Structural Control of Mineralization

at the Aurora Mining District, Mineral County, Nevada

by

William R. Green

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INTRODUCTION

Location

The Aurora mining district is in southwestern Mineral County, Nevada, and is shown on the Aurora, Nevada 15-minute quadrangle of the U. S. Geological Survey. The area encompasses about four square miles in secs. 17, 18, 19, 20, and 30, T. 5 N., R. 28 E., Mount Diablo meridian. The ghost town of Aurora, in the northwest corner of the district, is three miles airline distance northeast of the California border, eight miles northeast of Bodie, California, 17 miles northeast of Bridgeport, California, and 22 miles southwest of Hawthorne, Nevada.

Access to Aurora is provided by a good, graded road from Hawthorne via Lucky Boy pass, Fletcher, and Nevada state highway 3C to a point six miles from the California border. From this point an unmain­tained road branches to the south and continues up a narrow canyon for four miles to the old townsite (fig. 1). Aurora can also be reached from the south along the extension of Nevada state highway 3C into California.
Figure 1. Index map of Mineral County, Nevada showing the Aurora mining district
This road passes through Bodie, and connects with U. S. 395 seven miles south of Bridgeport, California. During several months each winter the road becomes impassable because of heavy snowfall, and in the summer automobile travel is somewhat restricted by rough road surfaces and occasional washouts in Bodie Canyon caused by cloudbursts. However, four-wheel drive vehicles can traverse most routes.

**Climate and vegetation**

A semi-arid climate, typical of the moderate elevations in the western Great Basin prevails in the area. Ross (1961, p. 6) gives the following climatic data for Aurora:

<table>
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<th>Altitude</th>
<th>Yrs of record</th>
<th>January average (°F)</th>
<th>July average (°F)</th>
<th>Max. temp (°F)</th>
<th>Min. temp (°F)</th>
<th>Annual Precip. (in)</th>
</tr>
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<tr>
<td>7400</td>
<td>3</td>
<td>26°F</td>
<td>67°F</td>
<td>94°F</td>
<td>-6°F</td>
<td>7.08</td>
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Much of the precipitation occurs as snow during the winter, but violent rain storms of short duration are common in the summer.

Sagebrush covers much of the region, but patches of grass surround water seeps and springs. Well-developed pinon pine dot the district and, together with juniper, form scattered thick stands (fig. 2). A grove of aspen is found near the head of Cottonwood Canyon in the south-western part of the district.

**Surface features**

The Aurora mining district embraces four low hills called Silver, Middle, Last Chance, and Humboldt (plate 1). About two miles south of the district Brawley Peaks rise to an altitude of 9545 feet, and three miles
Figure 2. General view of the Aurora district, looking northwest from Middle Hill.
to the north, the rim of Aurora Crater is 7700 feet above sea level.

Altitudes within the district vary from 7100 feet in the north to 8400 feet in the south. Topographic relief is generally moderate, particularly in the northern half. However, weathering of rhyolitic rock has formed steep slopes and cliffs in some areas, and silicification near veins in adesite has created rugged cliffs in the southern part of the district.

Water and power supply

Water is available from wells, springs, and some of the deeper mine workings. The two small streams which drain the area are tributaries of Bodie Creek and are fed by several springs, but during the summer months they yield very little water.

The Prospectus tunnel was reported to have a discharge of 46 gallons of water per minute (Stickney, 1936, p. 10). However, this tunnel is now caved near its portal where it crosses the Prospectus fault, and during the summer of 1963, no water could be observed flowing from it. The lower workings of the Juniata mine and the Real Del Monte shaft encountered a large volume of water (Hill, 1915, p. 142) and could be considered the important sources of water in the district.

At the present time, the Aurora district has no electric power. The nearest source of supply is the Mineral County Power Company transmission line at Del Monte, about two miles away. In recent years operators in the district have used diesel-generator units to supply their power needs (J. R. Wilson, oral communication).
Present conditions

The present condition of the district is one of neglect and decay. The once thriving town of Aurora is uninhabited, and only a few buildings remain standing. Power and telegraph lines have been removed, and the Flying M ranch utilizes the entire region as open cattle range. Nearly all of the mines, with the exception of parts of the Juniata, are inaccessible and mining activity in the last few years has been limited to milling dumps.

Previous work

The earliest published geological report on the Aurora mining district was prepared by White (1868), who at that time was the Nevada state mineralogist. Hill (1915), while a member of the U.S. Geological Survey, spent three days mapping in the area in 1912 and later wrote a brief report including a small-scale geologic map and notes on the petrography of various rock types.

Several unpublished reports written by Bunker (1879), Farrell (1934), Rogers, Mayer, and Ball (1936), and Stickney (1936 and 1940) are in the possession of J. R. Wilson of Sparks, Nevada. Lundby (1957), while a graduate student at the University of Nevada, mapped an area bordering the Aurora district to the northwest. Ross (1961), while a member of the U.S. Geological Survey, wrote an extensive report on the general geology of Mineral County which included the Aurora district.
Purpose and scope of investigation

This investigation was designed to study the general geology of the Aurora mining district and prepare a large-scale geologic map as a means of interpreting vein and ore shoot configuration. During the course of the study, other data concerning location, description, and production of various mines were also collected and synthesized.

Field work was carried out during the months of August through November, 1963 and included mapping of the lithologic units and veins on an aerial photograph enlargement (scale approximately 1:7200) of exposure 70, row 6, CNL project of the U.S. Forest Service flown in 1940. No underground examination or sampling program could be conducted because the workings were inaccessible. Lithologic units were sampled on the surface.

Laboratory studies included preparation of a geologic map (scale 1:6000) and petrographic examination of thin sections. Correction for photographic error was accomplished by the direct tracing of geologic data from the original field sheet overlay on which claim corners had been recorded, to a transparent claim map. This method, as discussed by Campbell (1961, p. 368), is a rapid and accurate method of eliminating most of the displacement of photographic images imposed by topographic relief.
HISTORY

Early period

Ore was first discovered in the Aurora mining district by J. M. Bra-
ley, J. M. Cory, and E. R. Hicks in 1860. The three men had prospected
most of the summer without success until the morning of August 22, 1860
when they found silver ore near the summit of Silver Hill. They staked
four claims on the Esmeralda lode and took samples of the ore to Virginia
City to be assayed. By the end of the month when the results of the assays
became known, a rush to the Esmeralda district ensued, and by October
25, 1860, a total of 375 claims had been staked (Wasson, 1878, p. 44).

The ore extracted in this early period came from rich pockets on
the surface or from very shallow depths and contained higher gold than
silver values (Hill, 1915, p. 150). Ore from the Wide West vein assayed
by G. N. Shaw and Company of Virginia City, was reported in the "Mining
and Scientific Press" of November 3, 1860 to contain 485 ounces of silver
and 220 ounces of gold having a value of $5,445.00 per ton. Ore from the
Esmeralda lode was reported by the same source on January 18, 1861 to
contain $10,331.00 per ton. The price of gold and silver at this time was
$20.67 and $1.33 per troy ounce respectively.

The first ore was shipped from the district on November 10, 1860.
It was produced from the Esmeralda claim (M&SP, Nov. 30, 1860), and
shipped to Virginia City by pack mule. As the rush to the area continued,
the town of Aurora was formed and the mining area became known as the
Aurora mining district. However, the question remained as to which state it was in, California or Nevada. On March 24, 1861, Aurora became the county seat of Mono County, California, and on November 25, 1861, it became the county seat of Esmeralda County, Nevada as well. The controversy over the location of the state boundary was not resolved until September 16, 1863 when Aurora was found to be three miles east of the California Nevada state boundary (Wasson, 1878, p. 49).

In 1862, after nearly two years of unsystematic mining of outcrops, the first major ore shoot, the Wide West bonanza, was found on Last Chance Hill at a depth of 60 feet (Wasson, 1878, p. 45). This development gave new impetus to mining activity in the district and led to the discovery of other rich ore shoots adjacent to the Wide West including the Real Del Monte, Pond, and Chihuahua. The Utah and Antelope mines on Silver Hill also made significant discoveries. Most of the ore produced during this period averaged $150 per ton, while some ran as high as $300 per ton (M&SP, Sept. 7, 1863).

The first pan amalgamation mill in the district was erected in June, 1861 and by 1864 there were 17 such mills in the area (Wasson, 1878, p. 46). Production from all mills in the district amounted to just under two hundred thousand dollars per month (M&SP, Nov. 30, 1863). The thriving town of Aurora could boast of telegraph service, many brick buildings, and an estimated population of ten thousand.

Near the end of 1864, the district began to decline. The rich
deposits within 200 feet of the surface were becoming depleted, and shallow exploratory shafts yielded little encouragement. Litigation involving most of the important producers, together with a depression in the mining stocks, hastened the closing of most mines. Ore continued to be produced in the district for some time, however, as leasers salvaged the ore remaining in the underground workings. Inferior mining methods employed by these operators left the workings in irreparable condition.

Periodic attempts were made in the late 1800's to revive the district by deep exploration programs. In 1877, a group of business men, including John Mackay and J. G. Fair (Wasson, 1878, p. 52), started the Real Del Monte shaft on Last Chance Hill. The shaft reached a depth of nearly 900 feet in 1881, but attempts to keep it free of water failed and the project was abandoned (fig. 3).

Later an English company acquired most of the claims on Last Chance Hill. This company, which also failed to hold the water below the 800-foot level, confined its work to drifting on the 400-foot level to connect with the Durant shaft of Middle Hill, and to sinking the Humboldt shaft to a depth of 400 feet (Farrel, 1934, p. 2). However, efforts to discover ore at depth were unsuccessful, and operations were suspended in 1892.

Later period

Between 1906 and 1911, Cain Consolidated Mining Company of Aurora, which then owned most of the claims in the district, produced
Figure 3. Dump of the Del Monte shaft on Last Chance Hill.
some bullion by cyaniding old dumps and mill tailings (Vanderburg, 1937 p. 16).

In 1912, Cain Consolidated sold its interests to Aurora Consolidated Mines Company. This company drove a long adit to connect with the 400-foot level of the Humboldt shaft. Development work in the Humboldt and Prospectus areas resulted in blocking out nearly one million tons of ore that averaged $5.00 per ton (Mining & Eng. World, 1914, p. 62). A 500-ton per day mill was erected and an underground electric haulage system was installed.

In 1914, Goldfield Consolidated Mines Company gained control of Aurora Consolidated and started production. Operations were profitable for several years, but began to show a loss in 1917. Efforts were made to develop more ore reserves by extending the main haulage tunnel under the old workings of the Juniata (Hutchinson, 1917) and (Julian, 1918). Although some ore was produced from this area, apparently sufficient reserves were not developed and Aurora Consolidated closed its operations at the end of 1918.

Since that time, the only underground mining in the district was done by the Chessco Mining Company, which had some production from the Juniata mine in 1949 and 1950.

**Production**

Production records of individual mines have never been listed. However, during the course of this investigation, a list was compiled of
all mines in the district which yielded some ore and their locations given on plate 2. Mines having major production were:

Del Monte  Garibaldi
Wide West   Humboldt
Pond        Juniata
Chihuahua   Antelope
Johnson     Utah

The locations of the mines as shown on the map, indicate that although there were several areas of major production, mines with minor production were scattered throughout the district.

Production records for the district are incomplete. During the early days, much of the ore was shipped from Aurora to Virginia City and included in the production records of that camp. However, production from Aurora between 1860 and 1869 has been reported as nearly thirty million dollars (Hill, 1915, p. 142). During the next forty years, intermittent mining of old dumps and tailings yielded an estimated several hundred thousand dollars (Couch and Carpenter, 1943, p. 99). Production between 1910 and 1920 amounted to nearly two million dollars (Vanderburg, 1937, p. 15).

Using the above figures as a guide, it is reasonable to assume that the Aurora mining district has had a past production of between thirty and forty million dollars.
GENERAL GEOLOGY

Mesozoic rocks

The oldest rocks in the Aurora mining district consist of a metavolcanic assemblage which Ross (1961, pl. 2) mapped as part of the middle Triassic Excelsior formation. The corppings in the southeast part of the district near the head of Willow Gulch, occur as a small roof pendant in a granitic intrusive. Alteration accompanying intrusion, has produced an abundance of chlorite and epidote and given these metavolcanic rocks an overall dark green color.

An outcrop of an intrusive in the same area is deeply weathered and has a characteristic greenish-grey color. It is a phryritic granite containing large phenocrysts of pink orthoclase up to 50 mm in length. The intrusive is presumably part of the Sierra Nevada batholithic complex, a large igneous body, the main portion of which was intruded along the western margin of the Great Basin in Cretaceous time. Satellite intrusive bodies of similar composition and age are found scattered throughout a large area east of the main intrusive in western Nevada.

Tertiary rocks

Aurora volcanics: -- Altered volcanic rocks, which are host to all veins in the district, unconformably overlay the Mesozoic basement complex. Although their highly altered condition makes definite determination difficult, the rocks were originally siliceous to intermediate in composition. The groundmass is commonly dark grey to greenish-brown,
fine-grained, and thickly studded with white plagioclase phenocrysts. These phenocrysts, together with much of the groundmass, have been altered to sericite. Small cubes of pyrite commonly are disseminated throughout the rock, especially near the veins.

A fine-grained purplish rock is exposed in the northern part of Aurora townsite. When examined in thin section, this rock appears as moderately fresh andesite, possibly intrusive in character. This rock was not differentiated on the geologic map accompanying this report, and is considered to be a part of the volcanic sequence.

Hill (1915, p. 145) identified these volcanics as biotite quartz latite and associated andesite, and further stated that the andesite is probably intrusive but possibly interbedded. Ross's reconnaissance map (1961, pl. 2) shows them as pre-Esmeralda volcanics, a general map unit comprised of all early Tertiary volcanic rocks in the county. These rocks have been mapped as Aurora volcanics on plate 1.

**Bodie Canyon volcanics:** A sequence of younger volcanic rocks overlies the Aurora volcanics. A pronounced erosional unconformity marks the base of the unit. The basal contact is very irregular, indicating an old, buried topographic surface (Cross Section A - A', plate 3). This distinct hiatus indicates that uplift and erosion were taking place in the district during a time when clastics, shales and volcanics of the "Esmeralda formation" were being deposited in local basins throughout much of the region. The age of the hiatus would thus be equivalent to the Esmeralda formation, which has been found by Ross (1961, p. 46) to contain...
fossils which range in age from Miocene to early Pliocene.

The relatively fresh Bodie Canyon volcanic rocks cover the Aurora volcanics on the east, north, and west sides of the district (plate 1). Rhyolitic flows and associated tuffaceous rocks predominate, with lesser amounts of andesite interbedded and possibly intrusive within the sequence.

On the northern edge of the district, rhyolite contains small phenocrysts of quartz set in a fine-grained groundmass which is grey to light brown. Martinez Hill (Granite Mountain), in the eastern part of the district, is composed entirely of a tuffaceous rhyolite erosional remnant.

Aurora Peak, located just east of the district, is composed of biotite-hornblende andesite having a composition closely resembling that of an intrusive located three miles northwest of the district, and described by Lundby (1957, p. 13). Alteration near the contact between this rock and the rhyolite flows indicates that it is possibly intrusive in nature.

A porphyritic andesite is exposed on the western edge of the district, south of Aurora Creek and west of Cottonwood Canyon. It consists of a fine-grained groundmass containing plagioclase phenocrysts from two to seven mm in diameter.

Erosion of this younger volcanic sequence has created a three sided "window" or "keyhole", thus exposing the mineralization contained in the underlying Aurora volcanics.

Ross (1961, pl. 2) has mapped this sequence as "post-ESmeralda felsic volcanic rock", a term in his reconnaissance work which embraces
all late Tertiary siliceous volcanic rocks. These rocks have been shown as Bodie Canyon volcanics on plate 1.

Active vulcanism characterized the Tertiary of the Great Basin. Deposition began in early Tertiary and continued into the Quaternary however the bulk of the volcanic material was deposited during early to middle Miocene. The volcanics were derived from many widely scattered sources and are considered to have preceded or accompanied important faulting (Van Houten, 1956, p. 2820).

**Quaternary rocks**

A sequence of Quaternary basalt flows unconformably overlies late Tertiary volcanic rocks. The flows, which crop out in the northern part of the mapped area, were extruded from Aurora Crater, a small volcanic vent two miles north of the district (fig. 4). The flows are dark green, fine-grained, and are commonly vesicular near their base.

Aurora Crater is remarkably free from the effects of weathering and erosion, and hummocky relief and overturned flow structure (Hill, 1915, p. 144) along the present southern limit of the basalt indicate that very little erosion of this sequence has taken place.

Deposits of volcanic ash in several locations on Last Chance Hill have a variable thickness of twenty feet or less and consist of a fine-grained, unconsolidated material. Lundby (1957, p. 27) describes similar deposits north of the district as rhyolitic ash which was originally deposited in a thin layer over a large area and later eroded and
Figure 4. *Aurora Crater, from the south.*
redeposited in small local depressions. These deposits have not been shown on plate 1, but occur in the vicinity of the Johnson and Chihuahua mines.

Quaternary alluvium is present along most stream channels and in broad areas in the wider valleys. It consists entirely of locally derived sedimentary detritus.
The geological structure of the Aurora district is comparatively simple. Folding is negligible, and all of the Tertiary volcanic flows were observed in the field to dip gently and evenly to the north. Detailed work thus supports the earlier observations of Hill (1915, p. 143) and Lundby (1957, p. 30).

Faulting played a major role in the development of the mineral deposits and is the dominant structural feature of the district. Two systems are clearly evident. Both episodes of faulting are of Tertiary age, and the time interval between them is not believed to be great. An older system strikes from north 45° east to north 55° east, is cut by the other, which strikes more nearly north and south.

Northeast-southwest faults

The older system of faults cut the Aurora volcanics but not the younger volcanic rocks, and are of early to mid-Tertiary age. These faults, which dip from 30° southeast to 75° northwest, exhibit great continuity. Displacement is believed to have been principally along dip, although this cannot be clearly proved by surface evidence. Some strike displacement of lesser degree may also have occurred. Fracturing of vein filling and the presence of slickensides and fault gouge indicate that there has been post-mineral faulting. Nearly all of the ore bodies in the district have been found in faults of this system.

The northeasterly-striking faults follow a trend that is observed
in Tertiary faulting throughout western Mineral County. Ferguson and Muller (1949, p. 45) pointed out the marked parallelism between the trend of these faults and the trend of the Mesozoic folding.

**North-south faults**

The north-south faults, which commonly offset the northeasterly-striking faults, are actually shear zones which have steep dips and persist with continuity along strike. Most have displacements resulting from right lateral movement, but left lateral movement was observed in some of the faults on Silver Hill.

Most of the fault zones in this system are from 10 to 20 feet wide and have displacement of from 10 to 50 feet. However, the Prospectus fault zone, which cuts across the center of the district, has a width of nearly 100 feet (Stickney 1936, p. 8) and a right lateral strike-slip displacement of 1400 feet. This fault, which can be traced for more than two miles on the surface, is nearly vertical and strikes from north 20° east to north 20° west. Continued movement along this fault in late Tertiary times has offset the Bodie Canyon volcanic rocks in the northern end of the district (plate 1).

Movement along the north-south faults has been intermittent over a long period of time, and displacement has taken place before, during, and after at least one of the major periods of mineralization. The faults in this system have an apparent relationship to a regional pattern of right lateral, strike-slip faulting observed in the western margin of the Basin.
and Range province. Nielsen (1964, p. 157) described such faulting in the eastern part of Mineral County and placed it in late Cenozoic.

With the exception of the Esmeralda lode on Silver Hill, the north-south faults contain little mineralization. However, some of the zones do contain drag ore (Stickney, 1940, p. 4) and possibly some hypogene ore (Rogers, et al., 1936, p. 5).

Lundby (1957, p. 30) mapped and described a major north-south hinge fault in Bodie Canyon northwest of Aurora. He believes that the block to the east moved upward in relation to the western block, with displacement increasing to the south.
MINERAL DEPOSITS

Description of veins

Vein outcrops are usually conspicuous and, in some instances, stand 20 feet above the present erosional surface. The veins are complicated in structure and tend to branch into the surrounding rock. Angular fragments of wall rock are commonly enclosed in the quartz filling (fig. 5) and in some places, the veins actually consist of a number of closely spaced, reticulating stringers.

The veins vary in width from less than an inch to as much as 60 feet, and have an average width of about four feet. Most veins are wider near cross faults, but tend to be narrow and show horsetail characteristics at their extremes. All have good continuity, and some have been traced for more than 7,000 feet along the strike and to a vertical depth of 500 feet. Dips vary greatly throughout the district, but remain fairly constant along the strike of a given vein. At depth, however, the dip of a vein often changes notably (White, 1868, p. 92).

In most of the district, the veins have been offset by the barren north-south faults which also created tension fractures that were later filled with vein material. However, near the southern end of the district, a fault of the north-bearing system containing the Esmeralda lode has been offset by a barren fault of the northeast-striking system.

Minerals

The principal mineral deposits in the district are of gold and
Figure 5. Vein outcrop, showing typical inclusion of wallrock fragments.
silver. Base metal sulphides are notably absent, but "Mineral Resources of the United States" credits the district with a small shipment of lead ore (U.S. Bur. of Mines, 1929, p. 662).

Quartz is the main gangue mineral in all veins. An early, fine-grained quartz filling, almost porcelain-like in appearance, was fractured and re-cemented by at least one later quartz phase characterized by comb structure and crustified banding. The presence of some quartz with a lamellar texture indicates the replacement of earlier deposited calcite. Vugs lined with quartz crystals are common throughout the veins.

None of the lodes are continuously mineralized. Dark grey or blue streaks in the barren white quartz are common in proximity to ore. Hill (1915, p. 148) described these streaks as a very fine-grained assemblage of quartz, adularia, tetrahedrite, pyrite, chalcopryrite, free gold, and a silver-gold selenide. Stickney (1940, p. 2) stated that he found minor amounts of argentite.

Gold to silver ratio

The gold to silver ratio of the ore varies throughout the district. Lateral variation in the Au:Ag ratio between the northern and southern part of the area is evident. The richest ore was mined from the northern part and owed its value to a high gold content. Production from the Antelope, Utah, Cortez, and other important mines in the southern part, though significant, came from lower grade deposits having a lower Au:Ag ratio. Vertical change in the Au:Ag ratio is seen throughout the district.
White (1868, p. 94), in a general description of the veins of the area, states that gold is found in quantity usually above 100 feet in depth, but decreases below this point with the silver content increasing until a "barren" or low-grade zone is reached at about 200 feet in depth.

Hill (1915, p. 150) estimated the average Au:Ag ratio to be 2:1 for near surface deposits and 1:5 for deeper deposits. Ferguson (1929, p. 138) stated that the ratio was 1:14. Spurr (1923, p. 689), after an exhaustive sampling program, concluded that the Au:Ag ratio decreases from 1:2 in the northern part of the district, to 1:46 in the souther part. Taking all data into account, it would seem that Hill's Au:Ag ratio of 1:5 would be a representative average.

**Wall rock alteration**

Propylitic and sericitic alteration on the Aurora volcanics is found throughout the district. Younger volcanic rocks are essentially unaltered.

Propylitic alteration is widespread and intense, and consists of the formation of pyrite and chlorite at the expense of iron and magnesium minerals originally contained in the rock. Pyrite becomes much more abundant near the veins, and is commonly oxidized giving a brown stain to the volcanic rocks.

Sericitization is moderately strong near the veins, where it alters feldspar phenocrysts and groundmass alike. This alteration decreases with distance from the vein, but is present in minor amounts throughout the area.

Near the northern edge of the Aurora townsite, where the
Prospectus vein splits and branches, an argillic type of alteration is most prominent. Such alteration is also found along the northern edge of the district where it is localized along faults of the north-striking system (plate 1).

In the southern part of the district, intense silicification encloses both veins and zones of interfingering quartz veinlets (fig. 6). Rugged outcrops of the silicified zones are often several hundred feet wide.

**Ore shoots**

In the Aurora district, ore was deposited in shoots within the quartz veins, but characteristics of individual shoots were variable. In some veins, there were areas in which nearly all of the quartz had been mineralized to form large, low-grade, orebodies. In others, rich ore occurred in smaller lenticular shoots or pockets. High-grade shoots usually were contained within low-grade deposits, but sometimes were surrounded by quartz of noncommercial grade. Pockets of high-grade ore were found in vein outcrops by early day operators. These deposits were small, irregular, and did not continue to depth.

The large, low-grade, deposits were usually mineable over the entire width of the vein and had considerable length and depth. However, the distribution of values in these orebodies was variable, with the better grade ore usually occurring along the walls. At the Juniata mine, low-grade orebodies in three nearly parallel veins had lengths of 500 feet along the strikes, average widths of seven feet, and extended down the dip nearly
Figure 6. Silicified outcrop, showing interfingering quartz veinlets.
400 feet. Deposits of similar size were mined in the Humboldt and Prospectus mines.

High-grade shoots discovered at several widespread localities in the district produced most of the values. These shoots occurred as sheets or pipelike bodies, usually in the hangingwall portions of the veins, and were continuous for 50 to 100 feet down the dips. At the Esmeralda mine, a high-grade ore shoot was mined over a width of 2 1/2 feet for 70 feet along the strike and to a depth of 70 feet. This shoot was in the hanging wall of the Esmeralda lode at a point where the lode was 50 feet wide. At the Antelope (fig. 7), Utah, and Cortez mines, sheet-like orebodies were mined from the surface to a depth of 100 feet for several hundred feet along their strikes.

The richest and largest ore shoots discovered in the district were localized along a 1000-foot segment of one vein on Last Chance Hill in the Wide West, Johnson, Chihuahua, Pond, and Del Monte mines (plate 2). The deposits were similar, with the tops of all shoots being found about 60 feet below the surface, and the bottoms at a vertical depth of about 120 feet. Widths ranged from 16 to 36 feet, and all were mined for 100 to 200 feet along their strikes. Between the shoots, the veins were narrow and low-grade.

Control of mineralization

Evidence of lithologic control of ore deposition within the pre-Esmeralda volcanic rocks was not observed. Structural control, especially continued movement along faults of the north-south system, is the most
Figure 7. Stopes along the Antelope vein.
important factor in the localization of ore deposits.

There is a close spacial relationship between ore deposits and the north-south faults. Nearly all production of gold-rich ores came from mines located within 500 feet of faults of this system. The extremely rich shoots on Last Chance Hill all lie within 300 feet of either the Prospectus or Johnson faults (fig. 8).

Veins filling tension fractures along the north-south faults indicate that movement took place before at least one period of deposition. As these same faults offset the veins, it is apparent that movement continued after the last period of deposition. This continued movement, particularly where two faults were relatively close together, caused re-fracturing of the veins at and near their intersections with the faults. Openings resulting from re-fracturing permitted enrichment of the veins by hypogene, and later by supergene, solutions.

Successive periods of mineralization with gold content increasing in the later solutions, is the most probable explanation for the lateral variation in the Au:Ag ratio discussed earlier. This type of mineralization has been found at Oatman, Arizona (Lausen, 1931, p. 72), and possibly at Silver City, Idaho (Piper and Laney, 1926, p. 57). In nearby Bodie district, successive periods of mineralization are progressively richer in gold (Wisser, 1960, p. 77). Data gathered during the present investigation, although not conclusive, indicate that there were at least two phases of quartz filling and that the later phase contained the higher grade ore (Rogers, et al., 1936, p. 6). North-south faults having major displacements
Figure 8. Relationship between ore deposits and north-south faults
cut the veins only in the northern part of the district. Continued movement along these faults is thought to have re-opened the veins in this area so that later gold-rich solutions were able to fill the new openings, thereby enriching the original deposits.

The vertical zoning of gold-silver values, described earlier, is prevalent throughout the district. Higher gold values found near the surface decreased and silver values increased as depth was attained. The bottom of the high-grade ore was reached at a depth of less than 200 feet, even though the altitudes of the outcrops varied as much as 800 feet. Therefore, it is evident that supergene processes were an important factor in the development of the ore deposits.

Silver, and perhaps gold, was leached from the surface deposits by acidic ground water, carried downward by the descending water, and redeposited at or near the water table. The primary ore was enriched by this process. As several hundred feet of the Aurora volcanics were eroded, the surface, as well as the water table, was continually being lowered. In this manner, the enriched ore was eventually leached and redeposited at a new water table, so that the high-grade deposits consisted of a concentration of the values originally contained in several hundred feet of vein.

A primary requirement for supergene enrichment is a permeable host rock through which fluids can pass easily. The quartz veins of Aurora are, in most locations, dense and impervious. However, the continued movement along the north-south faults shattered and re-opened
the veins so that zones were created along which the downward-moving solutions could travel. Here then, permeable zones coincide with areas of hyogene enrichment, and extremely rich shoots such as those on Last Chance Hill resulted.

### Classification and origin of deposits

Textural and mineralogical characteristics indicate that the ore deposits of the Aurora mining district belong to that general group of deposits classified as epithermal by Lindgren (1928, p. 516). Such deposits were formed relatively close to the surface where low temperatures and pressures prevailed.

The Au:Ag ratio of 1:5 would further classify the Aurora deposits as belonging to the silver-gold deposits as defined by Ferguson (1929, p. 131) and later discussed by Nolan (1933, p. 625).

No intrusive rock outcrops in the district that can be considered genetically related to the ores. It is believed, therefore, that primary ores were deposited by hot ascending solutions which were derived from a deep magmatic source. The faults of the north-south system served as conduits for the mineralizing solutions, but because of their comparatively tight nature, did not, for the most part, provide favorable loci for ore deposition.

The ore deposits of the district are even more limited in vertical extent than is usual in deposits of this type, indicating that considerable erosion of the veins may have taken place. The veins are therefore
considered to have been formed prior to the erosion represented by the hiatus between the Aurora and Bodie Canyon volcanics. It has previously been stated that this hiatus occurred during late Miocene to early Pliocene. This would limit the vein formation to middle to late Miocene time.
EXPLORATION POSSIBILITIES

Past exploration in the district has been directed toward the discovery of extensions of known orebodies. Over the years, the area has been intensively prospected, particularly in the vicinity of the high-grade deposits on Last Chance Hill, and it does not appear that any new or unknown veins of significant character will be found. The original orebodies did not extend to more than 200 to 300 feet of depth and deep exploratory shafts and crosscuts seem to have exhausted the possibility that downward extension or deeper blind ore deposits will be found within the area.

There are, however, unexplored areas which offer definite possibilities. These areas are covered by the Bodie Canyon volcanic rocks which are younger than the veins. In the eastern part of the district, strong veins pass under the volcanic cover and little exploration has been done to follow them. Projections of some of the faults of the north-south system also continue into areas covered by the younger volcanics. Field investigation indicates a good possibility that structural controls similar to those of the known orebodies will exist under this covering, and it is a reasonable assumption that ore deposits might be found. As it is known that the Aurora volcanics were eroded before they were covered by later flows, the conditions necessary for supergene enrichment are present and ore of a comparable grade to that already extracted, might exist.

The veins and the north-south faults both have strong continuity,
and by careful mapping, it would be possible to predict within close limits the positions of their intersections. Field mapping indicates that several of these hidden intersections may lie reasonably close to the edge of the cover rock. It would be possible to inspect some of these intersections by extending open underground workings for only a few hundred feet. Most of the favorable areas could also be explored from the surface by diamond drill holes having lengths of 200 to 300 feet.
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