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ORE DEPOSITS OF THE GOLD CIRCLE MINING DISTRICT, ELKO COUNTY, NEVADA

By EDWARD H. ROTT, JR.
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FOREWORD

This bulletin is a thesis, with some additions thereto, submitted by Mr. Rott for the degree of Master of Arts at the University of California.

The policy of the Bureau of Mines is to publish pertinent information regarding Nevada mining districts. This paper deals with a district which has not heretofore received any comprehensive petrographic study of its ores or country rocks, and is therefore the first scientific geologic treatise in detail on the district.

JOHN A. FULTON,
Director.

THE ORE DEPOSITS OF THE GOLD CIRCLE MINING DISTRICT, NEVADA

By Edward H. Rott, Jr.

INTRODUCTION

FIELD AND LABORATORY WORK

This paper is based on work done in the Gold Circle mining district during the summer of 1927 and during brief visits to the district in June, 1928, and April, 1929. The field work was supplemented by laboratory study of the specimens collected in the district at the University of California during the fall and spring semesters of 1927 and 1928, and by a brief review of the material in the geologic laboratory of Consolidated Coppermines Corporation at Kimberly, Nevada, in the fall of 1930.

A considerable part of the district was studied in detail, and a geologic map prepared (Plate I). Detailed underground geologic mapping was done on the 300 level of the Elko Prince and June Bell veins, in the Grant and Jackson mine, in the Reco tunnel, and in the Rex tunnel. Other workings in the district were examined for the general character of the veins, wall rocks, associated intrusives, and faulting.

ACKNOWLEDGMENTS

The author is sincerely grateful to the staff of the Gold Circle Consolidated Mines, especially to Senator Noble H. Getchell, general manager, who made this work possible. Dr. George D. Louderback and Dr. Carlton D. Hulin have given invaluable advice, suggestions and criticism during the progress of this work at the University of California.

LOCATION OF THE DISTRICT

Gold Circle, also known as Midas District, is in the northcentral part of Nevada just east of the west boundary of Elko County. It lies about forty-five miles north of Battle Mountain, and fifty miles northeast of Golconda, towns on the Southern Pacific Railroad (Figure 1). Tuscarora, a thriving camp from 1872 until 1890, lies thirty-five miles east. Red House, a station on the Western Pacific Railroad, is about thirty-five miles southwest. Stage lines are operated on alternate days, except Sundays, from Midas to Golconda and Battle Mountain.

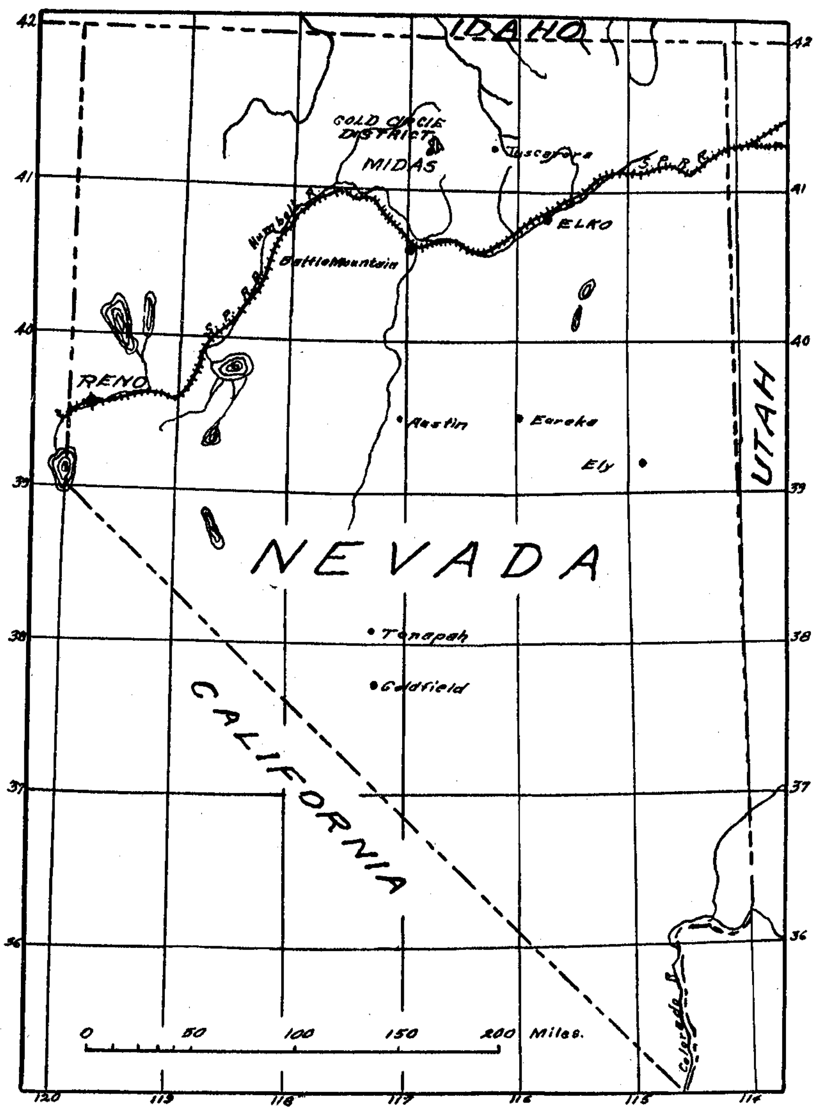

FIGURE 1
Index Map of Nevada Showing the Location of Gold Circle District.
(Revised from U. S. G. S. Bulletin 408.)

TOPOGRAPHY

The district lies in the hilly country along the southeast slope of the Owyhee Bluffs, between the bluffs and Squaw Valley. The area gradually increases in elevation from south to north, merging with the bluffs to the north and northeast. In the area covered by this work the maximum relief is about 1,000 feet. In the immediate vicinity of Midas the bluffs are sharply separated from the hilly country, and swing to the west, south of town, away from the hill area.

HISTORY OF THE DISTRICT

Gold was discovered in the summer of 1907 and by March, 1908, the camp was booming. The first excitement soon subsided and the town, which increased in population to over 1,500 people during the boom, shrunk to a settlement of 250 by September.

A number of companies were organized to operate the mines of the district, and in all six or more mills, ranging in capacity from twenty-five to seventy-five tons per day, were built and operated at different times during the life of the camp. The operations of the Elko Prince Mining Company and the Gold Circle Consolidated Mines were the most extensive in the district.

The Elko Prince mine was located in 1907 and taken over by the Elko Prince Mining Company in 1908. By agreement with the Dorr Company, a fifty-ton cyanide mill was erected at the mine in 1915 and operated until 1922, when the mill burned. Soon after the mill burned the company ceased operation. By 1926 this and the most promising holdings in the district had been acquired by the Gold Circle Consolidated Mines. Mining operations were begun and a seventy-five ton cyanide mill constructed by the Gold Circle Consolidated Mines. Treatment of ore started in the spring of 1927 and operations continued until the fall of 1929. The principal production during this period came from the Grant-Jackson vein above the 225 level, and from the Missing Link vein. From the latter part of 1928 until the mill was shut down in the fall of 1929, some production came from the Elko Prince vein above the 600 level, principally from the 450 level, and from the 300 level on the June Bell vein.

Through reorganization, the Gold Circle Consolidated Mines absorbed the Betty O'Neal Mines in Nevada, and its holdings in Arizona. The company has started to dewater the Elko Prince shaft to the 900 foot level, and plan to sink the shaft to the 1,200 foot level. Development on the other holdings will follow. Some leasers are working in the district, and through agreement with the Gold Circle Consolidated Mines their ore is treated at the company's mill.

From 1908 to 1929 the gross production of the district was slightly over $3,000,000. Two-thirds of this amount was produced in the years 1916 to 1922, during which time the Elko Prince mill was in operation, and one-fifth of the total production came from the Gold Circle Consolidated Mines during the period from 1927 to 1929.

GEOLOGY

GENERAL GEOLOGIC FEATURES

The terrane examined was one of extensive Tertiary volcanic activity. It includes flows of rhyolite, andesite, and basalt, with minor areas of rhyolite tuff, rhyolite breccia and less important exposures of olivine diabase. To facilitate geologic mapping these formations have been divided according to lithologic differences rather than major structural breaks. The three major divisions in the order of their time sequence are: pre-andesite rhyolite, andesite (principally andesite flows, some basalt, and minor occurrences of olivine diabase), and post-andesite rhyolite. Acid and basic dikes locally cut horizons as young as the basal portion of the post-andesite rhyolite.

Hydrothermal alteration has affected most of these rocks to such a degree that fresh specimens are rarely met within the mineralized area. The alteration is greater near the veins, diminishing proportionately with the distance from them.

Faulting changed the original position of the flows, and aided in opening channels along which hydrothermal solutions passed. These solutions deposited silica, calcite, and the metallic minerals which comprise the ore-bearing veins. During this process the country rock was generally bleached to a white, chalky formation which stands in noticeable contrast to the less altered rocks farther away from the zone of intense mineralization. In places the more basic rocks were acted upon to such an extent by the hydrothermal solutions that they now appear as white, friable masses of calcite and silica.

Thin sections of the principal rock types were prepared and studied microscopically. In some cases the altered condition of the rocks made it difficult to determine their true character.

PRE-ANDESITE RHYOLITE

The pre-andesite ryholite, known as the Elko Prince rhyolite, after the area in which it was differentiated from the June Bell rhyolite and post-andesite rhyolites, occurs in both the east and west walls of the Elko Prince vein at the surface, and in the east wall of the vein on the 300 level. This rhyolite is moderately hard, and white to light gray in color. It is compact with a few dull phenocrysts and shows some small vesicules. The groundmass is devitrified glassy material. The rock contains phenocrysts of alkali and soda-lime feldspar, quartz, and a notable amount of zircon in small crystals. What appears to be tuffaceous material occurs occasionally in the formation.

The Elko Prince rhyolite is in contact with the andesite underground and at the surface. The underground contact indicates that this series of flows is conformably overlain by the andesite flows. This rhyolite has not been differentiated from the post-andesite rhyolites and the June Bell rhyolite in the major portion of the district.

ANDESITE

Closely following the Elko Prince rhyolite, andesite with some intercalated basalt and diabase flows was poured forth on the surface of the rhyolite. The parts of the contact that were exposed in underground workings gave no indications of an erosion interval between the rhyolite and the andesite. The andesite and associated flows occur in the southeast, southwest, and northern portion of the area mapped, with some irregular masses and dikes occurring within the rhyolite area.

The andesite varies considerably in appearance, but in a generalized description it may be designated as a greenish-brown, hypocrystalline, porphyritic rock, with feldspar and pyroxene phenocrysts in a matrix of undifferentiated constituents. Under the microscope the feldspar was seen to be acid andesine, and the pyroxene to be augite. The feldspars are partly altered to calcite and sericite, and the pyroxene to calcite and chlorite. In general, the rock is fine-grained, with lath shaped phenocrysts of acid andesine and augite in an altered groundmass of glass, chloritic material, and calcite.

Another specimen contained phenocrysts of basic andesine and augite in a groundmass composed principally of brown glass, with some feldspar laths (about acid andesine), minute prisms of apatite, relatively large crystals of magnetite and intensely altered material composed of serpentine, calcite, and iron oxide. Secondary silica and remnants of biotite occur, also amygdules of calcite and chalcedonic silica.

The diabase is a black, holocrystalline, medium coarse-grained rock composed of soda-lime feldspar, pyroxene, and olivine, with some magnetite. Microscopic determination showed the original minerals to be basic andesine, augite, olivine, magnetite, apatite. and brown biotite. The olivine is almost completely altered to serpentine and antigorite, with associated calcite and iron oxide. Kelyphitic structure is well developed about the olivine. Pigeonite, a pyroxene of small, variable axial angle, was noted in one specimen. 2V for the mineral in this specimen measured less than 15°.

The basalt is a black, hypocrystalline, medium-grained porphyritic rock, with phenocrysts of labradorite, augite, and olivine, in a groundmass of very small laths of feldspar, grains of augite and greenish to brownish glass, with such alternation products as chlorite, calcite, and iron oxide. The olivine is largely altered to serpentine.

Some of the basic rocks are intensely altered to a white or yellowish white rock, with few partly preserved mineral particles. Under the microscope this rock is seen to consist of serpentine, calcite, quartz, amorphous silica, probably some kaolin, a few magnetite grains, and an occasional partly altered feldspar. Apparently the major portion of the femic minerals has been altered and the heavier constituents removed. Phases of more extreme alteration appear to contain chiefly amorphous silica, serpentine, and calcite in a form soft, friable, and of low specific gravity. This can be traced through gradations into the relatively fresh, black basalt.

POST-ANDESITE RHYOLITE FLOWS AND TUFF

The post-andesite rocks consist chiefly of rhyolite flows and tuffs. Some of these were examined microscopically. A typical example of the flow rocks contained phenocrysts of acid oligoclase and orthoclase. Some quartz occurs in the devitrified glassy groundmass. In some specimens examined microscopically the mineralogic character of the rock was that of a trachyte rather than a rhyolite. It is sometimes impossible to determine whether one is dealing with post-andesite or pre-andesite flows. This can only be decided by detailed mapping of the formations and petrographic study of a number of specimens.

The tuffs vary notably in character. Some are white, differing little from the flows in general appearance, but showing shards and fragments of feldspar in a pasty matrix of minute mineral and glass fragments. Devitrification of the glass is common. Another facies is composed of poorly consolidated, soft, white, pasty material with greenish spots. The distribution of this material indicates that it is probably the latest facies of post-andesite eruption.

Amygdaloidal post-andesite rhyolite occurs on the Colorado Grande No. 3 claim on Queen Peak, and on the ridge south. Some chalcedonic amygdaloids, three-fourths to one inch in diameter, were found south of Queen Peak.

On the surface, the June Bell rhyolite is limited to a small area on the June Bell claim; underground it is more extensive. It occurs in the west wall of the Elko Prince vein on the 300 level and in both the footwall and hanging wall of the June Bell vein. This rhyolite is a very hard, dense type, showing perfect flow structure. Microscopic examination revealed phenocrysts of oligoclase, small apatite prisms and, rarely, minute prisms of zircon or titanite, accompanied by occasional spherulites, in a dense, devitrified, glassy and micro-crystalline groundmass. The quartz occurs chiefly in micrographic intergrowth with feldspar, and as small, irregular patches that are apparently secondary silica.

The flow structure in the June Bell rhyolite has a consistent strike and a steep dip. On the surface it is in distinct discordance with the Elko Prince flows. The data obtainable on the contact between the two formations were insufficient to determine whether the June Bell rhyolite was intrusive into the Elko Prince rhyolite, or the Elko Prince flows were resting on an erosion surface. Underground, there was not an opportunity to observe this body of rhyolite in other than fault contact to other formations. From the data available this rhyolite cannot be designated as either extrusive or intrusive. If extrusive, it is a uniform series of flows which have been either intensely folded, or steeply tilted by faulting, and is older than the Elko Prince rhyolite, separated from it by a structural and erosional break. If intrusive, it is younger than the Elko Prince rhyolite and probably associated with the first series of rhyolite flows in post-andesite time.

DIKES

Both acid and basic dikes occur in the district. They are more numerous than is shown on the map. The dike rocks studied microscopically proved to be either rhyolitic or andesitic.

Adjacent to the Missing Link vein is a dike which differs in character from those generally observed in the area. This dike appears to be a typical lamprophyre. It is black in color, very dense, and in general altered and softened. The dike is younger than the vein, which may be found on either side of it, cutting it, or splitting it to form a sheeted zone within it. The dike ranges in width from one to three feet.

STRUCTURE

The Elko Prince rhyolite is the only formation in the district known to be definitely pre-andesite in age. Exposures of the contact between the two formations in the underground workings show the andesite lying conformably upon a series of flows of Elko Prince rhyolite. Following the andesite, rhyolite flows and tuffs were poured forth. The earlier flows of this period lie conformably upon the andesite, and are separated from a later one by an unconformity, marked by both erosional and structural features. The earlier lavas consist of rhyolite flows and well-consolidated tuffs; the later ones are poorly consolidated tuffs.

During the period of suspended volcanic activity, marked by the unconformity, erosion continued, accompanied by pronounced faulting.

The fissures, sheeted zones, and shattered zones were formed at this time and later became the channels in which the mineralizing and metallizing solutions moved, depositing their load and hydrothermally altering the wall rock. Some of these are zones of fracturing, suitable locations for solutions to circulate and deposit their contents; others are pronounced faults.

Following this period of disturbance, volcanic activity was renewed, and the country buried by the late post-andesite tuffs to a depth of several hundred feet. Erosion followed, carving out the present physiographic expression of the region. Neither veins nor other evidence of mineralization have been found associated with these tuffs, and the faulting and tilting affecting them is of minor importance.

The country is divided into fault blocks, and within the different blocks the attitudes of the formations vary from practically horizontal to nearly 60° dip. Faulting started in pre-mineral times, when it apparently reached its maximum intensity. It continued with less intensity during the period of mineralization, and there is some minor post-mineral faulting.

The major fault zones of the district, and the faulting which developed most of the vein openings, belong to two periods of pre-mineral faulting. Some of the fissures in which veins have formed were developed before the major faults, and have been offset by them prior to the mineralization. In these cases the ore may be found in both segments of the vein and along the section of the fault between the separated vein segments.

Post-mineral faulting has not been found to have produced more than a few feet of displacement, and in general no evidence has been found to indicate that great importance should be attached to post-mineral faults. In one case there is evidence of post-mineral faulting of more than average intensity. This is at the southeast end of the Gold Crown vein where it is cut by a fault at a very acute angle. The character of the movement, and the extent of the displacement has not been determined. This movement was evident from the crushing and rounding of fragments of vein matter, which were found in the gouge along the fault, 50 or 60 feet from the intersection.

In general, the veins of the district strike N 30° to 60° W and vary from 65° E to vertical dip. Some have steep west dips. One vein showing no important mineralization strikes N 10° W and dips 75° to 80° west. The major pre-mineral fault zones show a general east-west trend and steep southerly dip. More extensive mapping may show other trends for major pre-mineral faults.

ORE DEPOSITS

DISTRIBUTION AND CHARACTER

The veins of the Gold Circle District lie in a highly altered area in which the rocks have been leached and bleached to chalky white, with occasional tints of brown and red iron strains. This leached and bleached area roughly coincides with the distribution of the veins. Near the mineralized channels alteration of the rocks has been most intense, with devitrification of the groundmass, destruction of all ferromagnesian minerals, and almost complete alteration of the feldspars.

The principal veins lie in a zone from one to one and one-half miles wide and approximately three miles long, extending in a general northwest-southeast direction. Northwest of this area some ore has been found which may extend the metallized zone.

An area ranging from one-half to one mile in width and extending from Midas Peak at the north to Queen Peak on the south was studied and mapped in detail. The formations, veins, and faults are shown. From a rapid observation of outlying areas, it appears that the characteristics of the ore deposits in this area will apply to the deposits throughout the district. In the southern two-thirds of the area the rhyolite flows were not differentiated as in the northern third (Plate I).

The veins occur as shattered zones, and sheeted zones, and as fissure fillings in rhyolite, and along the fractured contact between rhyolite and andesite. The vein material is principally silica and brecciated wall rock, generally rhyolite, with minor amounts of calcite and adularia. Fracturing has occurred repeatedly along these zones, and the vein material, as well as the wall rock, has repeatedly undergone shearing and brecciation, followed by cementation. In general throughout the district, fissure fillings and sheeted zones in rhyolite form the smaller veins, a few inches to three or four feet in width. On the other hand, the shattered zones in rhyolite, and especially those along andesite-rhyolite contacts, form the larger veins, often ten to fifteen feet in width. Similar zones twenty and twenty-five feet wide have been reported. The tenor of the ore is generally higher in the sheeted zones and fissure fillings, but their small size, commonly only twelve to fifteen inches wide, makes them difficult to mine. The shattered zones contain the larger ore deposits of milling grade. A number of veins have been traced along their strikes for distances ranging from 1,500 to 3,500 feet.

VEINS AND ORE SHOOTS

The veins were formed along open fissures or zones of brecciation which existed during the period of mineralization. These controlled the distribution of the veins, their physical characters, their length, width, and trend. Within such veins there are ore shoots. Any factor that may have acted physically or chemically to localize or aid in the formation of the ore shoots will be considered a "control."

The major ore shoot on the Grant-Jackson vein, which occurs in the southern portion of the Jackson claim and the north portion of the Grant claim, is an example of an ore shoot formed at the intersection of a vein with a fault (Fig. 2). The Grant-Jackson vein intersects a strong pre-mineral fault, about ninety feet inside the north end line of the Grant claim, and here the major ore shoot occurs. This ore shoot starts at the fault and is inclined upward at a flat angle

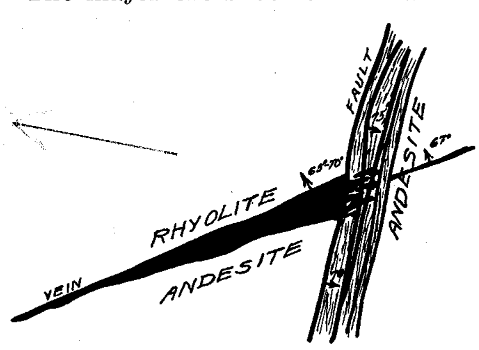

FIGURE 2
Plan of Major Ore Shoot in Grant-Jackson Vein at Intersection with Premineral Fault.

toward the north. On the 225 and the 165 levels the stope length of the ore shoot is approximately 100 and 200 feet, respectively. Drifting on the vein and crosscutting have been carried over 500 feet north from the end of the ore shoot on the 165 level, and no important pay shoots have been found outside the zone of influence of the controlling fault structure.

The Grant-Jackson vein is found along a fault contact between andesite and rhyolite. The ore shoot consists of finely brecciated rhyolite, rhyolite boulders seamed with and recemented by sugary quartz and quartz replacing calcite (which was apparently the earlier cement), and sugar-quartz near the andesite footwall. The average width of the vein is about ten feet. North of the ore shoot the vein is narrower and less mineralized.

Two factors were active in the formation of this ore shoot: First, a variation in dip of from 5° to 10° between the surface and the different levels created a lenticular opening partly filled with brecciated material when movement occurred (Fig. 3). Second, intermineralization movement along the pre-mineral fault aided in keeping a passage open within the vein for the circulation of mineralizing and metallizing solutions. This fault forms a zone of intense shearing forty-five to fifty feet wide, striking eastwest and dipping south. Abundant calcite occurs near the footwall of the fault at its intersection with the vein. Ore was found within the shear zone for approximately thirty feet south from the footwall. This ore was bunchy and showed indications of disturbance. The hanging wall of the fault is andesite. On the projection of the Grant-Jackson vein south through the fault a vein was found in the hanging wall block. This consists of about eight inches of quartz between andesite walls, with strike and dip the same as on the vein north of the fault, but this part of the vein was not the locus of such active movement as that north of the fault. Its gold and silver content is low.

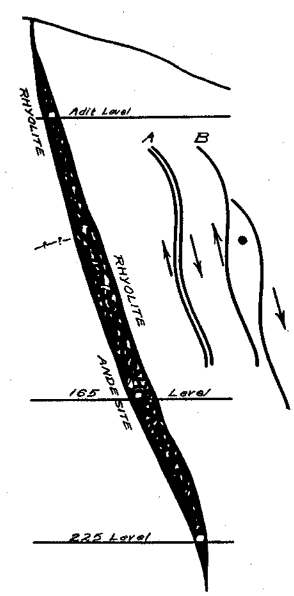

FIGURE 3
Section Through Major Ore Shoot in Grant-Jackson Vein with the Mechanics, Which Aided in Its Formation, Illustrated.

Indications are that the vein is younger than the fault and was poorly developed in the soft gouge of the fault zone and to the south of the fault. Slight intermineralization movements on the fault, centering near the footwall, helped keep a channel open for mineralizing solutions to enter the vein and cement the rock fragments together; for later solutions to replace earlier deposited material, and finally for the metallizing solutions to deposit their load of gold and silver.

The Missing Link vein is a typical fissure filling at places along a single fissure, and again in a sheeted zone in the wall rock, or in the lamprophyric dike which courses with the vein for some distance. The ore shoots do not show any pronounced control as in the case of the Grant-Jackson ore shoot. The fissure filling varies in character and in richness. Generally the pay streaks contain both gold and silver, with the silver predominating, but pay shoots do occur in which either metal may predominate in value. The occurrence of the two types of metallization, separately, in ore shoots within a few feet of each other, indicates two stages of metallization with the possibility of an overlap between them. As a whole the pay streaks are chiefly dependent on gold for their commercial value. This is generally true of the ore shoots throughout the district.

The Elko Prince vein is a fissure filling along a steep fault of considerable displacement, with the June Bell rhyolite on the west wall and the Elko Prince rhyolite on the east wall of the adit or 300 foot level. The vein will average about two feet in width, and commonly, in addition to the siliceous vein matter, there are several inches to a foot or more of gouge developed on the east wall. The walls are firm and well defined. On the adit level mining operations were extended over 1,500 feet along the strike of the vein. The 450 foot and 600 foot levels were extensively worked, but these levels were only briefly examined in 1929 when they were partly reopened. Some mining was done on the 750 foot level, and a winze from the 750 foot to the 900 foot level near the north end of the vein was sunk in ore averaging $75 per ton. The main ore shoot was 630 feet long on the 300 foot level and averaged fifteen inches in width; on the 600 foot level it was 810 feet long, and by November, 1917, 230 feet had been opened on the 750 foot level showing an average width of thirty inches.[1]

No definite control is evident for the ore shoot in the Elko Prince vein. The vein varies as much as 5° either direction from vertical and there are slight variations in the strike, but these have no apparent affect on the metallization.

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[1]Weed, W. H., "The Mines Handbook," Vol. XIII, 1918.

The June Bell vein is a fissure filling in rhyolite. The average width of the vein matter is less than a foot. An ore shoot opened in 1929 on the 300 foot level appeared where small step faults offset the vein. The ore shoot continued for 120 feet south of these step faults, to a point where it was intersected by a fault with andesite hanging wall, where it turned and followed the fault to the east. Along the fault the ore was in place, but was irregularly developed. A similar occurrence was noted on the 600 foot level at the south end of the Elko Prince vein, where the same fault was encountered.

Zones of shattered mineralized rhyolite of milling grade along rhyolite-andesite contacts and in rhyolite have been reported along the Gold Crown vein and the Rex lode. These zones are larger than the fissure fillings and range from five to twenty-five feet in width.

Post-mineral movement along the Gold Crown vein has been reported by Emmons. This was also noted by the author at the southeast end of the vein, near its intersection with the Colorado Grande fault, which cuts the vein at a very acute angle and apparently terminates it. This fault also shows definite evidence of post-mineral movement. Large, well-rounded boulders of high-grade ore have been found in the soft gouge along the fault, near its intersection with the Gold Crown vein. The ore is typical brecciated vein matter, recemented. It may have formed in the fault at the intersection with the vein, and been broken up and rounded by later movement on the fault; or it may have been torn out of the vein as "drag ore" when movement occurred along the fault. The size of the boulders, one of which weighed several tons, would indicate an original deposit of more than average size.

A seam of ore two to three inches wide, assaying several thousand dollars per ton, occurs in the Gold Crown vein at its intersection with the fault. Northwest of the fault, along the vein, the ore feathers out into fine seamlets within twenty-five or thirty feet. This ore is similar mineralogically and comparable in value to the boulders found in the gouge along the fault adjacent to and north of the intersection. Surface exposures are poor in this area and underground development is not sufficient to prove definitely whether this is an ore shoot formed at the intersection of the vein with the fault, or that it represents a segment of a faulted ore shoot. The information available favors the former possibility. Southeast of the fault the vein has not been recognized.

MEGASCOPIC CHARACTER OF THE ORE

The open fissure filling is best represented by the ores of the Missing Link, Elko Prince, and June Bell veins, where simple banding is the prominent structure. Within the individual bands the structure may be highly complex with intricate banding, vugs, and cavities (Plate II, A and B). These features are depositional rather than deformational, though prior deformation obviously controlled the surroundings during deposition of the vein matter, and thus determined the structure in the banding. There is notable variation in the metallic content from one band to another, and also in the ratio of gold to silver.

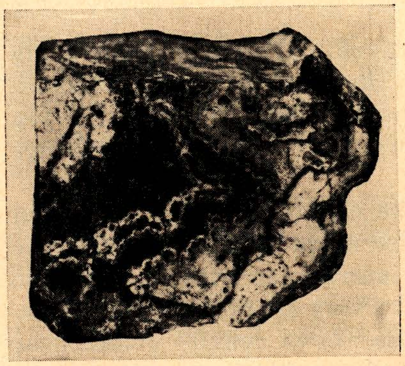


PLATE II(A)
Complex Banding Within Simple Band of Vein Filling. The metallic minerals occur chiefly within the dark areas. Elko Prince Vein.

The Grant - Jackson vein is a zone consisting of brecciated rhyolite (finely crushed material and blocks ranging up to one or two feet in diameter), sugar-quartz, and cellular quartz seams. These cellular quartz seams are apparently the result of silica replacing the calcite along the cleavage planes and the remaining calcite being removed by solution before complete replacement occurred (Plate III).

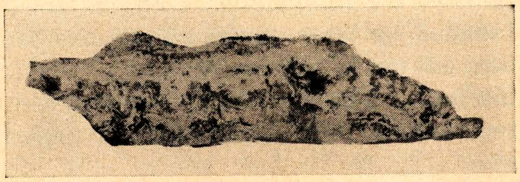


PLATE II(B)
Intricate Banding and Vugs Within an Individual Band of Vein Filling. Missing Link Vein.

Plate IV shows typical brecciated rhyolite vein filling, recemented, from the upper part of the Grant-Jackson vein. The high-grade boulders found in the Colorado Grande fault were chiefly brecciated quartz and chalcedonic material, with some crushed country rock cemented together by a later deposition of silica (Plate V).

Large cavities are common along the veins and in the vein matter. Generally these are a foot or less in length, but locally they are several feet long and one or two feet wide. Frequently these cavities are lined with chalcedonic material, drusy crystals,

PLATE III

Siliceous Boxwork Formed by the Replacement of Calcite by Silica Along Cleavage Planes, Followed by Solution and Removal of the Remaining Calcite Before Complete Replacement Could Occur. Grant-Jackson Vein.

and occasional well-formed clear crystals of quartz, one-half to three-quarters of an inch in length.

PLATE IV
Brecciated Rhyolite Vein-Filling Cemented by Finely Crushed Material and Silica. Grant-Jackson Vein.

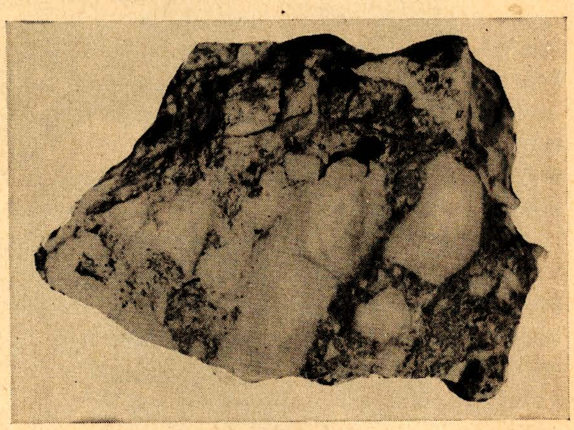


PLATE V
Brecciated Quartz and Chalcedonic Material with Some Finely Crushed Fragments of Country Rock Cemented Together by a Later Deposition of Silica. Colorado Grande Fault.

MICROSCOPIC CHARACTER OF THE ORE

Mineralogy—Neither the ore nor the gangue is complex in the mineralogic make-up. Three metallic minerals, pyrite, stromeyerite, and native gold supply the bulk of the metallic content in the veins, with other metallic minerals appearing in minor amounts. The gangue material consists of individual minerals and brecciated rhyolite. The principal mineral constituents are quartz, chalcedony, and calcite, with a small amount of adularia, and traces of chlorite. The mineral species of the vein matter are listed in the following table in two groups, metallic minerals and gangue minerals, arranged in the order of their relative abundance within their respective groups:

Metallic Minerals—		
Pyrite	FeS_2	Abundant
Stromeyerite	$(Ag, Cu)_2S$	Moderate
Gold	Au	Sparse
Tetrahedrite	$Cu_8Sb_2S_7$	Trace to Rare
Proustite	Ag_3AsS_3	Rare
Chalcopyrite (?)	$CuFeS_2$	Rare
Sphalerite	ZnS	Rare
Gangue Minerals—		
Quartz	SiO_2	Abundant
Chalcedony	SiO_2	Moderate to Abundant
Calcite	$CaCO_3$	Sparse
Adularia	$KAlSi_3O_8$	Trace
Chlorite	--------------	Rare

Pyrite is almost always present in the ores of the district, but in some localities it is rare. It is usually the dominant metallic mineral observed, except in specimens of high-grade ore in which the minerals of the precious metals may dominate. Pyrite can be easily recognized by its high relief, hardness, creamy white to yellow color, the cubic form which is commonly developed, and by microchemical tests. It is fine grained.

Stromeyerite is the principal silver-bearing mineral. It can be seen in small amount in all polished surfaces of the ores from the Missing Link, Elko Prince, and Colorado Grande fault, and Gold Crown veins. Stromeyerite closely resembles argentite (Ag_2S) and jalpaite ($3Ag_2SCu_2S$) in microchemical tests and appearance. Nitric acid and ferric chloride are more intense and more rapid in their action on stromeyerite than on either argentite or jalpaite. The color, relief, and sectility of the mineral helps to identify stromeyerite, but to further check its identity, light etching and polarized light are employed. Light etching slowly develops small, rather widely spaced blebs on the exposed surface. This reaction distinguishes the mineral from argentite, which reacts intensely to light etching. The anistropic character displayed under polarized light serves to differentiate it from jalpaite and argentite.

Gold is considerably less abundant than the minerals already discussed. It is identified by its color, relief, sectility, and its reaction with KCN on a polished surface.

Tetrahedrite was recognized chiefly by its color, relief and negative reaction to all reagents used. This mineral was observed in several specimens of ore but only as very small specks.

Proustite, the silver sulph-arsenide commonly referred to as ruby silver, was not definitely recognized, but a mineral was observed as small bluish-white specks, almost blue in contrast to the gray and yellow background, in specimens from the Colorado Grande No. 1 claim and the Missing Link vein. The physical and microchemical properties observed in this mineral indicate that it is proustite. One assay for arsenic of mixed ore from the district shows that proustite or some other arsenic-bearing mineral is more common in the ore than is indicated by microscopic study. No evidence of other arsenic-bearing minerals was noted.

It is questionable whether chalcopyrite is present in the ore. On two or three surfaces a few small specks of a yellow mineral, apparently having a higher relief and more brittle than gold, were observed. Sphalerite was noted in a number of cases, occurring as very small grains often associated with stromeyerite.

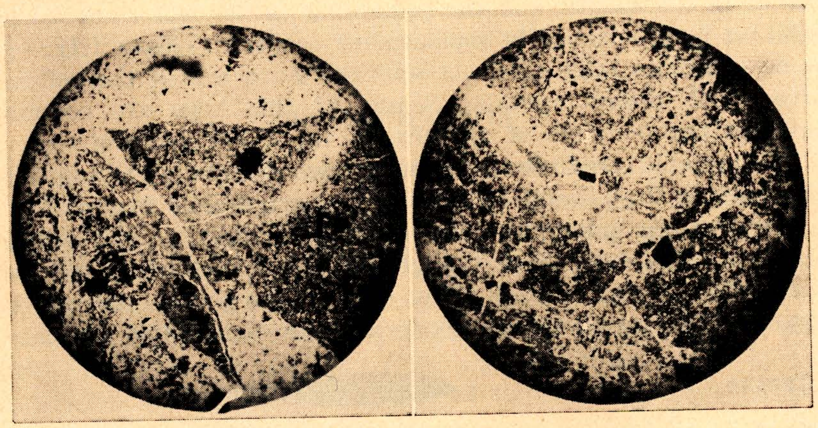
Textural Character of the Ore—The gangue minerals are mainly chalcedony, quartz, calcite, adularia, and occasionally some chlorite. They will be discussed in relation to each other, and to metallic constituents of the vein.

The veins were not completely developed at one time, nor were the minerals all deposited in them contemporaneously. This is clearly shown by the banding in the vein filling, the brecciation and cementation, and the replacement of one mineral by another.

In the sequence of the vein-forming processes the chalcedonic material was deposited first along the fissures and zones of brecciation. After the introduction and solidification of this material, movement occurred, shattering the earlier vein matter and sometimes the wall rock, producing new openings to be filled. Then solutions entered these openings and deposited crystalline quartz, cementing the fragments of chalcedonic material and country rock. It is probable that the adularia was formed in the veins at this stage, though in one or two cases it appears that some of the adularia belonged to vein matter older than the chalcedonic filling.

Following this stage, movement and shattering again occurred, followed by the introduction of fine-grained quartz. Thus three phases of silica deposition are seen. The specimens studied showed the earliest to be chalcedonic silica; the next, medium to coarse crystalline quartz; the last, fine-grained quartz (Plate VI, A and B). These phases of silica deposition may be assigned to a single period of vein formation, characterized by repeated reopening of the veins, and recementation by deposition of silica, carbonates, etc., from solutions of changing composition, and under varying physical conditions.

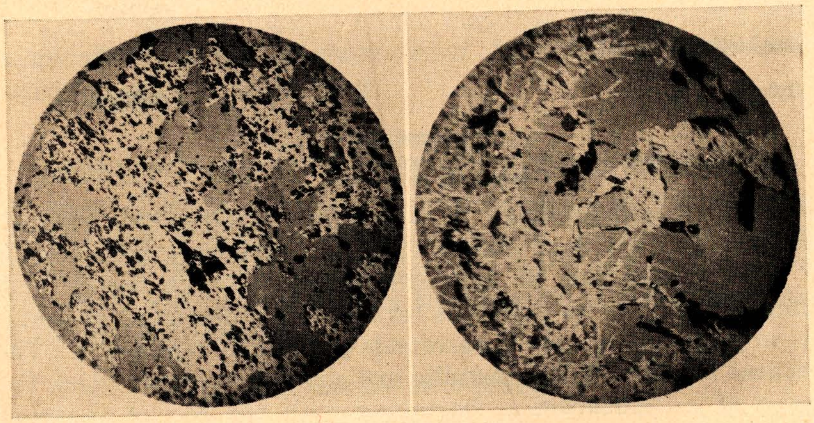
To place the carbonate portion of the vein matter in the sequence of vein filling is more difficult. It appears that most



A PLATE VI(A, B) B

A. Three Stages of Silica Deposition in Vein Filling. 1. Chalcedonic silica (dark). 2. Medium-grained crystalline quartz (light-colored area surrounding dark chalcedonic fragments). 3. Seamlets of fine-grained crystalline quartz (light-colored) cutting both chalcedonic silica and the light-colored medium-grained quartz.

B. Same as A. Boulder of ore from fault gouge, Colorado Grande No. 1 claim.



A PLATE VII(A, B) B

A. Calcite (Light-Colored Areas) Replacing Siliceous Vein Filling (Dark Areas). Missing Link Vein.

B. Calcite (Light-Colored Areas) Cementing Angular Fragments of Siliceous Vein Filling (Dark Areas). In this surface there is not so strong a tendency toward replacement as in A. Missing Link Vein.

of the carbonate was introduced during the last phase of silica deposition or immediately following it. Calcite of this period occurs irregularly, replacing the earlier vein filling, and as a cement to the angular fragments. (Plate VII, A and B.) It is not uncommon to find calcite lining cavities in the ore.

There is some evidence of an earlier period of calcite deposition prior to the silica. This was noted in one vein, the Grant-Jackson. In this instance the calcite was replaced by the silica, which developed cellular siliceous boxwork along the cleavage planes in the calcite, and the remaining calcite was removed by solution before complete replacement occurred (Plate III). In some instances later siliceous solutions have coated the cellular areas with drusy crystals. Seams of this type are common between the boulders of rhyolite in the Grant-Jackson vein.

The metallic constituents taken as a group were introduced into the veins in the general order indicated graphically in Fig. 4.

The metallic minerals were deposited later than the second phase of silica deposition, though some pyrite occurs associated with silica of that period. The bulk of the pyrite and all the other metallic minerals are apparently associated with the third

FIGURE 4
Graphical Representation of the Order of Introduction of the Metallic Minerals in the Veins.

period of silica deposition. In every surface and section studied, metallic minerals were absent from the carbonate vein matter or were present only as inclusions associated with earlier vein filling. In one or two instances carbonate was observed as seamlets in pyrite; in others it surrounds pyrite and replaces it. The textural relation of the metallic and gangue minerals place the period of metallization as beginning with the second phase of silica deposition, and continuing possibly to the beginning of calcite deposition.

Pyrite is one of the most persistent minerals in the ore, occurring in all the vein matter, and was present in the metallizing solutions from the beginning almost to the close of the period of metallization. The earliest pyrite is found as isolated grains in the second silica phase. Later pyrite replaces earlier gangue material (Plate VIII). In pyrite showing this relation, it is not unusual to find specks of gold scattered through it.

The metallizing solutions began depositing native gold with the pyrite after the close of the second period of silica deposition. The gold also occurs in the gangue, filling seamlets and open cavities.

Before the cessation of gold deposition the solutions began depositing stromeyerite. The latter occurs with mutual boundary relations to much of the gold.

Tetrahedrite and proustite probably accompanied the stromeyerite. Chalcopyrite and sphalerite seem to be contemporaneous with the bulk of the metallization.

Open cavities still remaining in the ore are frequently lined with

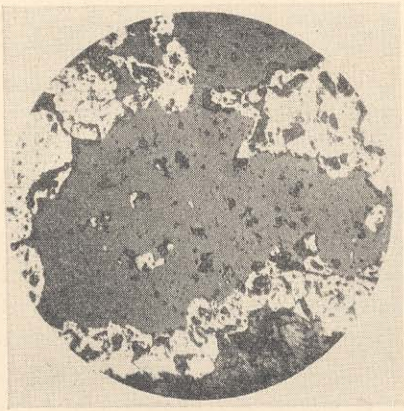


PLATE VIII

PLATE IX

Plate VIII. Pyrite Replacing the Earlier Siliceous Gangue. This concentric replacement of the gangue by pyrite is generally confined to definite bands. Missing Link Vein.

Plate IX. "Petal" Form Calcite Lining Cavity in Siliceous Gangue. Missing Link Vein.

calcite or siliceous material. The calcite quite commonly develops "petal" forms in cavity linings (Plate IX), and the silica is generally crystalline quartz.

GENESIS OF THE ORE

The ore deposits of the Gold Circle district are found in a series of volcanic formations of relatively recent age. These are generally correllated with the formations developed by volcanic activity in the Great Basin region during Miocene time.

The question arises, at what depth below the then existent surface were these veins formed? One means of answering this would be to determine the amount of erosion which has taken place since the deposition of the ore. From a study of the veins and the formations, it appears that the mineralization took place during the period of extensive erosion, following the first period of post-andesite folding and faulting, and prior to the extrusion of the late post-andesite tuffs. All the earlier formations were greatly tilted, and faulted prior to the mineralization. The ore was deposited along fissures and faults developed during this disturbance. With the present knowledge of the thickness of the formations, their positions and attitudes, it is difficult to make a reasonably accurate estimate of the thickness of the rock prism that was removed by erosion.

The greatest erosion appears in the vicinity of the Elko Prince vein. Adjacent to the Grant-Jackson vein the formations are less disturbed, and it is possible to obtain a more definite idea of the extent of erosion. The vein occurs along a normal fault between andesite and early post-andesite rhyolite. On the foot-wall side of the vein, along the ore shoot, the andesite is still capped by fifty to one hundred feet of rhyolite. The amount of erosion is equal to the difference between the thickness of the remaining rhyolite and its original thickness. The thickest exposure of this formation is approximately 400 feet. Though this may not represent the original thickness, it appears probable that it did not greatly exceed that which remains. These deposits therefore must have formed at relatively shallow depths below the surface.

The mineral associations, the structures in the vein, and the textural features of the vein filling all serve as indicators of the depth at which the deposits were formed. The typomorphic minerals in these deposits are: Chalcedonic silica, adularia, fine-grained pyrite, stromeyerite, and proustite. The typomorphic structures are chambers, cavities, and open fissures along the vein. In the vein filling there are numerous cavities, delicate banding, and cellular structure. The mineral assemblage, the structures in the vein, and textural features of the vein filling are typical of hydrothermal mineralization at relatively shallow depths.

These features, taken with the evidence of depth indicated by the amount of erosion, serve to place the deposits in the epithermal type, which is the type of deposit in the mines of Goldfield, the Comstock, Tuscarora, Tonopah, and other important districts of Nevada.

SUMMARY AND CONCLUSIONS

1. The terrane examined is one of extensive Tertiary volcanic activity. It includes flows of rhyolite and andesite, with which are associated basalt flows and minor amounts of olivine diabase, rhyolite tuff, and rhyolite breccia. Cutting these formations acid and basic dikes are occasionally noted.

2. The volcanic series is divided into three major groups: Pre-andesite or Elko Prince rhyolite, andesite, and post-andesite rhyolite flows and tuff. The andesite overlies the Elko Prince rhyolite with no apparent angular or erosional break. Conformably overlying these flows are the early post-andesite rhyolite flows with some interbedded tuff. Intense tilting and faulting followed this period of volcanic activity, ending in mineralization and erosion. After this period of disturbance and erosion, the late post-andesite tuffs covered the region to a depth of several hundred feet. This period was followed by some slight disturbance, and the erosion cycle which developed the present topography of the region.

Since the June Bell rhyolite cannot be definitely designated as an intrusive or extrusive mass, it can be assigned to the pre-mineral division only.

3. The ore deposits of the district occur as fissure fillings, sheeted zones, and shattered zones in rhyolite and along fault contacts between andesite and rhyolite. The inclosing rocks show notable effects of hydrothermal alteration.

4. Generally the ore shoots of the district do not show a definite control. But in the case of the Grant-Jackson vein the major ore shoot is controlled by slight flattening in the dip of the vein, and by a strong premineral fault which intersects the vein. During mineralization, movement occurred along this fault near the footwall, aiding in the opening of that portion of the vein in the footwall of the fault and keeping a channel open for the mineralizing and metallizing solutions.

5. There were three phases of silica deposition and one of calcite in the veins. The metallization is associated with the latter part of the second, and all of the third phase of silica deposition. There is no evidence of metallization associated with the calcite, the last mineral introduced into the veins.

6. The evidence on the amount of erosion, the mineral assemblage, the structural features of the veins, and the textural character of the vein filling indicate that the formation of these veins took place at relatively shallow depths below the surface. These veins represent a typical epithermal type of deposit.

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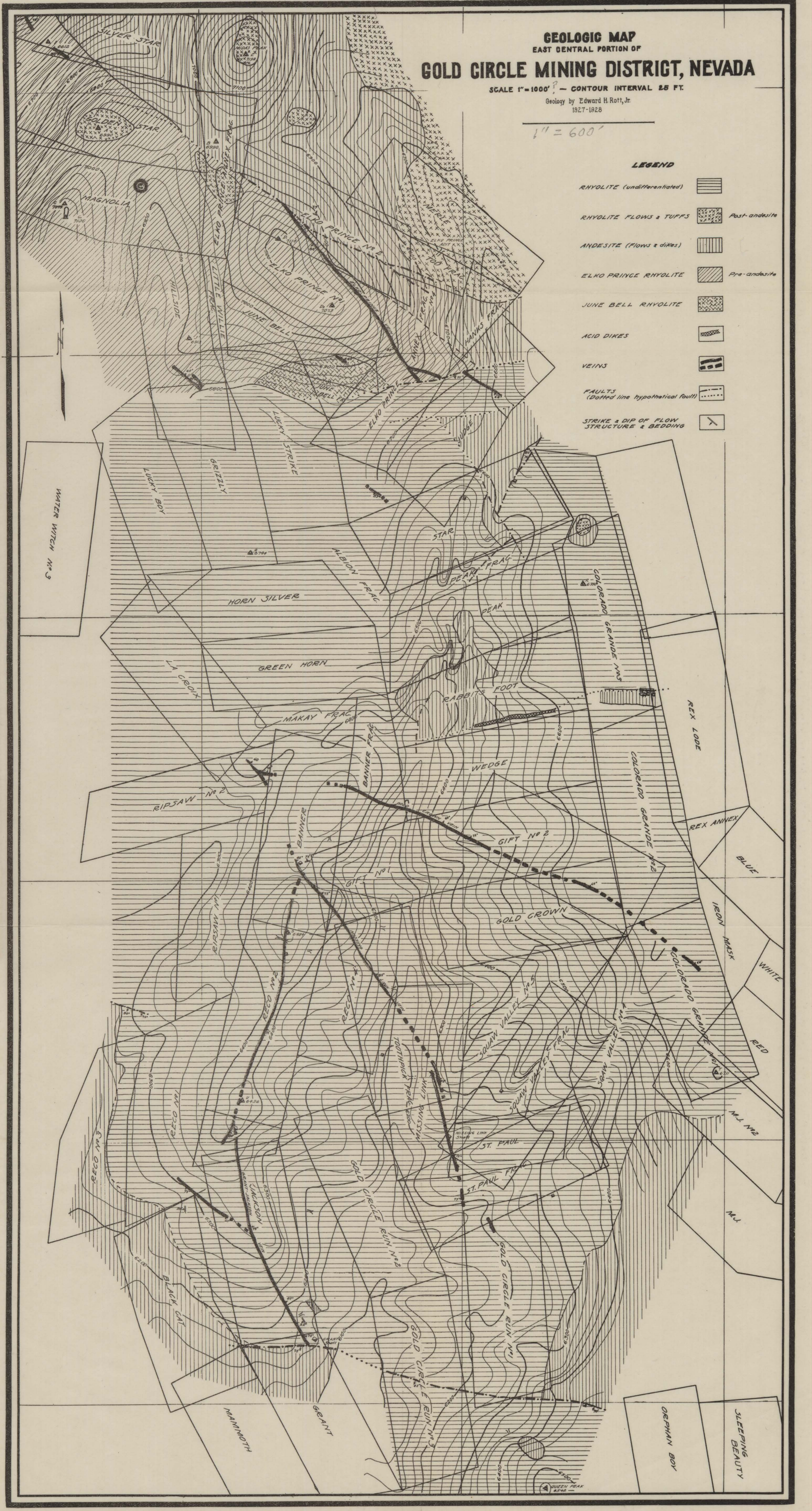

PLATE I