some interbedded quartzites. The calcareous schists are more abundant near the base of the formations and the quartzites near the top. As the quartz monzonite mass which limits the formation on the north is approached, the schists and quartzites are commonly somewhat bleached. Both schists and quartzites are fine-grained but locally they contain relatively large crystals (porphyroblasts) of andalusite or tremolite up to 5 mm. in length.

The siliceous schists are fine-grained dark gray to black rocks except where bleached by the quartz monzonite, and show a poorly defined schistosity that is commonly parallel to the bedding. Many of these rocks contain porphyroblasts but in some these are obscure. The matrix of the schists is shown by the microscope to be a fine-grained aggregate of quartz and alkali feldspar with considerable amounts of carbonaceous matter. Sericite is less abundant and calcite is present in variable amounts. The porphyroblasts are commonly of andalusite, but in the more limy members are of tremolite.

The quartzitic rocks, when studied microscopically, are seen to be metamor-

---

1/ Manuscript map.

phosed calcareous sandstones. They are fine-grained rocks that are pale greenish or bluish gray on fresh fracture, weathering to cream color but are locally colored by iron oxides. In thin section they are seen to contain considerable quantities of diposide and tremolite in addition to the quartz and alkali feldspar found in the schists.

The upper limit of the formation is not exposed in the area mapped because of the quartz monzonite intrusion to the north. At least two thousand feet of beds are present.

No fossils were found in the formation but the prevalence of calcium carbonate, especially in the highly calcareous schists near the base of the formation together with its apparent concordance in strike and dip with the lower beds, suggest that it may be of essentially the same age as the Carboniferous Banner limestone, from which it is separated by the igneous Nelson amphibolite.

Quartz monzonite.- The northern portion of the area mapped in Plate 1 is in large part underlain by quartz monzonite. This rock is part of an intrusive mass of considerable but as yet unknown extent, outcrops of which were recognized at several places for a distance of 15 or 20 miles southeast along the road that leads up California Gulch from Mountain City. About a mile north of Mountain City the intrusive disappears beneath younger volcanic rocks, and it is probable that it is similarly concealed to the west. Good outcrops of the quartz monzonite are rare because of its rapid disintegration into a granular soil. The quartz monzonite area, accordingly, is notably lower and more open than the adjacent country. The quartz monzonite is concealed by volcanic rocks and terrace gravels in a number of places, one large capping of volcanic rocks being situated just east of Mountain City.

The greater part of the intrusive is a light colored coarse grained rock in which are visible white plagioclase, plates of biotite up to 5 mm. in diameter, small but abundant grains of quartz, and pink potash feldspar, some crystals of which are more than 2 cms. in length. In a number of places, particularly near the contact of the quartz monzonite with the intruded sedimentary rocks, fine-grained aplitic rocks, essentially free from dark minerals are present. No lamprophyric dikes were noted within the quartz monzonite.

Thin sections of the quartz monzonite show that a zoned plagioclase (average composition about Ab_{25-30}) is the most abundant constituent. Quartz and perthitic orthoclase are less abundant light colored minerals. Brown biotite is the only dark mineral in some specimens, but in others small quantities of green hornblende are also found. Apatite and titanite are accessory constituents and minor quantities of calcite and epidote reflect later alteration. The following partial analysis was made by J.G. Fairchild of a specimen from "Point of Rocks" across California Creek from the Silver Banner Mine.

SiO_2	66.80
CaO	3.26
Na_2O	3.47
K_2O	4.45

This, together with the mineral composition of the rock, proves it to be a quartz monzonite.

The aplites are fine-grained pale grayish pink rocks, in which quartz and perthitic orthoclase are the two most abundant constituents. Albite is present in lesser although still considerable amounts. Muscovite and sericitized green biotite are scarce and locally there is minor sericitization of the feldspars.

On the cross-section shown in Plate 1, the contact between the quartz monzonite and the intruded sedimentary rocks is shown as dipping to the north. This is based upon the apparent influence of the topography upon the outcrop of the contact, as no direct observations were made either of the contact itself or upon the internal structure of the intrusive.

Beyond the fact that the quartz monzonite is post-Carboniferous, there is very little direct evidence available as to its age. The partial analysis given above is not unlike one of the Idaho batholith quoted by Lindgren[1/] and, as the intrusive of

[1/] Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey 20th Ann. Report, pt. 3, p. 82, 1900.

Mountain City district falls on the southward projection of the long axis of the larger body, it may be that the two are genetically connected. Ross[2/] has recently summarized

[2/] Ross, C. P., Mesozoic and Tertiary granitic rocks in Idaho: Jour. Geol. Vol. 36, pp. 673-693, 1928.

the evidence as to the age of the Idaho batholith and considers that it is of late Jurassic or early Cretaceous age, although he recognizes that other workers consider it to be somewhat younger.

Volcanic rocks.- A number of areas underlain by volcanic rocks are found in the vicinity of Mountain City. The largest of these, just east of the town, covers more than a square mile; the others are much smaller. All, however, appear to have been originally a part of a single body. The tuffs and flows are mostly of rhyolitic composition and appear to have been erupted upon a topography of low relief, but which had deeply entrenched streams, since the contacts between the lavas and the underlying rocks are, in some places, notably steep. Smaller remnants of the lavas show that this former drainage was in some respects quite different from the present one. Some of the lavas are more resistant ot erosion than the underlying schists and quartz monzonite and these now cap the present knobs and ridges. North of the area covered by Plate 1, volcanic rocks appear to be much more widely distributed.

The great bulk o f the volcanic rocks are surface flows, but some pyroclastics and one dike were recognized. The flows are porphyritic rocks which sparse, small feldspar phenocrysts are generally the only phenocrysts, although in one locality small biotite crystals were recognized, and in a few others, obscure and somewhat altered femic phenocrysts may be seen. The matrix is commonly gray and in many specimens is clearly composed of granulated glass. Small inclusions of lava of somewhat different texture are not uncommon. The lavas weather to shades of brown in most exposures. Pyroclastic rocks were recognized in the outcrop a half mile west of the Silver Banner Mine and at several localities east of Mountain City. They are light grayish or greenish gray porous rocks in which rock fragments up to 1 cm. in diameter are present together with smaller mineral and glass particles. The only dike recognized was found on the spur about half a mile east of south from the Rio Tinto Mine. This is not unlike many of the lavas in appearance but the feldspar phenocrysts are not abundant but are somewhat larger, reaching a length of 3 mm. The matrix is dense and dark gray to black in color.

Most of the specimens of the lavas show a rather close similarity when examined in thin section. Plagioclase, commonly a calcic albite, but in one specimen a calcic oligoclase, is an abundant, and in places, the only phenocryst. Sanidine phenocrysts are abundant in two specimens but in both of these a calcic albite was present in considerable amount. A few phenocrysts of microcline and quartz may also be found. Dark minerals are either rare or lacking. Biotite, largely altered, was present in one slide, and dark green augite, in part altered to a brownish clay-like mineral with high birefringence and an index of refraction less than that of balsam, was found in two others. The matrix of the lavas is a brown glass, locally obscurely recrystallized. In a number of specimens, the glassy matrix is an aggregate of angular fragments, which is probably the result of rapid freezing, followed by continued flowage of the lava.

In the two specimens of pyroclastics studied microscopically, mineral fragments were at least as abundant as rock inclusions. Sanidine and oligoclase were abundant minerals but some quartz is also present. Larger glass fragments differing in character from the glass that forms the matrix are also found.

The dike south of east from the Rio Tinto Mine differed from all of the other specimens in the presence of phenocrysts of andesine-labradorite. These are set in a flow-banded matrix of dark brown glass, in which a tendency toward recrystallization is most evident parallel to the flow lines. A mineral with low index of refraction which does not stain after etching with acids is also present, both in this rock and in some of the flows. It is probably cristobalite, since it does not have the tabular form commonly shown by tridymite.

A specimen of the lava collected about 1,000 feet west of the portal of the Silver Banner was analyzed by J. G. Fairchild with the following result:-

SiO_2	69.59
Al_2O_3	13.17
Fe_2O_3	1.75
FeO	2.30
MgO	.15
CaO	1.49
Na_2O	2.82
K_2O	5.55
H_2O-	.74
H_2O+	2.09
TiO_2	.80
P_2O_5	.05
MnO	.09
	100.59

The analysis indicates that this rock is a potash-rich rhyolite of essentially normal composition, although a thin section of the specimen shows a zoned plagioclase whose average composition is about Ab_{90} as the only abundant phenocryst.

Crystals of green augite, microcline and quartz are distinctly rare. Since normative orthoclase and quartz amount to about 60 per cent of the rock, these two minerals must be present almost entirely in the glass matrix. It is probable that all of the lavas have a similar rhyolitic composition, since the thin sections are all of the same character as that of the rock analyzed. In the absence of an analysis, the lavas would certainly have been classified, on the basis of the microscopic examination, as keratophyres or trachytes. The association of augite and albite-oligoclase as phenocrysts in the lavas is unusual.

There is no direct evidence as to the age of the volcanic rocks. They are undeformed, but their distribution and the occurrence of terrace gravels upon the lavas show that they are nevertheless older than the cutting of this portion of the Owyhee River. They may be related to the Pliocene (?) rhyolites described by Kirkham in southwestern Idaho[1/] or the probably Pliocene "later series" of Fuller in southeastern Oregon [2/] in which rhyolites are also present.

[1/] Kirkham, V.R.D., Igneous geology of southwestern Idaho; Jour.Geol. vol.39, pp. 579-587, 1931.

[2/] Fuller, R.E., The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon: Univ. Wash. Publ. in Geol., vol. 3, No. 1, pp. 125-130, 1931.

<u>Terrace gravels</u>.- Terrace gravels are present on both banks of the Owyhee River, the two largest exposures being on either side of Mill Creek on the west side of the river. The smooth upper surface of the gravels ranges in elevation from about 5,800 feet down to 5,500 feet, but at no place is there a suggestion of more than one bench. The elevations of the surface of the two Mill Creek exposures suggest that the gravel was deposited at a time when the bed of the river was progressively being shifted to the east and at the same time being deepened.

The gravels are composed almost exclusively of well rounded boulders of quartzite that may be as much as eight inches in diameter. The surfaces of these boulders are covered by the circular markings or "percussion cracks" that are characteristic of so many gravels of this sort.

River alluvium.- The Owyhee River between Mountain City and the mouth of Dry Gulch flows on a flat floor of alluvium that is from an eighth to a quarter mile in width. This material, together with much narrower belts along Mill Creek and California Gulch, supports an abundant growth of vegetation, and practically all of it has been claimed by homesteaders and is under cultivation.

GEOLOGIC STRUCTURE

The Mountain City district, like the Centennial Range of which it is a part, appears to lie within a belt in which the major structures have an east-west trend. This part of the State thus contrasts notably with the region to the south, where a north-south trend is characteristic of the larger geologic structures. The area covered during this survey is much too small to determine either the significance or the extent of the discordant structural habit of the region in which the Mountain City district is situated.

So far as the small area mapped is concerned, the major structure is a northward dipping homocline, limited on the north by the intrusion of quartz monzonite. The presence of beds apparently similar to those at Mountain City for some distance to the south[1] suggests that the homocline may be part of one limb of a large fold. The only other structural feature of at all large scale is the fault at the contact between the Rio Tinto formation and the "footwall" quartzite, which may be a steep reverse fault. Minor structures include the north-south faults that offset the outcrops of the quartzite member of the Rio Tinto formation and the Banner limestone; minor crumpling, which may be due to strike faulting, in the Rio Tinto formation; and small faults of various trend in the quartz monzonite area.

[1] Emmons, W. H., op. cit., p. 68.

The evidence indicating the presence of a fault at the base of the Rio Tinto formation was briefly stated on pp. 9-10. Since the fault plane is not exposed, the direction of dip is uncertain, but it is believed that the dip is to the south, chiefly because of the apparent tendency of the outcrop to extend farther south in the valleys than on the ridges, and that the fault is therefore reverse. The evidence for this belief is indirect and in part negative. The chief reason is thought to lie in the apparently greater deformation in the vicinity of the fault, suggesting that compressive forces have been localized there. The Rio Tinto formation is much more disturbed in its strike and dip and has a much better defined schistosity in the vicinity of the Rio Tinto Mine near the fault than in the exposures south of Banner Hill which are more distant from the fault. If the fault is normal, it must have a minimum throw of more than a mile, since no beds comparable to the "footwall" quartzite are exposed north of the fault; if it is a reverse fault, on the other hand, the throw may be much smaller, and the normal stratigraphic position of the quartzite be a short distance beneath the quartzitic horizons near the exposed base of the Rio Tinto formation, which are somewhat similar lighologically.

The localization of the Rio Tinto orebody and silicified zones in the schists of the Rio Tinto formation in the belt of country immediately north of this fault suggests that it may have played an important rôle in mineralization, either by the formation of sympathetic fractures in the schist that were suitable for mineralization, or by its action in guiding the ore solutions.

The nearly north-south faults in the southern part of the area mapped have throws of a few hundred feet or less. They can be recognized only in regions where there is a contrasting lithology on the two walls and their true extent is unknown. The faults southeast of the Rio Tinto Mine have somewhat different strikes from the others of this group and appear to have localized a later silicification.

Crushed and crumpled zones in the schists of the Mountain City formation may be widespread, but at only three places could such zones be recognized. One of these is at the Rio Tinto Mine, where three minor crushed zones were recognized, which are marked either by crumpling in the adjacent schists or by the introduction of silica (page 37). At two other localities, just east of the center of Section 11, and in the NW¼ of Section 12, silicification and abnormally steep dips are also present and appear to represent similar zones of disturbance. The three localities show a rough east-west alignment and may all be part of a single structure. The relationship of the crumpling to the other structures is unknown. Since the dip is apparently to the north, they are probably of different origin than the fault between the "footwall" quartzite and the Mountain City formation.

The faults in the quartz monzonite area were not studied in the field. According to Emmons[1] they are rather abundant and are chiefly small normal faults.

1/ Emmons, W. H., Op. cit., pp. 81-84.

ORE DEPOSITS.

Two notably different kinds of ore bodies have been found in the Mountain City district: quartz veins, valuable chiefly for their silver content, and the copper replacement body in schist of the Rio Tinto mine. The quartz veins were the source of the early production from the district, but have been either abandoned or relatively inactive in recent years; the copper deposit of the Rio Tinto mine, on the other hand, is a recent discovery, and is entirely responsible for the present interest in the district.

RIO TINTO COPPER DEPOSIT

The Rio Tinto deposit is situated in Copper Gulch, a branch of Mill Creek, in the NW¼ of sec. 11. It is nearly 4 miles by auto from Mountain City, the road to the mine leaving the Mountain City-Deep Creek road just south of the mouth of Mill Creek. The deposit is at present owned by the Mountain City Copper Company, a subsidiary of the International Smelting Company. This Company acquired by purchase the nine claims owned by the Rio Tinto Copper Company, the original owners. Operating control of the Rio Tinto company had been previously purchased by the International Smelting Company.

At the end of 1932 the company had sunk a two-compartment inclined shaft a distance of 396 feet and from it had driven workings amounting to 355 feet on the 200 level and 41 feet on the 300 level. All this work was in the vein except that on the 300 level and the last 55 feet of the shaft, which passed into the hanging wall.[1/]

1/ The Mining Review, (Salt Lake), p. 11, Apr. 11, 1932.

The International Smelting Company found it necessary to temporarily withhold permission to publish any of the information about the orebody gathered by the writer. The following account is therefore based on the surface observations of the writer, for which permission to publish was granted, supplemented by the published accounts of others, based chiefly upon observations made by them before control of the original company passed to the International Smelting Company.

Geologic setting.- The wall rocks of the Rio Tinto ore body are chiefly schists of the Mountain City formation, but locally some thin and lenticular quartzite beds are present. At the surface the schists are the light gray quartz-sericite variety similar to those in most of the exposures of the formation. Surface trenching, about 600 feet east of the shaft, shows a series of relatively thin quartzite bands which are interbedded with the schist and which appear to pinch out to the west.

The poor exposures at the surface obscure the minor structural features in the vicinity of the mine. The evidence available, however, suggests that the schists and associated quartzites are cut by three minor crushed zones or faults, which converge towards a point in the vicinity of the Rio Tinto shaft. A nearly east-west zone extending eastward from the shaft is marked by some white quartz, considerable iron oxide, and by variations in dip in the adjoining schist from 52 degrees to 85 degrees. Another zone, extending southeasterly from the shaft has also localized the introduction of silica, and its approximate course is shown by a series of jasperoid outcrops. Where it crosses the road, the schists in the walls are crumpled, particularly to the south. The only evidence on the surface for the third zone, which strikes northeasterly, also lies in the presence of jasperoid outcrops. The few outcrops available suggest that this zone is the youngest of the three and cuts across the other two without offset. The presence of quartz along all three indicates that they are all pre-ore.

Outcrop of the orebody.- The gossan or oxidized cappint of the Rio Tinto orebody crops out at a few places and has been further exposed by trenches and pits. Its location is apparently controlled by the intersection of the three fracture zones described in the preceding paragraph since the intersection appears to be about in the center of the gossan. The thoroughly mineralized zone has a strike length of about 400 feet, [1] and is about 100 feet wide. There is no

---

1/ Smith, A.M., and Stoddard, C.F., Nevada State Bureau of Mines Memorandum for the Press, June 30, 1932.

---

apparent distortion of the schistosity around the gossan and at the east end, the schistosity strikes into the gossan. This relation, in so far as deductions can be made from the gossan, suggests that the ore was introduced by replacement of the schist. Extensions of the capping or gossan, which is composed almost entirely of iron oxides and quartz, are found along the three fracture zones. In the northwesterly and northeasterly zones, there is a high proportion of siliceous material, but in the east-west zone, narrow bands of iron oxides, locally with only a small quartz content, are present in the schist for a distance of nearly 500 feet east of the shaft. The dominance of silica in the northwesterly and northeasterly zones, as contrasted with the low silica orebody suggests that the silica-filled fissures either consitutu or are close to the main feeding channel of the orebody. A fingering-out westward from the massive gossan similar to that on the east was not recognized since trenching in the thick soil and gravel that exists in this region had not exposed the bedrock.

According to Smith and Stoddard[1/], the gossan extends to a depth of 230

[1/] Nevada State Bureau of Mines Memorandum for the Press, June 30, 1932.

---

feet, below which the sulphide ore body was 75 feet wide. It is reported that 160 feet of drifting has been done in ore.[2/]

[2/] The Mining Review (Salt Lake), p. 13, Jan. 24, 1933.

<u>Mineralogy of the ore and gossan</u>.- Crawford and Frobes[3/] describe speci-

---

[3/] Crawford, A.L., and Frobes, D.C., Mimcroscopic characteristics of the Rio Tinto, Nevada, copper deposit; The Mines Magazine (Colorado School of Mines), vol. 22, p. 8, Aug. 1932.

---

mens of ore furnished them by Mr. S. F. Hunt as follows: "Typical samples vary from a spangled brassy yellow to a sooty bluish black porour crumbly mass. To the trained mineralogist, chalcopyrite is obviously a prominent consituent. The porous crumbly nature of the aggregate shows clearly the effect of leaching and the bluish black sooty coatings, which cover all but the freshly broken surfaces, strongly indicate secondary chalcocite enrichment of the type frequently found at or near the water table. Very little gangue is noticeable in the ore. Oxidation products in the form of malachite, cuprite and iron oxides are abundantly developed in some of the specimens and pyrite is only occasionally prominent. Owing to the prevalence of iridescent tarnishes, and to the copper content shown by assays of the average ore, bornite, a rich copper-iron sulfide, was at first suspected by the owners as the dominant mineral."

They recognized the following minerals in polished sections of the ore: quartz, pyrite, chalcopyrite, chalcocite, covellite, bornite, and sphalerite. The

PLATE L. Sketch geologic map and section of Mountain City and vicinity, Nevada.
Contour interval 100 feet

following notes on the occurrences of these minerals are based upon their published description.[1]

---

[1] Op. cit., pp. 8-9.

Quartz, some of which is secondary, constitutes practically all of the gangue, which forms about 20 per cent of the specimens examined. It is both older and younger than the pyrite. Pyrite is believed to be the oldest of the sulphide minerals and in their specimens was much less abundant than quartz.

Chalcopyrite has two modes of occurrence. A massive chalcopyrite is the dominant constituent of the ore and is clearly later than pyrite and quartz, which it replaces. Small quantities, however, are found as tiny inclusions (average diameter 5 microns) in pyrite. Some of these small blebs have elongate protusions extending to lines of weakness in the pyrite and in places the inclusions are aligned in roughly parallel bands suggesting a dependence upon crystallographic planes. The authors conclude that this form of chalcopyrite may either be an early generation contemporaneous with pyrite, or may replace the pyrite and be of the same age as the massive chalcopyrite.

Small inclusions of bornite, similar to those of chalcopyrite, were also found in the pyrite. The relations of the small amount of sphalerite found were obscured by chalcocitization but it is believed to be simultaneous with or later than the massive chalcopyrite.

Chalcocite was slightly less abundant than chalcopyrite in the specimens studied. Figures 2, 4 and 5 in Crawford's and Frobes' paper are photomicrographs of ore in which the older sulphides are replaced by a porous sooty chalcocite. A more massive form of the chalcocite is shown in Figures 3 and 6. Veinlets of this chalcocite in Figure 3 divide the chalcopyrite areas into a series of polygonal blocks and from these veinlets, smaller ones extend into the interior of the blocks. In Figure 6 chalcocite has more or less completely replaced chalcopyrite veinlets in pyri pyrite, the replacement being particularly complete at the edges of the veinlets.

Covellite is considerably less abundant than chalcocite, the ratio being estimated as 1:7. It is a replacement product of the chalcocite, and in Figure 3 is shown as developing in the central portions of chalcocite veinlets. The authors note that the Rio Tinto chalcocite has a decidedly bluish color and is difficult to distinguish from covellite except by the use of polarized light. The bluish chalcocite presumably carries some of the covellite molecule in solid solution.

Malachite and cuprite are found in small amounts in the veinlets of iron oxides that locally traverse the ore.

Specimens of the gossan collected by the writer at the surface consist almost entirely of goethite and quartz. Much of this material is reddish brown in color and porous but considerable proportions are powdery yellowish brown or dense dark brown. These color variations are probably due to variations in the quantity of quartz present, the yellow-brown material being relatively free of quartz and the darker varieties containing larger proportions. No hematite or jarosite could be recognized by immersion tests under the microscope and several specimens were tested for the SO_4 radicle chemically, all of which were negative. Malachite and other oxidized copper minerals, are almost entirely lacking from the exposures of the gossan near the surface. The only locality where they were found, so far as known, is in a siliceous outcrop about 60 feet east-northeast of the shaft.

The water table was reached a few feet below the 225-foot level, and 40 to 60 gallons of water per minute were being pumped in the latter part of 1932. This had decreased to 10 gallons per minute at a depth of 385 feet in the shaft.[1/]

1/ The Mining Review (Salt Lake), Vol. 35, p. 13, Jan. 24, 1933.

Grade of the ore.- Records of the copper content of the ore zone as a whole have not been available to the writer. Assays from the 225-foot level are reported to have shown a copper content of 22 to 47 percent.[2/] Smith and Stoddard[3/] report an

2/ The Mining Journal (Arizona), vol. 16, p. 12, May 30, 1932.

3/ Nevada State Bureau of Mines, Memorandum for the Press, June 30, 1932.

average copper content of 40 per cent across the 75-foot width of ore exposed on the 225-foot level. Five cars of ore were shipped before the International Smelting Company acquired operating control of the company. These shipments totaled 718.5 tons and yielded net returns after freight and treatment of $6,383[4/] from an average copper

4/ The Mining Review (Salt Lake), vol. 34, p. 11, Nov. 29, 1932.

content of 37.26 percent.[1] The United States Bureau of Mines at Reno analyzed a

[1] The Mining Review (Salt Lake), vol. 35, p. 11, Apr. 11, 1923.

sample of the richer ore with the following results:

Insoluble..........	9.19
Copper.............	53.68
Iron...............	11.73
Al_2O_3	0.34
Sulphur	24.46
	99.40

The ore has a silver content of about an ounce per ton, and a very small gold content.[2] In the first car of ore shipped 0.5 ounces per ton silver and a

[2] The Mining Journal (Arizona), vol. 16, p. 12, May 30, 1932.

trace of gold were found. Small quantities of zinc are also present, judging from examinations of polished sections of the ore by Crawford and Frobes.[3]

[3] Crawford, A. L., and Frobes, D. C., op. cit., p. 8.

The ore encountered in the shaft below the level is reported to be of lower grade.[4] A depth of 396 feet had been reached at the end of 1932.

[4] The Mining Journal (Arizona), vol. 16, p. 23, Dec. 15, 1932.
The Mining Review (Salt Lake), vol. 34, p. 11, Dec. 13, 1932.

Wall rock alteration.- At the surface the only apparent alteration affecting the schists surrounding the gossan has been a considerable introduction of silica, chiefly along the fracture zones that are believed to have helped localize the ore. The resistant bodies of jasperoid developed as a result of this introduction of silica are composed of fine grained quartz somewhat stained by iron oxides and appear to be in part at least the result of replacement of the schist, although there is some evidence that part of the quartz has formed as a result of recrystallization of quartzitic horizons interbedded with the schist.

At several other places on the surface within the area underlain by the Rio Tinto formation, there are outcrops of silicified schist, and of chert and quartzite veined by white quartz. The larger of these bodies are shown on Plate 1. In most specimens from them, the amount of introduced quartz is less than in the rocks adjacent to the gossan, and the mechanism of its emplacement appears to be different, so that there may be no genetic connection between the two. In the regions away from the ore, almost all of the quartz is in the form of veinlets, which have clearly forced their way into the schists (Figure 2), although there is locally some

---

Figure 2. Sketch tracing of photomicrograph of schist, showing distortion of schistosity by a quartz veinlet. Plain light. x 35.

---

suggestion of replacement of recrystallization in the angular fragments of schist included within the veinlets. In the quartzite a half mile south-southeast of the shaft there has definitely been recrystallization.

Enrichment of the ore.- The high grade of the sulphide ore, together with the thickness of the barren gossan above the ore,[1] indicate clearly that the original orebody has been considerably enriched by surficial processes. The sooty chalcocite obviously is the result of the enrichment and the more massive chalcocite that replaces the chalcopyrite almost certainly had a similar origin, since it is apparently rare or absent in the lower part of the shaft.[2]

Crawford and Frobes, [3] possibly because they recognized two modes of occurrence of chalcopyrite (as veins, and as blebs), suggest that some of this mineral may be supergene, and that the hypogene ore may have been a low grade massive pyrite ore; although they recognized that both occurrences of chalcopyrite might have been formed during one continuous period. Moreover, the absence of jarosite and the abundance of goethite in the gossan appears to disprove the existence of a highly pyritic

---

1/ Crawford and Frobes, op. cit., pp. 7-8.

2/ The Mining Journal (Arizona), vol. 16, p. 23, Dec. 15, 1932.

3/ Crawford, A.L., and Frobes, D.C., Microscopic characteristics of the Rio Tinto, Nevada, copper deposit: The Mines Magazine (Colorado School of Mines), vol. 22, pp. 8-9, Aug., 1932.

primary or hypogene ore. The thorough oxidation of such a pyritic body, as Locke[1]

---

[1] Locke, Augustus, Leached outcrops, Baltimore, p. 108

---

has shown, would have produced such a strongly acid solution that neither of these minerals could have formed. Jarosite is unstable in contact with strongly acid or very dilute solutions, and goethite is stable only in contact with weakly acid solutions.[2] It would therefore appear that the dominance of goethite and the absence

---

[2] Posnak, E., and Merwin, H.E. The system $Fe_2O_3.SO_3.H_2O$: Journ. Amer. Chem. Soc. vol. 44, p. 1192, 1922.

---

of jarosite in the outcropping gossan implies that the solutions causing enrichment were dilute and of low acidity, which in turn suggests a relatively small pyrite content in the original ore.

Furthermore, if an original pyritic ore, which may be assumed ot have had a copper content of about 1 per cent, were to be enriched to an ore body containing 40 per cent copper and with a vertical extent of 100 feet, the erosion of 4,000 feet of material and the concentration of all of its copper into one enriched shoot would be necessary. On the other hand, hypogene ore containing 12 per cent copper,[3] which

---

[3] An ore containing 40 per cent copper (page 44) in which chalcopyrite and chalcocite are present in equal amounts (page 41) would contain 12.08 per cent copper in the form of chalcopyrite.

---

roughly represents the amount of chalcopyrite in the ore, would require the erosion of less than 350 feet, which is much more consistent with the topographic evidence.

SILVER-GOLD QUARTZ VEINS

The silver-gold quartz veins were not examined closely during this survey. They are either within the quartz-monzonite area or in the sedimentary rocks close to the quartz-monzonite contact.

Emmons[/] has given the following description of these quartz veins:

[/] Emmons, W.H., op. cit., pp. 81-84.

The ore deposits are fissure veins in granite and in metamorphosed limestones. They outcrop plainly at the surface, where some of them carry good values in silver. The veins do not fall into well-defined parallel systems but strike in various directions, the prevailing dip being toward the south.

Some of the veins, as shown on California Hill, are later than the aplitic phase of the granite which cuts the normal coarse-grained granite. None of the developed deposits are in rhyolite or basalt, although some gold-bearing veins in rhyolite are said to occur in the country east of Mountain City. In the Nelson mine the lodes pass from granite to limestone without much change in width or value. There is little replacement of the limestone, for the walls are clear cut and angular fragments of the country rock are included in the veins. Where the wall rock is granite the dark silicates have been leached out and sericite and pyrite have been developed in the granite by secondary processes.

The unoxidized ore is composed of quartz, pyrite, galena, zinc blende, gray copper, argentite, gold, and arsenopyrite, with a little chalcopyrite. All of the ore is highly siliceous, quartz constituting as much as 90 per cent of the rock. The oxidezed ore is composed of quartz, chalcedony, horn silver, pyromorphite, iron oxides, native gold and silver, lead carbonate, and copper silicate. Brittle silver and dark ruby silver are said to be present also. The oxidation of the deposits is erratic, the sulphides occurring at some places within a few feet of the surface, while some of the minerals of oxidation are to be found as deep as the lodes have been explored, or about 250 feet below the surface. The greater proportion of the silver values are in decomposed chloride and lead carbonate ore. Specimens of rich ore show large flakes of greenish-yellow horn silver deposited in the cavities of dark quartz. Some of the iron-stained siliceous ore pans gold liberally.

The lodes are fractured and faulted, and locally the ore is reduced to a white sand, in which there are numerous small rounded fragments of quartz about the size of a hazel nut. The faults that cross the lodes are mainly of the normal type, the hanging wall having dropped with respect to the foot wall.

MINE DESCRIPTIONS.

Protection Mine. The Protection mine, located three-fourths of a mile below Mountain City, was one of the early discoveries of the district and was worked in the early seventies, when considerable chloride ore is said to have been treated in a silver mill near by. In late years the mine has been reopened and considerable exploration work has been done. A 10-stamp amalgamating and concentrating mill was built near the portal of the tunnel to treat the ore. At present part of the mine is leased and is being worked in a small way, but the mill is shut down. The principal vein is a fissure filling in granodiorite and has a maximum width of about 4 feet. The sulphide ore is composed of quartz, pyrite, galena, zinc blende, gray copper, brittle silver, and ruby silver. The surface ore is stained with iron and manganese oxides and contains horn silver, a little copper carbonate, pyromorphite, and a yellowish-green mineral, said to be silver bromide. The sorted ore carries $100 a ton in silver and gold. At some places near the vein teh agrnite wall rock is but little altered; at others it is a light-colored decomposed rock, the ferromagnesian minerals having been leached out and the feldspar sericitized. A shaft is sunk to a depth of 62 feet and a level turned at the bottom. This is connected with an adit driven 80 feet below the bottom of the shaft, which gives a depth of 142 feet at this place.

The Protection vein strikes a few degrees west of north and has been followed into the hill on the adit level for a distance of some 750 feet to a point where it abuts against a fault that strikes eastward and dips about 40°N. A drift has been run on this fault for 400 feet, but no vein has been encountered on the hanging-wall side at this end of the drift. On the other side of the fault a vein with the same general dip and strike as the Protection vein is 35 feet farther south and is possibly the same vein, but if so the fault is reverse - a rare type of faulting in this part of Nevada. Along this fault there are stringers of quartz in place, and in the level above both the Protection vein and the faults are mineralized on both sides of their intersection. The relations indicate that the Protection fissure was displaced by faulting before deposition of the ore and that there has been considerable movement subsequently.

Resurrection Mine.- At the Resurrection mine, a few rods north of Mountain City, a large amount of work has been done in tunnels, pits, and shallow inclines, but most of the workings were inaccessible when the mine was visited in 1908. The country rock is granodiorite, to the east of which are flows of rhyolite and basalt. The granodiorite, which is highly altered, is sheeted by closely spaced fissures that strike northeastward. Several narrow quartz veins cut the granodiorite parallel to the sheeting. The surface ore is composed of quartz, horn silver, lead carbonates, and iron oxide; the sulphides are galena, gray copper, a little pyrite, and chalcopyrite. In the seventies considerable rich chloride ore was taken from the surface pits and worked in silver mills near by.

Nelson Mine.- The Nelson mine is on a branch of the north fork of the Owyhee, about 1 3/4 miles above Mountain City. Some 4,000 feet of workings have been run, mainly on two adit levels driven at a difference in elevation of about 100 feet. When the mine was visited in 1908 only the lower adit was accessible. A mill recently built at the portal of the lower adit is equipped with Blake crusher, nine stamps, amalgamation plates, and three Wilfley tables, and has treated a small amount of ore. The country rock of the mine consists of granodiorite, limestone, and aplite. The granodiorite intrudes the limestone and causes contact metamorphism with the development of epidote, actinolite, garnet, and mica in the limestone. In places this rock is so rich in actinolite that it has the appearance of a basic igneous rock and has been mistaken for diabase. The granodiorite is cut by aplite, which occurs as dikes and irregular intrusive masses. The ore deposits are fissure fillings from 1 to 3 feet wide and occur in granodiorite, limestone, and aplite. Several veins outcrop boldly on the hill above the mine, cutting across beds of metamorphosed limestone. The veins cross the contact of igneous and sedimentary rocks unbroken, but have been developed mainly in the granodiorite. The sulphide minerals present are quartz, pyrite, galena, zinc blende, gray copper, chalcopyrite, and arsenopyrite, with here and there a small amount of ruby silver and ~~xxxxxxxxxxxxxxx~~ argentite. Native silver and horn silver are present near the surface, where the ore is stained with copper carbonates, iron oxides, and manganese oxides. Free gold, some of it with the crystal form, is associated with quartz and brown iron oxide. The sorted ore carries good values in both silver and gold, some specimens containing a high percentage of horn silver.

The Standard vein, which is developed in the lower tunnel, strikes southeastward and has been followed for about 1,000 feet, with overhead stoping here and there. This vein is faulted at three places by faults that strike eastward and dip northward at various angles. One of the faults shows a horizontal displacement of about 150 feet, the other two of less than 15 feet. All are of normal type, the hanging wall having dropped with respect to the foot wall.

Mountain City Mine.- The Mountain City mine is located about 1 mile southwest of Mountain City, at the top of a low, flat ridge that rises some 200 feet above Owyhee River. The country rock is a metamorphosed black, shaly limestone which strikes eastward and dips 50°N. The lode is a fissure vein which cuts across the limestone, striking N.50°W. The ore is highly siliceous and is a simple fissure filling, cementing angular fragments of the altered limestone. It carries silver chloride and native silver, and in the seventies, according to report, several hundred thousand dollars' worth of silver ore was taken from the deposit through a shaft now inaccessible. About 500 feet S. 75° E. of the principal workings of the old Mountain City vein and lower on the hill are a number of open pits, some of which have been sunk on a vein which strikes N. 32° W. Possibly it is the faulted continuation of the Mountain City vein, but this has not yet been determined. This ground has recently been acquired by J. Hall and others, of Mountain City, and is called the New Yorkeys claim. The country rock of the lower deposit is a dark-gray metamorphosed limestone flaked with tremolite crystals. A tunnel is driven 95 feet N. 70° W. to the vein, which it follows for 90 feet, and a winze is sunk on the ore body 60 feet below the adit level. The deposit is a fissure vein and at some places a sheeted zone composed of several narrow veins with slabs of limestone between. Much movement has occurred since deposition, for at places the quartz is brecciated almost to powder. The ore is composed of quartz, iron oxides, copper carbonates, and silicates, and a little pyrite is present at the bottom of the winze. The vein strikes N. 32° W. and dips from 56° to 85°.S. It has a maximum width of 5 feet, and is said to carry good milling values.

Ferguson—/ has included the Mountain City veins within a group of ore de-

—/ Ferguson, H.G., The Mining Districts of Nevada: Econ. Geol., vol. 24, pp. 115-148, 1929.

posits which are "similar in appearance to the auriferous veins of California. These, however, have been valuable only for their oxidized and enriched silver ores." The Banner vein, which was seen by the writer, certainly resembles in many respects some of the Mother Lode veins of California.

RELATIONSHIPS OF THE ORE DEPOSITS.

The similarity of the quartz veins at Mountain City to those of California, already noted, adds significance to the resemblance that exists between the primary mineralization at the Rio Tinto mine and that at some of the mines of the "Foothill Copper Belt" of California, particularly those at Copperopolis. The deposits, which have been described by Knopf,—/ Reid,—/ and others,—/ are lenticular replacements of the

—/ Knopf, Adolph, Notes on the Foothill Copper Belt of the Sierra Nevada: Calif. Univ. Dept. Geol. Bull., vol. 4, pp. 411-423, 1906.

—/ Reid, J.A., The ore deposits of Copperopolis, Calaveras Co., Calif.: Econ. Geol., vol. 2, pp. 380-417, 1907.

—/ ______, ______, Foothill Copper Belt of the Sierra Nevada: Min. and Sci. Press, vol. 96, pp. 388-393, 1908.

—/ Forstner, William, Copper deposits of the western foothills of the Sierra Nevada: Min. and Sc. Pfess, vol. 96, pp. 743-748, 1908.

—/ Lang, Herbert, The Copper Belt of California: Eng. and Min. Jour., vol. 84, pp. 909-913, 963-966, 1006-1010, 1907.

country rock by chalcopyrite, with varying amounts of pyrite and sphalerite, and in some places at least are localized along shear zones. Gangue minerals, other than unreplaced fragments of country rock, are relatively uncommon. In both California and at Mountain City, the copper deposits are more distant from the major intrusive than the associated quartz veins.

NOTES ON PROSPECTING FOR ADDITIONAL COPPER DEPOSITS.

The Rio Tinto ore body is the only copper deposit thus far discovered in the vicinity of Mountain City, although the country surrounding the mine has been thoroughly covered by mining claims. The bulk of the activity thus far appears to have been expended chiefly in the actual location of the claims and the excavation required by State laws at convenient places within the claims. Locally there has been a search for a "gossan" similar to that at the Rio Tinto in the expectation that it too would be underlain by copper ore.

Some bodies of iron oxides have been found outside of the area mapped in Plate 1, but locally at least these have proved to be the result of hydrothermal alteration or oxidation in volcanic rocks which are considerably younger than the copper ore at the Rio Tinto. An exposed gossan is certainly worthy of careful prospecting but it is probable that over much of the region even large bodies of iron oxides, in which the silica content is moderate to low, would fail to crop out, except where streams have trenched through the "wash" that covers so much of the surface. Moreover, if the analogy with the Foothill Copper Belt is correct, lenses of copper ore may exist which do not reach the surface and in this case there would obviously be no outcropping gossan.

The structural relations of the Rio Tinto ore body suggest that minor faults might prove helpful in prospecting. The difficulty encountered in tracing known faults in the field, however, makes this an unpromising line of attack, although projections of faults from regions in which they are exposed might indicate concealed intersections that could be explored by trenching.

It is possible that the most fruitful method of prospecting may lie in the close investigation of the zones of silicified schist which crop out prominently in several places. The widespread silicification in the vicinity of the Rio Tinto mine suggests that the ore body of that mine has an irregular border or casing of silicified rock, which is possibly the result of the solution and reprecipitation of silica from the space now occupied by ore. If the other silicified zones in the Mountain City formation have had a similar origin, the associated ore bodies might be developed, either by trenching along the extensions of the silicified zones or by diamond drilling directed towards the downward extensions of the zones.