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Geology of the MOUNTAIN CITY COPPER MINE and MOUNTAIN CITY QUADRANGLE Elko County, Nevada

By ~~D. C. Gilbert(?)~~ E. C. Stephens

ABSTRACT

The Mountain City quadrangle is in north central Elko County, Nevada adjoining the Idaho State boundary. The Mountain City Copper mine is in the southwest part of the quadrangle, 12 miles south of the Idaho line.

Little geologic work had been done in this part of Nevada prior to 1932 when the ~~replacement~~ copper ore deposit of the Mountain City Copper mine was discovered. Surface mapping in the vicinity of the mine was begun at that time and in 1938 was extended to include the Mountain City quadrangle.

The rocks of the Mountain City quadrangle consist of granodiorite intrusive into metasediments of upper Paleozoic age and amphibolites which were formerly andesitic and dioritic rocks. There was a long interval of erosion following the intrusion of the granodiorite and steep-walled valleys were cut. Volcanics, including flows and pyroclastics, were extruded, presumably in the Miocene period, and now cover over half of the quadrangle. Gentle post-volcanic tilting occurred in the southern part of the quadrangle. Terrace gravels, stream alluvium~~s~~ and glacial deposits were formed during the ~~Recent period~~. Piracy of streams which flowed south into the Basin and Range province by northwestward flowing streams of the Columbia-Snake River system occurred during the Recent period.

The outcrop of the Mountain City Copper orebody ~~consists of~~ a rusty stained, porous mass of quartz. The ground was originally located in 1892 as a gold prospect. A short adit was driven in the gossan but as no gold was found, the prospect was abandoned. In 1919, Mr. S. F. Hunt, a prospector-geologist, recognized the gossan as being derived from copper minerals although practically no copper minerals are found in it at the surface. He developed the prospect on

sound geological principles and on February 27, 1932 discovered high grade copper ore at a depth of 215 feet below the surface. The initial crosscut workings disclosed a width of 72 feet of ore that averaged 51 per cent copper. Up to this time no copper orebodies had been found in the district. It is noteworthy that copper prices in 1932 were nearly at an all-time low.

The Mountain City Copper mine, during the years 1932 to 1947 inclusive, produced 1,162,176 tons of ore which averaged 9.745 per cent copper, 0.274 ounces silver per ton and 0.0054 ounces gold per ton.

The copper orebodies are of two types - replacement and disseminated. The replacement orebodies are lenticular and replace beds of a definite stratigraphic position in the Rio Tinto formation (upper Paleozoic). The series of beds which contains the orebodies are intensely deformed in contrast with adjoining less deformed argillaceous beds. A few altered igneous dikes are found near the replacement orebodies. The ore deposits probably had their source in emanations associated with the granodiorite which outcrops one mile to the north of the mine. The beds in the mine dip north toward the nearly vertical contact of the granodiorite. Other sulphide bodies are found in the same general series of beds that contain the Mountain City Copper replacement body but these do not contain enough copper minerals to be commercially important. The orebodies are accompanied by wall rock alteration, part of which was of consequence in localizing the supergene enrichment. The disseminated orebodies, which are of supergene origin, are found in the footwall shales adjoining the main replacement orebody.

INTRODUCTION

Location of Quadrangle

The Mountain City quadrangle comprises an area of 223 square miles in north central Elko County, Nevada between longitude 115° 45' and 116° and latitude 41° 45' and 42°. The north side of the quadrangle extends 1000 feet into Owyhee County, Idaho. The greater part of the quadrangle is included in the Humboldt National Forest. A strip of the Duck Valley Indian reservation, 3/4 of a mile in width, occupies the northwestern portion of the quadrangle.

Purpose and Scope of the Report

The huge amount of geologic work that accompanies a mining operation often is lost once the mine is closed. Records are usually kept in the files of the operating company, and sometimes these can be studied and incorporated in publications but the geologist who compiles the information is handicapped by inability to make his own field observations. Such is the situation at the Mountain City Copper mine. The mine workings are now largely inaccessible and even during the mining operation rocks were exposed for but a short time as the openings required close timbering. Progressive accumulation of underground data was required to obtain complete geologic information. Surface exposures are scant but fortunately extensive underground workings at Mountain City Copper mine allowed a detailed study of the Rio Tinto formation including its relationship to adjoining formations as well as to the orebodies.

The geology of the Mountain City quadrangle is described to supply an adequate background for the mine geology. One of the important purposes for mapping the geology of the Mountain City quadrangle was to determine what areas may be desirable for prospecting. Many interesting problems were left unfinished because they had no direct bearing on the established purpose of the work.

Field Work

During the late summer of 1932 the surface near the Mountain City Copper mine was mapped by M. B. Kildale and the writer.

The first preliminary topographic map of the Mountain City quadrangle was ready for use in 1938 and was immediately utilized as a base for geologic mapping by S. K. Droubay and the writer.

Underground mapping was a regular activity of the writer from July 1932 to November 1938. Occassional visits were made to the mine after November 1938 and the mine developments were closely followed.

Summary of Earlier Work

Little geologic work was done in the Mountain City district before 1932. W. H. Emmons visited the district in 1908 and recorded his observations in U. S. G. S. Bulletin 408 entitled "A Reconnaissance of Some Mining Camps in Elko, Lander and Eureka Counties, Nevada". According to Emmons* " ----- no geologic mapping was undertaken except that incidental to examination of the ore deposits".

In August 1932 Crawford and Frobes* published a description of some polished sections of the ore from the Rio Tinto (Mountain City) Copper mine.

In 1932 T. B. Nolan, through a joint arrangement between the Nevada Bureau of Mines and the U. S. G. S., visited the district and prepared a report** which is not published.

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* Crawford, A. L., and Frobers, 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.

** Nolan, T. B., The Mountain City Mining District, Elko County, Nevada.

Acknowledgements

Many geologists of the Anaconda Copper Mining Company and its subsidiaries worked in the Mountain City district. Their work is incorporated in the accumulated geologic data and now it is impossible to acknowledge all to whom credit is due. The writer has freely used all available information and accepts full responsibility for any errors. The notes of the original examination by Mr. R. H. Sales, the surface map of the mine area by Mr. M. B. Kildale and the writer, the general reconnaissance map of the Centennial Range by Mr. D. C. Gilbert, the quadrangle map of Mr. S. R. Droubay and the writer, the underground maps and correlation charts made by Mr. G. R. Beechel after November 1938 are but a few of the sources of information included here. The final records of the mine were obtained through the courtesy of Mr. M. B. Kildale. Mr. Tom Lyon, former Chief Geologist for the International Smelting and Refining Company, supervised the greater part of the geologic work at Mountain City. Officials of the Anaconda Copper Mining Company, particularly Mr. C. E. Weed, Vice President in charge of Mining and ~~to~~ Mr. V. D. Perry, Chief Geologist, have permitted the publishing of this paper. Mr. Jay Carpenter, director of the Nevada State Bureau of Mines and Mr. T. B. Nolan, Assistant Director of the U. S. Geological Survey, have generously allowed the writer to use Nolan's unpublished report. The writer is indebted to Mr. T. B. Nolan and Mr. M. B. Kildale for critically reading this manuscript.

PHYSICAL FEATURES

Topography

The Mountain City quadrangle is a mountainous region in which altitudes range from 5500 feet at the Owyhee River to 8789 feet at Merritt Mountain. The mountainous area continues eastward beyond Jarbidge, Nevada. North of the quadrangle is the southern Idaho volcanic and lake bed province. West of the quadrangle, in the adjoining Owyhee quadrangle, the mountains end at Duck and Chellis valleys which, topographically, are part of the Owyhee desert. The Wildhorse range in the south central border of the Mountain City quadrangle is one of a series of rugged volcanic mountains which extend southward beyond Maggie Summit and flank the higher mountains of the Centennial Range. The portion of the Mountain City quadrangle which lies southeast of the East Fork of the Owyhee River is part of the Centennial Mountain range.

The greater proportion of the mountains are well rounded.

Drainage

The quadrangle is drained by the East Fork of the Owyhee River and other streams which flow to the northwest and north and form a part of the Columbia - Snake river system.

The drainage forms an interesting barbed pattern. Creeks enter the river pointing up stream indicating that originally they drained into the Basin and Range Province to the south. The East Fork of the Owyhee River has a grade of 17 feet to the mile across the Mountain City quadrangle. Its flood plain is from 1000 feet to 1500 feet in width and during the peak run-off season a large part of the plain is covered with water. In late summer there is little water in the river. The river alluvium, which ranges from a few feet to 15 feet in thickness, contains placer gold in certain localities.

Terrace deposits are found largely on the west side of the Owyhee valley between Patsville and Mountain City. There are two terrace levels: the lower one, which is approximately 120 feet above the river, forms the flat for the

Mountain City airplane landing field; the upper terrace, which is 200 feet above the lower terrrace, forms the ridges east of the Mountain City Copper mine and north of Mill Creek.

The present stream bottoms represent, within a few feet, the greatest depth to which stream cutting has progressed since the last orogenic disturbance. The present water table is determined by the major elements of the present drainage system. The water table at the Mountain City Copper mine is at the elevation of Mill Creek directly north of the mine. Past water table levels are well marked in the gossan at the Mountain City Copper mine and indicate the progressive lowering of the table to its present position.

Accessibility

Shipping points are Elko, Nevada, which is 84 miles by road south of the mine and is on the Union Pacific and Western Pacific Railroads; and Mountain Home, Idaho which is 117 miles north of the mine and is on the Oregon Short Line Railroad.

There were two roads in 1932 that connected Mountain City with Elko, Nevada. One of these, by the way of North Fork, crossed two high summits; the other, by Deep Creek and Spanish Valley, crossed three high summits. Usually these roads were open for travel from late June to October, November or December when the winter snows arrived. Roads were of vital importance to the mining operation and the mining company cooperated with the State of Idaho, the State of Nevada, County and Federal agencies to obtain better roads. Two new roads were started in 1935, one south to Elko, Nevada and the other north to Mountain Home, Idaho. By 1938 these roads were well surfaced with gravel and in part were oiled.

A rough airstrip was constructed on the bench opposite Banner Hill and was often used during the years 1933, 1934 and 1935.

Climate and vegetation

Summers at Mountain City are characterized by hot days and cool nights. Summer showers are common and usually occur during the middle of the day. Winters are usually quite severe mostly because of strong winds. Below zero temperatures are not uncommon. In the winter of 1932-33 a temperature of 35° below zero was recorded at the Mountain City Copper mine for a period of ten days. The maximum variation in temperature during this 10 day period was 2 degrees. At the town of Mountain City and other places in the East Fork of the Owyhee River valley winter temperatures are usually from 8° to 10° lower than those at the mine. Snow is often 3 to 4 feet in depth on the level. The spring season is of short duration.

The larger creek and river bottoms are cultivated for hay. A large part of the bottom land is flooded during the heavy spring run off and commonly a thin veneer of silt is deposited on the hay land.

The area contains an abundant growth of wild grasses and sagebrush. The wild grasses are suitable for feed for cattle and sheep and a large part of the quadrangle has been placed in the Humboldt National Forest so that grazing can be regulated.

The quadrangle contains but few trees. Willows and quakenaspen are found along the larger creek and river bottoms. The area designated the Mahogenies contains an abundant growth of scrub mahogany trees. Balsam fir trees are found in the Centennial range a few miles south of the mine but these trees are not suitable for mine timber.

The type of vegetation is controlled in a large measure by the underlying rocks. For example, mahoganies are limited in distribution to certain acid volcanic flows and balsams show a preference for limestone. No detailed study has been made of the relationship of the various grasses and brush to the underlying rock types but the Mountain City quadrangle would be an ideal place for this type of study.

A thick growth of brush was found over the outcrop of the Mountain City copper orebody. The brush cover extended to the east of Copper gulch where the overburden was only a few feet in thickness and marked the extent of the gossan.

GEOLOGY

General Geology

The oldest rocks in the Mountain City quadrangle are sedimentary and metamorphic rocks of Paleozoic age. These have been segregated for convenience in mapping into the following units (from oldest to youngest):

Van Duzer limestone, Crosby formation, Copper Mountain quartzite, Copper King shale, Black Rock quartzite, Rio Tinto Formation, Banner formation, Mountain City formation and undifferentiated metamorphics which include parts of the Mountain City, Banner and Rio Tinto formations. All of the above mentioned formations are considered to be of Paleozoic age. The Jenkins Peak formation, a series of sediments which possibly may be correlative with the Banner and parts of adjoining formations, occurs in the southeastern part of the quadrangle.

Fossils found in the Banner formation were identified as being of Upper Mississippian age. The lowermost formation exposed in the Mountain City quadrangle is the Van Duzer limestone. The thickness of the Paleozoic rocks above the top of Van Duzer limestone exposed in the Mountain City quadrangle is about feet. Southwest of the Mountain City quadrangle in the Centennial Range is an apparent thickness of more than 20,000 feet of sediments underlying the base of the Crosby formation. The column is broken by faults and no accurate measurement of the section has been made. D. C. Gilbert constructed a tentative geologic column based upon his reconnaissance of the Centennial Range in 1932, as follows:

Surficial formations in the Mountain City quadrangle include terrace gravels, glacial deposits and alluvium.

The rocks of igneous origin comprise intrusives, volcanic flows and pyroclastics. The intrusives consist of granodiorite with associated dikes, and amphibolites which presumably were derived from andesites and diorites. Porphyritic dikes, such as those found in the Mountain City Copper mine, are a separate type of intrusive. A soft black amygdaloidal rock composed mostly of carbonate grains is found in the Rio Grande mine workings. This rock has been grouped with the amphibolites though, in part, it may be of extrusive origin.

The volcanic rocks consist of flows and pyroclastics, which are generally of rhyolitic composition. Petrified wood is found in ash beds north of Haystack Mountain. Hot springs with siliceous sinter occur northwest of the Peck Ranch at Devils Gate.

Rocks of Sedimentary Origin

The rocks of sedimentary origin are divided into two groups: 1.) Paleozoic age and 2.) post-Paleozoic age.

Paleozoic Sediments

Van Duzer Limestone

The Van Duzer limestone was named by the writer from Van Duzer Creek in the extreme southwestern corner of the Mountain City quadrangle. Only the upper part of this formation occurs in the Mountain City quadrangle. The formation is predominantly a bluish grey limestone, the greater part of which is well bedded. It contains argillaceous members and narrow quartzite lenses. The top of the formation is the top of the limestone series. West and south of the Mountain City quadrange this formation is exposed in the upper part of Van Duzer Creek and on Pennsylvania Hill.

Crosby Formation

The Crosby formation was named by the writer from its occurrence on the Crosby mining claims which covered a vast acreage a mile and a half south of the Mountain City Copper mine. It lies conformably on the Van Duzer limestone and consists of bluish grey, well bedded cherts with varying amounts of shale, schist and sandstone. A large amount of jasperoid is found in this formation. The Crosby formation is less resistant to erosion than adjoining formations and forms the relatively low terrain that typifies the Rocky Gulch? (Rock Creek) area. The Crosby formation is approximately 5000 to 7000 feet in thickness.

Copper Mountain Quartzite

The Copper Mountain quartzite was named by the writer from Copper Mountain, also known as Bald Mountain, which lies a mile southwest of the Mountain City Copper mine. The quartzite is generally massive, light colored, and varies greatly in thickness in different parts of the quadrangle. Its maximum apparent thickness is 2500 feet (on the hill southeast of Patsville on the east side of the Owyhee river). In places it is cross bedded. It is much more resistant to erosion than the adjoining formations and forms conspicuous ridges such as the one south of the Mountain City Copper mine and the summit of Merritt Mountain.

Copper King Shale

The Copper King shale is named from its occurrence south of the Copper King prospect east of Patsville. The rocks are predominately black and grey shales which weather to a light color. The formation attains a maximum thickness of 540 feet in Haystack Creek; although, the exposures are discontinuous and some beds may be repeated by folding and faulting. The Copper King shale conformably overlies the Copper Mountain quartzite.

Black Rock Quartzite

The Black Rock quartzite was named by the writer from its occurrence on the Black Rock claims west of the Mountain City Copper mine. The rock is a massive, dark grey quartzite that often contains white quartz veinlets. The grains are medium to coarse and are subrounded. Bedding planes are rarely seen. The thickness of the formation varies greatly but has an apparent maximum thickness of 1000 feet. The Black rock quartzite conformably overlies the Copper King shale.

Rio Tinto Formation

The Rio Tinto formation was named by D. C. Gilbert from the Rio Tinto (Mountain City Copper) mine. It is exposed in three general areas in the Mountain City quadrangle. (See Quadrangle Map). One exposure can be traced from the western limit of the quadrangle for 5 1/2 miles easterly to the head of Haystack Creek where it is lost beneath volcanics. Another exposure is at Merritt Mountain and a third exposure lies approximately 5 miles north of Merritt Mountain; the repetition is due to faulting.

It is composed of shales, schists, slates, quartzite lenses, argillites, cherts, and conglomerates. The shales, which are black, alternately light and dark, and light grey, grade into schists and slates. The line of the demarcation between a shale and a schist has been drawn on the basis of field evidence; that is, when bedding is a recognizable and predominant feature of the rock, it is called a shale and when schistocity or cleavage obscures the bedding, the rock is called a schist or slate.

The formation is less resistant to erosion than adjacent formations and the argillaceous rocks are easily converted to soil. As a result surface exposures are few.

An enormous amount of detailed information on the Rio Tinto formation has been mapped on a scale of one inch equals twenty feet in the Mountain City Copper mine underground workings. Units of the formation vary in thickness rapidly, and numerous faults and complicated tight folds make any measurement of total thickness an approximation useful only for the particular locality in which it is made. Careful thickness calculations of the formation in the mine area show a maximum of 2085 feet. In the Merritt Mountain area the Rio Tinto formation contains units that are not found in the Mountain City Copper mine area. Detailed columns compiled for the mine area illustrate local variations of the formation.

A considerable proportion of the Rio Tinto formation shales have been converted to a schist in which sericite is abundantly developed. Quartz also is an important constituent of the rock. Nolan* reports that locally tourmaline, green hornblende and other minerals are found in small quantities.

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* Nolan, T. B., op. - cit.

The Rio Tinto formation conformably overlies the Black Rock quartzite. This contact is well exposed underground on the Mountain City Copper mine 300 level. The basal unit of the Rio Tinto formation is 145 to 300 feet of dark grey, thin-bedded chert.

Other details of the formation will be discussed later under the heading Mountain City Copper mine.

Banner Formation

The Banner formation was named by D. C. Gilbert from its occurrence at Banner Hill. It is composed of limestones, sandstones, conglomerates, quartzites and minor amounts of schist. It unconformably overlies the Rio Tinto formation. The units vary greatly in thickness and it is not uncommon for a unit to disappear in a short distance. The limestone is the most conspicuous member of the formation at the surface. Where it lies near the granodiorite, it contains an abundance of lime silicate minerals. There is a wide silicate zone on Banner Hill which contains a small amount of molybdenite and scheelite. Garnet, epidote, white mica, tremolite, actinolite, chiastolite and other silicates are common constituents in the silicate zone.

A section of the lower part of the Banner formation was obtained in the underground workings at the Rio Grande mine. Here the sequence, from oldest to youngest, is: 1.) Conglomerate composed mostly of angular to subrounded shale and some limestone fragments with occasional rounded quartzite boulders. Thickness 143 feet.

2.) Brownish sandstone; grains medium to fine, subangular to rounded. Thickness 163 feet.

3.) Limestone: arenaceous in the lower 100 feet grading upward into a soft massive bluish grey limestone. Thickness 250 feet - top of formation not exposed.

Calculations from cross sections in this area give an estimated thickness of Banner formation slightly more than 1100 feet. These sections contain a gap of 500 feet where the formation is covered with alluvium and soil. Approximately 3 miles north of the McDonald mine, the Banner formation is much thicker than it is at the Rio Grande location but no reliable continuous section that would allow for accurate measurements is exposed.

A collection of fossils made by M. B. Kildale, T. B. Nolan and the writer from a pit a short distance east of the Rio Grande shaft stratigraphically near the base of the limestone member mentioned above in the Rio Grande mine section was submitted by Mr. T. B. Nolan to Mr. C. H. Girty. He reports*,

"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 specie of Campophyllum or Cyathophyllum, and the other fossil, as just remarked, to represent a species of Productus. It would be easy to over estimate 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

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* Nolan - op. cit.

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."

Mountain City Formation

The Mountain City formation was named by D. C. Gilbert from its occurrence at the Mountain City mine which lies approximately a mile north of Mountain City Copper mine. It occurs in four localities in the Mountain City quadrangle. (See quadrangle map). The rocks comprising this formation are predominately schists and quartzites. The lower members of the formation are usually calcareous schists followed by dark siliceous schists. North of the Mountain City granodiorite mass a large part of the undifferentiated metamorphic rocks are probably the lower member of the Mountain City formation. The lower rocks of this formation consist of knotty mica schists and intercalated quartzite layers. The rocks overlying the schists to the north are predominately quartzites.

The Mountain City formation lies close to the intrusives and has been intensely metamorphosed. Originally it was derived from sandstones; carbonaceous and calcareous shales.

Nolan* describes a part of the formation in the vicinity of the Mountain City mine as follows: "The siliceous schists are fine grained dark grey to black rocks except where bleached by the quartz monzonite, and show 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

* Nolan - op. cit.

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 tremolite. The quartzite rocks, when studied microscopically, are seen to be metamorphosed calcareous sandstone. They are fine-grained rocks that are pale greenish or bluish grey on fresh fracture, weathering to cream color but are locally colored by iron oxides. In this section they are seen to contain considerable quantities of diopside and tremolite in addition to the quartz and alkali feldspar found in the schists."

Although a minimum of 4000 feet of beds are present, the upper part of the Mountain City formation is not exposed in the Mountain City quadrangle as either abuts against an intrusive rock or is covered by volcanics. It conformably overlies the Banner formation and is presumably also of upper Mississippian age.

The Jenkins Peak Formation

The Jenkins Peak formation was named by the writer from its occurrence at Jenkins Peak in the extreme southeastern part of the Mountain City quadrangle. Here the beds stand on end and some may be duplicated. These rocks are conglomerates, quartzites, sandstone, arenaceous limestones, limestones, schists and slates. On the north side of Jenkins Pead the arenaceous limestones and some of the limestones have a light purple color. The conglomerates are of two types; dark chert and quartzite pebbles cemented with silica, and angular to semi-rounded limestone fragments cemented with arenaceous limestone.

Fragmental fossils were found in one of the limestone beds but these were not identified. It is possible that a large part of the Jenkins Peak formation may be the equivalent of the Banner limestone.

Post-Paleozoic Sediments

Terrace Gravels

The greater part of the terrace gravels are on the west side of the Owyhee River. Two terraces are present, the upper one being by far the more extensive. The gravels consist largely of rounded quartzite boulders. The size of the boulders rapidly decreases to the east which, together with the gentle eastward inclination of the upper terraces toward the Owyhee River indicate that they were derived from the west.

Alluvium

The Owyhee River and the larger creeks and valleys have a flat floor on which Recent alluvium is deposited. Trenches and pits in Mill Creek and the Owyhee River near Patsville and between Patsville and Mountain City indicate that the alluvium is rarely more than 15 feet in depth.

Glacial Deposits

Glacial deposits are found in the southeastern corner of the quadrangle at Sunflower Flat. The glacial material contains boulders of a granitic rock resembling the Tennessee Mountain intrusive that lies 5 miles to the northeast in the adjoining Rowland quadrangle.

Rocks of Igneous Origin

Amphibolite

The rocks grouped under the term amphibolites are of a green to black color and are fine to coarse textured. They outcrop in three general areas in the quadrangle - north of Mill Creek, north and northwest of Merritt Mountain and in the east half of the northern part of the quadrangle.

Five specimens numbered 138, 138a, 183, 183a and 178 were sent to Mr. Charles Meyer of the Anaconda Copper Mining Company, Geological Laboratory at Butte, Montana for petrographic descriptions. Numbers 138 and 138a, which are from the area north of Mill Creek are discussed by Meyer as follows:

"Except for grain size, these two specimens are similar. Both are now holocrystalline rocks in which a low-birefringent blue-green-yellow pleochroic monoclinic hornblende or Na - amphibole is the dominant constituent. Plagioclase of approximately calcic oligoclase or sodic andesine composition (judging from refractive index) is also abundant - in 138 as a matrix to the shafts of hornblende, and in 138a both in the latter capacity and as large twinned and altered subhedrons. The larger amphibole crystals in 138a poikilitically enclose the quarfeloids in such a manner as to suggest that they are growing at the expense of these inclusions, to produce the low birefringent (Na-rich?) amphibole. Or, they may have altered from pyroxene which thus originally enclosed the feldspars in the diabasic texture.

"Secondary biotite, aggregated into irregular and occasionally elongated clumps of small anhedral grains, is a prominent constituent of specimen 138 and to a lesser extent to 138a. These clumps are megascopically visible in 138. They probably represent recrystallized phenocrysts of unknown original composition. A few biotite granules are scattered throughout each rock, also. Zoisite is conspicuous - apparently forming directly from plagioclase.

"Amphibolite is an acceptable name for these specimens, especially since it is not prejudiced with a mode of origin. According to Johannsen's quantitative mineralogical classification these specimens (in their present compositions) would be descriptively called mela-andesites since the plagioclase is sodic and the mafites outstrip the quarfeloids quantitatively. It may have been a straight andesite originally if the amphibole (or part of it) is an alteration product of the plagioclase. The large white phenocrysts now visible in 138a are plagioclase residuals."

Concerning Specimen 183 which is from a coarse black intrusive northwest of Copper Mountain in the northwest part of the quadrangle, Meyer states: "This specimen might also be called an amphibolite, or an amphibole-chlorite schist. The large amphibole grains show an irregularly interlocking coarse intergrowth of two amphiboles; brown-green pleochroic hornblende of intermediate birefringence and a higher birefringent colorless fibrous amphibole, probably tremolite. The ends, and to a lesser extent, the sides of the amphibole crystals are frayed through extensive replacement by fine-grained nearly colorless chlorite - which mineral now comprises a groundmass to the large amphibole grains. It is possible that the fibrous amphibole may constitute a kind of intermediate alteration stage in the conversion of hornblende to the colorless chlorite."

Meyer reports on Specimen 183a, which is from a fine textured dark grey intrusive northeast of Copper Mountain, as follows: "This specimen is a finely granular holocrystalline rock consisting of approximately equal amounts of amphibole and plagioclase. The amphibole appears to be a member of the hornblende series having intermediate birefringence and yellow-green-blue pleochroism. It is generally grouped in clusters of fine grains and shafts, some of which jut into the plagioclase grains. These may be alteration products of original pyroxene, though none of the latter mineral is now present. Judging from refractive index, the plagioclase appears to be in the low andesine range. Subhedral tabular to prismatic habit is characteristic of the plagioclase, though swarms of inclusions (replacements) and marginal corrosion by hornblende make this inconspicuous at first glance.

"A small amount of chlorite after hornblende, and zoisite after plagioclase, alteration is noticeable.

"This rock is undoubtedly an altered andesite or fine grained diorite, depending on whether or not the original fermags were macrocrystalline or not."

Specimen No. 178, which is from a dark intrusive at Little Salmon Creek, is described by Meyer:

"This is also an amphibole-plagioclase rock containing a minor quantity of quartz (which may have been introduced). Two amphiboles are again present. The cores of some of the larger grains appear to be hornblende, but their margins are altered to a stronger birefringent fibrous variety. Spicules of this fibrous amphibole are also scattered about in the plagioclase with a tendency toward preferred orientation and radial grouping. The fibrous amphibole is pleochroic in blue-green and has moderate to strong birefringence. It may be actinolite.

"The plagioclase is andesine, as in the foregoing specimens. It is doubtlessly an original constituent, and the original femag may have been pyroxene. Locally, plagioclase shows a considerable alteration to a nearly colorless, highly birefringent and refractive mineral with 2V nearly 90%, negative optical character, and strong dispersion. This is probably a variety of epidote.

"Altered and amphibolized andesite (or mela-andesite) is probably the most appropriate name for this specimen."

A soft dark rock of igneous origin is found in the Rio Grande mine workings and in diamond drill holes south of Mill Creek. This rock appears to have intrusive relationship to the Banner formation and is well exposed in the Rio Grande underground workings. The phenocrysts often contain native copper and cuprite as well as calcite. A specimen of this rock (one which contained no cuprite or native copper) was submitted to Mr. Meyer who returned the following description:

"There are no microscopic criteria in this highly altered specimen which might be used to corroborate its origin as a flow rather than as an intrusive, or vice-versa. The megascopically visible phenocrysts are almost entirely altered to porous carbonate (suggestive of high Ca content originally?). Surrounding many of them is a thin skin of chlorite. The groundmass to these phenocrysts is now at least microcrystalline, though owing to its highly altered condition - with much carbonate, epidote, (secondary ?) biotite, and smaller amounts of chlorite - it is impossible to state definitely whether or not it was originally glassy. Its present even granularity suggests microcrystallinity rather than glassy texture originally as well as presently. The rock was probably andesitic (or latitic) in original composition."

Granodiorite

One relatively small and three large masses of granodiorite are exposed in the Mountain City quadrangle. The largest of these is the Mountain City granodiorite which has a maximum width of four miles and a length of nine miles within the quadrangle. The long dimension is west and it extends west into the adjoining Owyhee quadrangle.

North of Merritt Mountain is the Clover Creek mass which has a maximum width of two miles and a length of nine miles. The long dimension strikes easterly and the intrusive extends eastward for a short distance into the adjoining Rowland quadrangle.

The northernmost mass, the Cottonwood Creek intrusive, which crops out in Little Salmon and Cottonwood Creeks is covered to a large extent by volcanics. The north-south dimension of this intrusive is greater than four miles and it continues north beyond the limits of the quadrangle into Idaho. The Enright Hill intrusive has a maximum dimension of less than a mile.

Four specimens of these acid intrusive rocks were submitted to the Geological Laboratory of the Anaconda Copper Mining Company at Butte, Montana for petrographic descriptions and Mr. Meyer returned the following report.

"Nos. 193, 177, 177a, 178a - From intrusives northeast of Huber Hills, Pixley Creek, Nigger George Draw and Little Salmon Creek, respectively.

"The four specimens of granitic rock cited by the above numbers show the following volumetric mineralogical percentages as calculated from integrating stage traverses of one thin section from each locality:

Mineral	193	177	177a	178a
Quartz	33%	22%	22%	16%
Orthoclase	12%	13%	11%	24%
Plagioclase - Average approx. An_{43}	48%	55%	62%	53%
Biotite	3%	9%	4%	1%
Hornblende	4%	1%	1%	6%

"Sphene and apatite are the principal accessories. Some amphibole (especially in 177 and 177a) is altered to secondary biotite. Alteration of calcic zones in plagioclase to epidote (plus some zoisite) and to montmorillonite type clays is notable in 193 and 177a, and to a lesser extent in the other two specimens. A little chlorite has formed from hornblende principally.

"High plagioclase content - near or over the 50% line, is characteristic of all the specimens. It ranges from 2/3 to 5/6 of the total feldspar. Judging from combined albite-carlsbad twins, the composition of the plagioclase averages about An_{30}, near the border between oligoclase and andesine.

"Orthoclase and quartz total between 30 and 40% in each specimen: Ferromagnesians are 10% or less by volume.

"According to the Johannsen quantitative mineralogical classification of rocks all these specimens would fall in the category designated as granodiorite, though specimen 178a barely makes it over the line from quartz monzonite (2/3 of total feldspar is plagioclase). 177a is a good granodiorite."

The greater part of the granodiorite is coarse textured. A border facies which is characterized by the scarcity of dark minerals, is extensive in the Mountain City, Clover Creek, and northernmost masses. The border facies is absent in some localities but often attains a width of 500 feet. Aplite dikes are numerous, especially near the margins of the intrusives. Pegmatite dikes are especially abundant in the part of the Mountain City granodiorite in California Basin and the Granite Ridge area. The pegmatites consist of quartz or feldspar or both.

Porphyry dikes

A few porphyry dikes are found in the quadrangle. Some are found in the Mountain City Copper mine where they are highly altered and their porphyritic texture obliterated by the alteration. The dikes in the mine are pre-ore and are displaced by the faults.

Volcanic Rocks

Volcanic rocks cover more than one half of the Mountain City quadrangle. They consist of porphyritic and felsitic flows, glasses, fine textured tuffs, and coarse textured agglomerates and breccias. Colors of the porphyritic rocks are purplish, dark grey and white; the felsitic rocks are dark grey or red; the tuffs are white, cream or green and the glasses are black to dark grey. They are generally rhyolitic in composition.

The volcanic rocks at Mountain City were extruded over an area of subdued relief composed of tilted Paleozoic sediments and later intrusives in which dissection had commenced and steep walled valleys existed. The pre-volcanic drainage is unrelated to present drainage.

Regional Structure

The greater proportion of the Paleozoic sedimentary rocks in the Mountain City quadrangle dip north. This homoclinal structure extends to the southwest beyond the quadrangle to Bluejacket Creek on the north side of Bull Run Mountain, where it becomes involved in the folded structure of Bull Run Mountain. Intrusive into the Paleozoic sedimentary rocks are amphibolites, which formerly were andesitic and dioritic rocks, and granodiorite. The andesitic and dioritic intrusions either accompanied or preceded the tilting of the sidiments. The granodiorite intrusions are later than the tilting. The larger granodiorite intrusives are elongated in a westerly direction. They usually have steep dipping south contacts and relatively gentle north dipping north contacts. Certain formations of the Paleozoic series are repeated in three belts which are separated by granodiorite intrusives. The repetition of the formations and the attitudes of the granodiorite contacts allows for the hypothesis that the emplacement of the larger intrusive masses may have been controlled by early east striking, north dipping faults.

The westerly elongation of the larger granodiorite masses, the relative abundance of larger granodiorite masses across the Mountain City quadrangle and easterly beyond the quadrangle in the Rowland quadrangle and at Contact, Nevada, and the amount of structural disturbance in this west trending belt west from the Raft River Mountains in Utah is highly suggestive that the belt is a westerly continuation of the Raft River uplift.

A series of large faults, which range in strike from north 70° west to north 30° east, displace the Paleozoic rocks. The more conspicuous faults of this system strike north to north 30° west. In the Mountain City quadrangle they are found in the two larger areas of Paleozoic sediments - one in the southwest part of the quadrangle and the other in the central area by Merritt Mountain. Some of the faults in the southwest part of the quadrangle extend beyond the map-area to the south and are part of the prominent fault system that strongly influence the topography of the Centennial Mountain Range. Many of the large faults have horizontal displacements to the left and for this reason the ridge line of the Centennial Range has a northeasterly trend. These faults were not observed displacing the granodiorite. They are earlier than the volcanics although, in a few locations, the faults were traced for a short distance into volcanic rocks. Faults of this system in the Mountain City Copper mine are post-mineral.

The Mountain City quadrangle lies at the junction of a generally north trending fault system that characterizes the larger structural features of the Basin and Range region to the south and the west trending structures that may be the westerly continuation of the Raft River uplift of Utah.

Development of Topography

The tilting of the Paleozoic series was either accompanied or preceded by the intrusion of andesitic and dioritic rocks which later were converted to amphibolites. During the orogenic disturbance, which resulted in the tilting of the Paleozoic sediments, west striking, north dipping faults developed. It is believed that the emplacement of the granodiorite was controlled by these faults. Following the intrusion of the granodiorite a topography of generally subdued relief developed. The entire quadrangle at that time may be classed as a matureland with two relatively high centers, the Merritt Mountain area the the present higher elevations of the Centennial Range. Dissection of the matureland had commenced and steep-walled valleys were cut at the time the volcanics were extruded. The pre-volcanic drainage is not related to present drainage. The volcanics filled in areas of lesser relief. Although a large part of the volcanics are stripped from the areas which surround the higher latitudes of the present mountains, remnants are found at altitudes of 7000 feet in the Centennial Range and 7900 feet at Merritt Mountain.

Following the extrusion of the volcanics the drainage was to the southeast into the Basin and Range Province and the major elements of the present drainage system were formed. The gentle tilting to the south of the south-central portion of the quadrangle ponded the runoff into a lake and terrace gravels were deposited from the west toward the river. The accumulation of gravels was ended by the encroaching streams of the Columbia-Snake River drainage system. The condition of extreme seasonal runoff has allowed for the accumulation of alluvium.

ORE DEPOSITS

The ore deposits of the Mountain City quadrangle are of two distinct types; veins in granodiorite and adjoining metasediments which are valuable for their silver content and massive sulphide replacement bodies in the Rio Tinto Formation which are valuable for their copper content. Associated with the latter are disseminated chalcocite masses of supergene origin.

Silver Veins

The silver vein mines were dormant during the years 1932 to 1938 when some of the workings were visited by the writer but no comprehensive study was made of this part of the district. At the present time work is reported to be in progress at the Protection mine.

Emmons'* description of these vein deposits follows:

"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 prevaling dip being toward the south.

"Some of the veins, as shown on California Hill, are later than the

* Emmons - op. cit.

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 little chalcopyrite. All of the ore is highly siliceous, quartz constituting as much as 90 per cent of the rock. The oxidized ore is composed of quartz, chalcedony, horn silver, pyromorphite, iron oxides, native gold and silver, lead carbonate, copper 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 the granite 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 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 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 inacessible 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 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 show 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 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 orebody 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 oxide, copper carbonates, and silicates, and 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."

Sulphide Replacement Bodies in Rio Tinto Formation (Mountain City Copper Deposit)

Location. The known deposits of copper ore in the Mountain City district are in the Mountain City Copper mine workings. The mine is south of Mill Creek in the southwestern part of the Mountain City quadrangle in section 11, T. 45 N., R. 53 E., M. D. M.

History. The early history of the district is given by W. H. Emmons (U.S.G.S Bulletin 408) to quote: "The 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 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 to 1932 little mining was done at Mountain City and production was negligible.

The history of the discovery of the Mountain City Copper mine is essentially that of S. F. Hunt from the years 1919 to 1932. Hunt was first attracted to the district in 1919 when the Duck Valley Indian Reservation was opened to the public for mineral locations. A small rush took place and, according to Hunt, he arrived too late to locate any claims as the entire southwestern part of the Indian Reservation was covered with new locations.

After spending a week or so in the reservation Hunt had satisfied himself of its lack of ore possibilities. Before he left the district, however, he investigated the Copper Gulch area which lies a mile and a half south of the Reservation. Local people told Hunt that the gulch received its name from a boulder of copper ore and that he could go there and see it. He found the boulder which contained a small amount of malachite, after which he walked up the gulch for a few hundred feet where he found an old dump of brown and yellow gossan from an adit that had been driven during the 1890 decade by the McGinnis brothers, local ranchers who were prospecting for gold. They had diverted the creek with a small flume and ground sluiced a few scars of the east side of the gulch. The tunnel was driven on the west side of the gulch where the gossan cropped. The McGinnis brothers failed to find gold and abandoned the claims.

Hunt stated that his uncle had once shown him specimens of gossan from the Rio Tinto copper deposits in Spain and the rocks found in the Copper Gulch dump bore such a marked resemblance to the Rio Tinto rocks that he called his claim the Nevada Rio Tinto.

After locating the property, Hunt interested Vivian P. Strange, a Salt Lake City, Utah contractor who agreed to supply money to develop the prospect for a three quarters interest. Hunt returned to Mountain City yearly and performed the annual assessment work. He built a churn drill rig and drilled one hole 135 feet in depth, and sank a shaft 73 feet in gossan. Strange then hired a reputable geologist from Salt Lake City, who visited the property with Strange and Hunt. The geologist recommended to Strange that the property be abandoned as it was a worthless prospect and Strange severed his partnership with Hunt. Hunt sought to interest most of the larger mining companies in the Salt Lake region in his property but failed. At the same time he sent specimens of the gossan to mining men and geologists in the southwest and in San Francisco who were familiar with copper deposits. The replies he received stated that the specimens did not represent a capping of a copper orebody and that the location of the property was too remote to warrant an examination. Hunt informed the writer that only one mining man, Reno H. Sales, offered him encouragement. Sales, who happened to be in Salt Lake City one winter when Hunt was making the rounds of the mining offices with his little sack of gossan specimens, advised Hunt to keep digging until he determined what the underlying sulphides were. Hunt did not forget the interview with Sales and it was this circumstance that allowed the Anaconda Copper Mining Company to make the entering purchase of stock in the Rio Tinto company from Hunt. Failure to get action from any of the established mining companies led Hunt to seek help for financing his prospect from Ogden C. Chase, a mining stock promotor in Salt Lake City. Chase formed the Rio Tinto Mining Company and mailed stock certificates to a list of prospective buyers along with a prospectus. If the prospective buyor wished to own the stock he was to pay five assessments of one cent per share. This stock was later transferred, share for share, for

Mountain City Copper Company stock which at one time sold for $17 a share. The prospectus contained a prediction by Hunt that a large body of 20 per cent copper ore would be found in the shaft at a depth of 225 feet below the surface. As a matter of record, ore assaying 50 per cent copper was encountered at 215 feet (vertical distance).

The total amount of money spent on the property from the time Hunt located it in 1919 until ore was found in 1932 amounted to less than $7000.

Many people, besides Hunt, had an important part in finding the ore. Ogden C. Chase, the promotor, his brother George, and his brother-in-law, Percy Christopherson, actually performed the manual labor to sink the prospect shaft from the depth of 73 feet to 242 feet, where ore was found. Jack and Walter Davidson, who ran the general store at Mountain City, put all of their money into the property and supplied the prospectors at the mine with food and materials so that they could keep working. Other local people including George Nelson, George Irland and Pat Maloney helped do the work and gave encouragement to the miners. Mrs. George Nelson gave Mr. Hunt board and room during the years Hunt performed the annual assessment work.

Production. The silver production of the Mountain City district up to 1908 is given as approximately $1,000,000 by Emmons*. From 1908 to 1938 the silver production was negligible. No figures are available for the small silver production since 1938.

Placer gold production of the Mountain City district amounted to less than $150,000 of which $100,000 is reported to have come from Van Duzer Creek. No figures are available on the minor gold production from lode deposits.

Production of the Mountain City Copper mine are as follows:

* Emmons - op. cit.

	Wet Weight Tons	% Moisture	COPPER Per Cent	COPPER Pounds	SILVER Ounces Per ton	SILVER Ounces	GOLD Ounces Per ton	GOLD Ounces
Ore Shipped * (1932 through 1947)	182,340.263	2.905	26.112	92,460,238	0.457	80,890.19	0.0071	1,256.780
Ore Milled ** (1936 through 1947)	979,836.020	4.797	6.639	123,865,822	0.239	223,408.58	0.0054	5,070.928
TOTAL	1,162,176.283	4.500	9.745	216,326,060	0.274	304,298.77	0.0057	6,327.708

* Figures obtained from actual smelter weights and assays.

** Figures calculated from "Poidometer" installed in mill.

Outcrop. The Mountain City Copper mine main orebody crops out in Copper Gulch, a branch of Mill Creek. The wall rocks are shales, schists, and quartzite of the Rio Tinto formation. At the surface the shales and schists are light grey and the quartzite is medium to dark grey in color. The few quartzite beds are lenticular and have a maximum width of 12 feet.

A large proportion of the surface is covered and structural features are obscure. The gossan is exposed in cuts on the west bank of the gulch and west of the collar of the No. 1 shaft. It consists of a porous mass of iron oxides and quartz. The colors are brown, yellow-brown, maroon and brick red. A few feet southwest of the main outcrops are thin isolated blocks of dark red and brown stained, banded quartz. These give the erroneous impression of a northeasterly strike of the orebody. The banding in the isolated blocks strikes northwest and dips from 50 to 70° north. Separation of the blocks is the result of minor north striking faults.

The gossan was well exposed by a pit in the bed of the gulch. Here a few specks of malachite were observed.

On the east side of the gulch a road cut exposes a southeast trending silicified schist zone which is from 3 feet to 5 feet in width. Northeast of the silicified schist outcrop the excavation for the ore bin for the No. 2 shaft exposes the gossan. Trenches in the vicinity of the present mine yard show narrow streaks of gossan and quartz. The schist in the trenches contains specks of malachite, azurite and cuprite.

It is noteworthy that Hunt laid out his claims on the basis of a detailed study of the meager surface information and that later underground development of the orebody showed the claim to be perfectly situated to cover the orebody.

The Oxide Zone. Minerals found in the oxide zones are quartz, goethite, malachite, azurite, cuprite, native copper, and chrysocolla.

The oxide zone extends from the surface to the 200 level which is 215 feet vertically below the collar of the No. 1 Shaft. The bottom of the oxide zone is usually within a few feet of the 200 level track (elevation , mine datum) but it ranges from elevation to . A good section of the oxide zone is exposed in the No. 1 Shaft from the surface to the 200 level. From the surface to a point 9 feet above the 200 level track, the gossan is a porous mass of quartz, iron oxides and yellow-brown mud. It contains an occasional moist area but is normally dry. The brown mud usually lies in flat streaks from 6 inches to 3 feet in thickness. Often the mud is banded in a wavy pattern and contains angular gossan fragments. From 9 ~~feet above~~ to 20 feet above the 200 level, the gossan contains flat lying bands from 6 inches to 18 inches in thickness of massive brown iron oxides and quartz which mark former water table levels. The line between the massive sulphides and the oxide is sharp and not more than 6 inches in thickness. The water table was found at the 200 level track elevation.

The transition from the oxide zone to the sulphide zone varies in other parts of the mine. In the extreme west end of the mine, the capping above the "banded ore" type sulphide zone, which will be described later, consists of banded quartz containing small vugs but iron staining is absent. In other parts of the mine to the west of the No. 1 Shaft the lower part of the oxide zone, which attains a maximum thickness of 20 feet, contained sufficient malachite, azurite, cuprite, native copper and residual fragments of sulphide to constitute shipping grade ore.

Sulphide Zone. Minerals of the sulphide zone are: quartz, pyrite, chalcopyrite, (covellite,) bornite, sphalerite, clay minerals and chlorite. A small amount of galena was found in one veinlet near the orebody on the 700 level. Some native copper and cuprite are also found in the shale wall rocks, 200 feet below the top of the water table.

Supergene enrichment in the Mountain City Copper deposit usually extends 125 feet below the base of the oxide zone with occasional prongs extending to a maximum depth of 175 feet. The supergene copper minerals are sooty chalcocite and covellite. In no place was chalcopyrite found to be a supergene mineral. Pyrite, however, is a supergene mineral in some places. For example, in the 200 level drift east from the No. 1 shaft, the top of the sulphide zone contains from a foot to three feet of loose fine pyrite. Loose pyrite was found immediately below the oxide zone in three winzes, which were sunk from the 200 level to the sulphide zone between the No. 1 and No. 2 shaft. The pyrite contained no copper and when the first of the three winzes entered the pyrite, the first impression was that the orebody in this area consisted of pyrite only. With six feet additional depth, however, chalcocite - chalcopyrite ore was found. Later, when stoping between the 300 and 200 levels, many places were found where prongs of the loose pyrite, devoid of any copper minerals, penetrated the ore for depths as great as 45 feet below the 200 level.

Chalcocite is by far the most abundant supergene mineral. Usually it is of the sooty variety. It replaces both chalcopyrite and pyrite. In places chalcite has replaced chalcopyrite veinlets enclosed in pyrite while in other instances the pyrite enclosing the chalcopyrite has been replaced. The lesser abundant massive variety of chalcocite is believed to be essentially the result of the replacement of chalcopyrite.

Chalcocite often is found in voids where no sulphides previously existed. It also occurs in shale where it certainly is not a replacement of sulphide minerals. At one time it was thought that carbon may have been the cause of the chalcocite forming in the shales but an analysis of the shales for carbon failed to show an increased carbon content in the beds that contain the chalcocite.

Covellite is less abundant than chalcocite. In the specimens examined by Crawford and Frobes*, they state: "It is a replacement product of chalcocite, and in Figure 3 is shown as developing in the central portion of chalcocite veinlets." They also note that the chalcocite has a decidedly bluish color and is difficult to distinguish from covellite except by the use of polarized light. Covellite is often found on the margins of chalcopyrite between the chalcopyrite and chalcocite.

Bornite is found in relatively small quantities and is believed to be of hypogene origin.

<u>The Massive Replacement Type Orebodies.</u> There are two distinct types of orebodies in the Mountain City Copper mine, the massive replacement and the disseminated types.

The massive replacement orebodies are lenticular deposits in the Rio Tinto formation. The contact between ore and wall rock is sharp. The long dimensions of the orebodies are parallel to the bedding. The tapering ends are irregular and often the contact between the ore and wall rock cuts across at an angle to the strike of the beds or schistocity.

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* Crawford and Frobes - op. cit.

Six distinct ore types are found in the replacement deposits. These are:

1.) Massive pyrite - quartz
2.) Dark grey quartz
3.) Replaced quartzite
4.) Banded quartz
5.) Massive sulphide
6.) Altered shale

The massive pyrite-quartz type usually forms the hanging wall layer of the orebody. The rock is hard and massive and is relatively less susceptible to supergene enrichment than the other three principal ore types. The pyrite is dense and is intimately mixed with the quartz. Chalcopyrite is finely scattered in the rock and its copper content in the hypogene zone seldom is greater than 10 per cent. Often this ore type contains a small proportion of sphalerite.

The dark grey quartz ore-type is a massive to banded rock in which the bands are from 3 inches to 8 inches in thickness. Often it contains streaks of the adjoining white banded quartz type and the contact between the dark grey quartz and the banded ore types is gradational. Pyrite, chalcopyrite, and supergene copper minerals are found as blobs, streaks and irregular patches.

The replaced quartzite ore constitutes but a small part of the orebody. The quartzite is a dark massive rock with a relatively few tiny discontinuous cracks in which there are quartz-pyrite-chalcopyrite veinlets. In the supergene zone the pyrite and chalcopyrite are replaced with chalcocite. The quartzite ore contains less copper than other ore types and seldom assays more than 5 per cent copper.

The banded quartz type usually has a high copper content. The bands range from a quarter of an inch to two inches in thickness and usually strike at an acute angle to the strike of the orebody. The banding in most places does not follow the strike of the orebody and is interpreted by the writer as being controlled by shear phenomena rather than by direct replacement of contorted beds. The bands represent an early silicification. Cutting the bands are tiny veinlets of glassy quartz with pyrite and chalcopyrite. The tiny veinlets criss-cross in all directions and often branch. The largest veinlets are a half an inch in thickness but more commonly are from a sixteenth to an eighth of an inch. The glassy quartz is the earliest mineral followed by pyrite and later by chalcopyrite. The rock usually is loose and broken and is ideal for supergene enrichment. The banded quartz type forms a belt overlain by the dark grey quartz ore type and underlain by the massive sulphide or altered shale types. Copper content in the supergene zone often is from 35 percent to 55 per cent.

The massive sulphide type contains chalcopyrite, chalcocite, covellite, bornite, pyrite, and quartz. The pyrite is relatively coarsely crystalline in contrast with the dense pyrite in the massive quartz-pyrite type. It occurs at the top of the sulphide zone and in the footwall portion of the orebody overlying the altered shale type. The massive sulphide types usually contain from 25 per cent to 55 per cent copper.

The altered shale ore type on the footwall of the orebody contains scattered pyrite which often is replaced with chalcocite in the supergene zone. The proportion of this type of ore to the total is small.

The distribution of the ore types accounts for the development of some internal structures of the orebody; for example, loose, open zones often developed in the brittle banded ore and formed the control for the richer supergene area. During the mining of the orebody differentiation between ore types was important because ore was classified as either mill ore or direct shipping ore according to the metallurgical properties of the individual ore type as well as its grade.

The hanging wall contact of the orebody with the wall rocks is sharp and often is a narrow clay selvage. The footwall contact, which is usually between massive sulphide ore and altered shale, is commonly accompanied by a wide zone of shearing.

The Disseminated Orebodies. Disseminated ore occurs in the shales which lie in the footwall of the orebody where the impervious altered shale is absent in the hypogene orebody or where the continuity of the impervious footwall is broken by faults. The largest disseminated area lies south of the east end of the main replacement orebody. Chalcocite and, to a less extent, cuprite, native copper, malachite and azurite is disseminated in black and alternating dark and light shales for horizontal distances as great as   feet from the massive replacement body. Rods of dark quartz or silicified shale, 1 inch by 2 1/2 or 3 inches in cross section, contain relatively large amounts of copper minerals. These rods are usually arranged with their long dimension vertical or steep and lie between bedding or schist planes. The shales of the Rio Tinto formation contain a scattering of pyrite which is either syngenetic or the result of dynamic metamorphism. Some of the pyrite is replaced by chalcocite or its oxidation products in the disseminated ore areas. Most of the chalcocite, however, is disseminated through the shales and apparently deposited without the aid of a pre-existing sulphide.

Alteration. The replacement bodies are found in a definite series of beds in the Rio Tinto formation. No microscopic study has been made of the alteration. In the footwall of the orebody is a highly altered shale composed of clay minerals and chlorite with a scattering of pyrite. The hanging wall beds lack the intense alteration that is found in the footwall beds. However, the entire series of ore beds has been altered near the orebodies. The shales are altered to a schist with slickensided surfaces and with a development of dark green chlorite. The schist, in places, breaks with a fracture that looks like wood and the rock has been termed "Woody" to describe this feature. The development of the alteration schist is gradational - the rock progressively passing from a shale in which the bedding planes are well preserved to a rock in which the chloritic or other dark alteration minerals penetrate bedding planes and joint cracks transverse to bedding planes, to a schist in which all traces of bedding are obliterated. Fading of the wall-rock alteration is well exposed laterally and vertically. It is especially well illustrated in the workings below the "600" orebody on the 700 level and in the raise to the bottom of the "600 orebody" from the 700 level. The hydrothermal alteration is not conspicuous on the surface because the weathering has produced a general bleaching of the shales.

Structure. The replacement bodies are lenticular. A reconstruction of the main replacement orebody before faulting shows the orebody to have had a discus shape - thick in the center and tapering toward the edges. All of the sulphide replacement bodies found to date occur within a certain series of beds in the Rio Tinto formation which are known as the ore beds. In the ore beds are narrow lenses of quartzite. From 2 to 40 feet stratigraphically above the replacement bodies is one of the thickest quartzite lenses in the Rio Tinto formation. The total thickness of the ore beds is roughly 150 feet while the orebody ranges up to 100 feet. In detail, different beds are selected for replacement in different parts of the deposit. The ore beds of this thick argillaceous series are considerably more broken and contorted than adjoining beds. Tight Z folds are common in and near the ore beds. The essential control of the orebodies is structure.

The main orebody is cut by three major faults, the No. 1, No. 2 and No. 3, all of which are post mineral. They strike northeast and dip north west. The No. 1 Fault is interpreted by the writer as a thrust fault. Where first exposed, in the No. 1 incline shaft, the fault has well developed mullion structure, the groves varying from 2 to 2 1/2 feet from crest to crest. Knowing the horizontal displacement of the beds, direction of movement (as given by the mullion structure) and dip of the fault, the solution of the problem is merely a simple one of descriptive geometry. The No. 1 fault increases in dip as it approaches the surface. Down dip the fault breaks into a number of sprays known as 1A, 1B, 1C, and 1D. The No. 2 and No. 3 faults have normal displacements.

The No. 1, 2, and 3 faults are interpreted as being the result of an east-west shortening adjustment, with the block between No. 1 and No. 2 faults having the greatest movement toward the greatest relief, in this instance, the surface. The blocks between No. 2 and No. 3 faults and the block west of No. 3 fault, respectively, lagged behind the more active block.

Other large faults in the mine which do not cut the main replacement orebody are the No. 4, 5, 6, and North-fault. No. 4 fault is roughly parallel to the strike of the orebody and dips north. Minor faults with displacements of 2 to 20 feet are numerous in the orebody.

The faults in the Mountain City Copper mine are part of the large generally north-trending system of the Centennial Range, and the fault movements are directly related to large block movements. The smaller faults are of limited lateral extent and represent an adjustment beyond the flexing stage of deformation. They usually strike transverse to the orebody and often the fault movement is absorbed laterally by bedding plane slips within a few feet of the walls of the orebody.

The faults displace the orebodies and are essentially post-mineral. Shearing parallel to the faults is not conspicuous nor well developed although, throughout the sulphide bodies, the pattern is preserved by tiny shears. The displacements of these tiny shears are measured in inches. Observations of the displacements on them in the initial 20 scale mapping of the orebody aided greatly in the solution of the fault problems. During the initial mapping two systems of shears were noted. Both strike north 30° east and dip west. The shears of one system dip west from 50 to 60 degrees and the other from 15 to 25 degrees. Normal displacements were noted on the 50 to 60 degree system and reverse displacements on the other. The first fault (No. 1) found in the mine workings had a strike and dip parallel to the tiny shears which have reverse displacements. This information was utilized, along with the other facts mentioned above, in solving the fault problem. The second fault, (No. 2) encountered in the development work cut off the orebody. The strike and dip of No. 2 fault is parallel to the steeper dipping shears and a crosscut was directed with success on the assumption the fault was normal. These early problems clearly demonstrated the value of detailed, 20 scale mapping at Mountain City.

Cleavage is normally parallel to bedding in the greater part of the areas that contain the orebodies. In the extreme west end of the main orebody the cleavage is normal to bedding. The cleavage planes diverge from the bedding near the ends of the other sulphide bodies exposed in the mine workings. The relationship of cleavage to bedding may be an important feature of the structure control for the ore deposits.

Genesis. The sulphide replacement deposits at the Mountain City Copper mine presumably have their source in emanations associated with the granodiorite intrusion although the nearest outcrop of granodiorite is a mile from the orebody. The ore replaces a definite series of beds in the Rio Tinto formation and the beds dip toward the granodiorite. The altered igneous dikes in the mine area presumably have a genetic relationship to the granodiorite. Disconcerting features of the hypothesis are that the main orebody and other lenticular sulphide deposits in the mine have been bottomed and no indications of feeding structures are found. The alteration envelope which accompanies the ore deposits fades out completely beneath the replacement bodies within a vertical distance of 50 to 75 feet.

Summary of Geologic History

The geologic history may be summarized as follows:

1. Accumulation of late-Paleozoic sediments with at least one major break in the sequence, between Rio Tinto and Banner formations.

2. Homoclinal tilting of Paleozoic sediments either preceded or accompanied by intrusions of andesitie and diorite which were later converted to amphibolites. During this orogeny certain beds (the ore beds) in the Rio Tinto formation became more contorted and broken than adjoining beds. Development of large west trending structures (presumably west striking, north dipping faults) that repeat certain of the Paleozoic formations in three west striking belts.

3. Intrusion of granodiorite. The emplacement of the larger masses presumably was controlled by west striking, north dipping faults.

4. Intrusion of "porphyry" dikes.

5. Alteration of the ore bed series and early silicification (introduction of the banded quartz) to complete the ground preparation.

6. Ore deposition - introduction of glassy quartz with pyrite, chalcopyrite, bornite and sphalerite.

7. Regional faulting represented by generally north striking and related faults of Centennial Range. The faults may have originated earlier than the orebodies although they cut and displace the orebodies.

8. Formation of matureland and cutting of steep walled valleys. Drainage unrelated to present drainage.

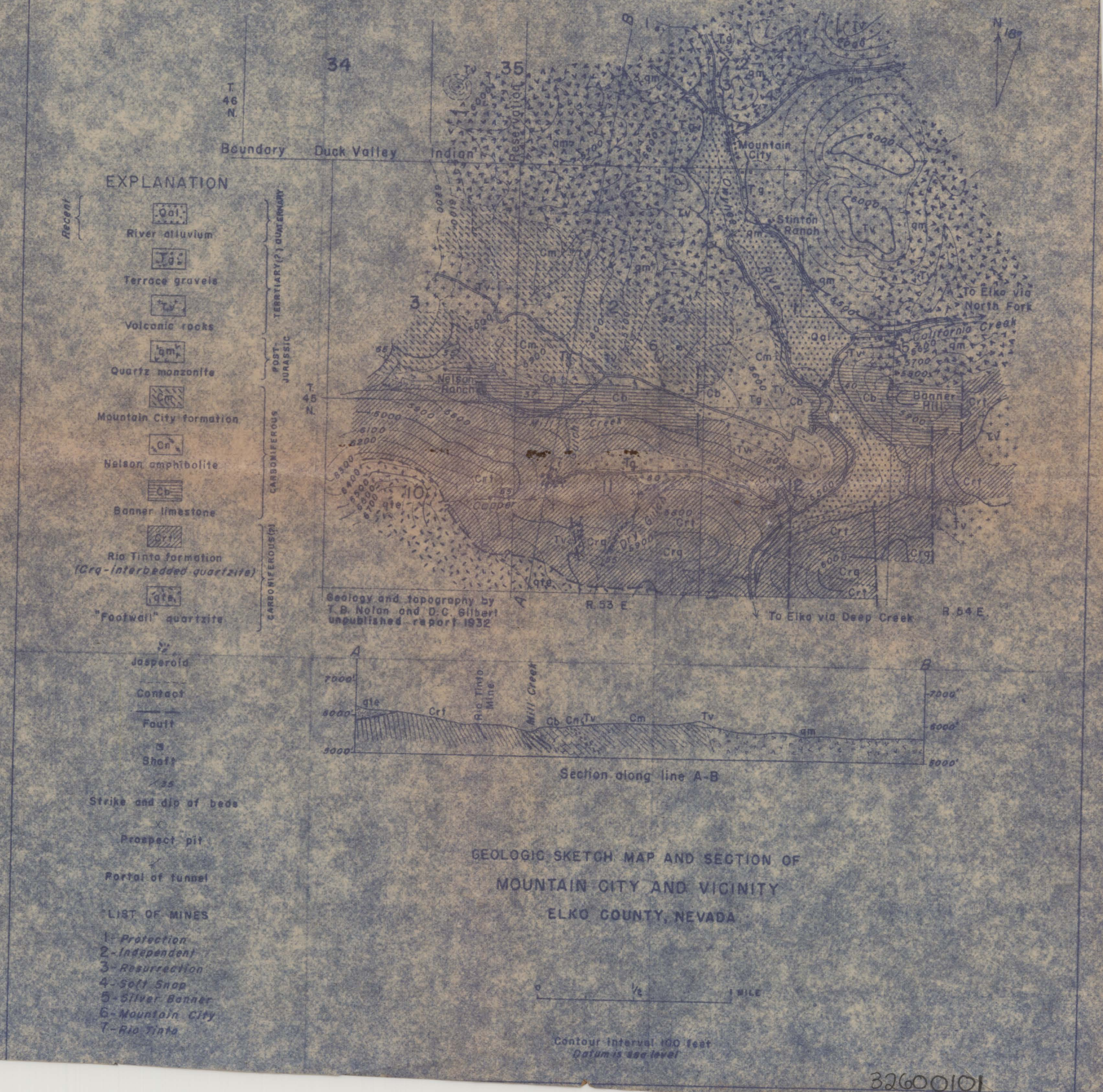
9. Volcanic extrusions (presumably late Miocene and / or Pliocene) drainage to south into Basin and Range Province.

10. Gentle south tilting in south central part of quadrangle, ponding of runoff, formation of terraces.

11. Piracy by the Columbia - Snake River system with progressive deepening of drainage channels and lowering of water table. This is the period of supergene enrichment of the Mountain City Copper orebody. Contemporaneous with this is alpine glaciation with one center in the adjoining Rowland quadrangle.

12. Accumulation of alluvium.

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



GEOLOGIC SKETCH MAP AND SECTION OF
MOUNTAIN CITY AND VICINITY
ELKO COUNTY, NEVADA


OWYHEE CO
ELKO CO
IDAHO
NEVADA
OWYHEE CO
ELKO CO
DUCK VALLEY INDIAN RESERVATION
Boulder Basin
Whiskey Point
Hillside Spring
McKenzie Ranch
Kunz Ranch
Horse Heaven Flat
Salmon Meadow
Pine Spring
Gedney Spring
Moonshine Spring
Clover Creek
HUMBOLDT
NATIONAL
FOREST
Dead Horse Point
Yankee Bill Flat
Summit Spring
MC DONALD MINE
Henrys Spring
TALUS
California Basin
Mountain City
Sugar Loaf
Hansen Gulch
NINTH
STANDARD
PARALLEL
NORTH
Hugh Bieroth Ranch
Big Springs Creek
Pixley
Rough Draw
Muddy Flat Spring
Allegheny Creek
Transient Spring
Haystack Mtn
Haystack Spring
Rough Mtn
Mountain City Ranger Station
Devils Gate
Hot Spr
Crosby Ranch
Roach Spr
Peck Ranch
Allegheny Sch
Jenneman Peak
Cold Springs
The Mahoganies
Vicente Canyon
Telephone Creek
Bridge Gulch
Sand Creek
Indian Johnnie Creek
Chipman Meadow
Jenkins Spr
Point of Rocks
Sunflower
Wild Horse

Scale 48,000