contains the greatest number of quartz veins, into a fine-grained substance, composed mainly of quartz, calcite, brown mica, and chlorite, by the addition of potash.

Knopf[1] has noted a similar alteration of the igneous rocks in the northern end of the Juneau belt by a large introduction of albite, the conversion of the hornblende and other amphiboles into biotite, and the introduction of apatite. This alteration shows a large addition of soda and potash demanded by the formation of albite and biotite, and a heavy loss of magnesia, lime, and iron. Knopf concludes that the mineralizing solutions were rich in soda and potash and that they were hot, ascending waters of deep-seated origin.

Spencer[2] has recently found a similar alteration of quartz monzonite in the Ely district, Nev. He finds the most intense alteration along zones of crushing and concludes that the alteration was produced by hot aqueous solutions carrying soda and potash which have changed the hornblende, plagioclase, and magnetite of the original rock into sericite and biotite and have deposited pyrite, chalcopyrite, calcite, and possibly quartz.

Rockland mine.—The Rockland mine, situated about 3 miles southeast of Pine Grove, though not visited, is presumably of the same type of ore deposits as the Wheeler and Wilson mines and may be on a continuation of the same fault zone, though it seems more probable that it lies in another zone of fracture. The "vein" is said to strike northwest and to dip 45°–55° NE. The footwall is the dark altered quartz monzonite and the hanging wall a "light-colored porphyry," presumably the intrusive granite porphyry, though it may be the rhyolite. The property is developed by three drift tunnels. The ore is said to contain very little copper, the value being chiefly gold and silver, the bullion having a value of $15 an ounce.

There is said to be a 20-stamp amalgamation mill on the property, lately installed to replace a dry process mill, which was unsuccessful on account of the large quantity of clay in the ore.

FUTURE OF THE DISTRICT.

This type of ore has probably been formed at considerable depth, for the accompanying alteration, as pointed out by Lindgren,[3] is such as to preclude the theory of shallow deposition. It seems probable, therefore, that the mineralization along the fault zone will continue for a considerable distance below the surface. It is to be expected, and is already shown in the lower workings of the Wilson, that the grade of the ore will not be as high as at the surface, but the unaltered sulphides at a depth of 250 feet carry $10 a ton, and ore of even lower grade has been successfully worked at numerous places. This pyritic ore, with such a small proportion of copper minerals, is amenable to cyanide treatment, and it seems entirely possible that if a sufficient quantity of ore can be treated the properties could again be producers. In fact, reports in the mining journals indicate that these mines are to resume production in the near future.

[1] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 36–41, 1912.

[2] Unpublished manuscript.

[3] Lindgren, Waldemar, Metasomatic processes in fissure veins: Am. Inst. Min. Eng. Trans., vol. 30, pp. 609–645, 1901.

AURORA (ESMERALDA) DISTRICT, MINERAL COUNTY, NEV.

LOCATION AND ACCESSIBILITY.

The old Esmeralda mining district at Aurora, Nev. (No. 14, Pl. I, p. 18), is 28 miles in an air line southwest of Thorne, a town on the Hazen-Tonopah branch of the Southern Pacific and its nearest railroad point. The town of Aurora is 3 miles east of the California-Nevada boundary, 16 miles north of Mono Lake and 1½ miles east of Bodie Canyon. The region is shown near the center of the west side of the Hawthorne topographic sheet of the United States Geological Survey.

The district is most easily reached by the automobile stage which runs daily between Hawthorne, Nev., and Bodie, Cal. It is possible to enter this part of Nevada by way of Minden, the southern terminus of the Virginia & Truckee Railway. Stages operate between that town and Wellington and thence south to Bodie, Cal., but the trip requires three days in contrast to the half-day run from Hawthorne.

HISTORY AND PRODUCTION.

The Old Esmeralda, near the southern limit of the productive area (see Pl. XVI, *A*, p. 148), was the first vein discovered in the Aurora district. According to Wasson,[1] James M. Brawley, J. M. Cory, and E. R. Hicks made the discovery on August 22, 1860, and immediately located four claims. The town of Esmeralda was built in the gulch just east of the discovery, but later in the year the present town site of Aurora, 1½ miles north, was laid out. The first mill, owned by Edmund Green, was put in operation in 1861, and was followed shortly by several arrastres and mills. In 1864 there were 17 amalgamation mills in the district, the largest, which had 30 stamps, being the Real Del Monte in Bodie Canyon. Up to the year 1864 the camp was very prosperous. Aurora had a population of about 10,000 and was the county seat of Mono County, Cal. During the year 1864, however, misfortunes befell the camp. The California-Nevada boundary was run and showed that the Esmeralda district lay in Nevada;

[1] Wasson, Joseph, Bodie and Esmeralda: a pamphlet published in 1878 by the Mining and Scientific Press, San Francisco, Cal.

the rich bonanzas in the Wide West vein on Last Chance Hill became exhausted and bitter litigation over the ownership of the veins on Last Chance Hill developed. The camp, however, continued to prosper until 1882, though the supply of $75 ore, which in earlier times could not be mined, was then becoming depleted. In 1880 an English company acquired possession of the main group of claims on Last Chance Hill. It began operations in 1887, starting the Real Del Monte shaft and connections with the Durant vein on Middle Hill, but suspended work in 1892 after a vain effort to keep the lower workings of the 800-foot shaft free from water.

Most of the claims in the Esmeralda district were owned in July, 1913, by two companies, the Cain Consolidated Co. and the Aurora Mines Co. The Aurora Mines Co.'s chief group, containing 11 claims, lies on Silver Hill, though they own 5 claims on Aurora Hill. The Cain Consolidated Co. controls about 40 claims, among which are some of the famous producers of the district. In the summer of 1912 these holdings were under option to certain financiers of Tonopah, Nev., who have, according to reports of the mining journals, taken up the ground and started operations.

Most of the productive ground of the district has now been acquired by the Goldfield Consolidated Mining Co. A 500-ton cyanide mill has been built, and there is every prospect that Aurora will again be a producing camp.

The records of production are incomplete. According to a statement of Wells, Fargo & Co. the bullion shipped through them up to 1869 had a value of $27,000,000. Mr. Wasson[1] gives the following table of gold bullion shipped without insurance:

Bullion shipped from Aurora without insurance from 1861 to 1869, inclusive.

1861	$43,417.28	1867	$130,656.89
1862	173,148.82	1868	98,188.88
1863	546,019.16	1869	28,166.50
1864	952,023.29		
1865	237,185.23		2,365,968.82
1866	158,162.77		

He further says that between seven and eight million dollars' worth of bullion was shipped by express in 1864 and about $12,000,000 prior to the year 1869. If the reports of production of some of the stopes are taken into consideration, even so large a sum as $27,000,000 seems a small showing for the camp.

TOPOGRAPHY.

There are four rather low hills south and east of the town of Aurora (see Pl. XIV), known as Silver, Middle, Last Chance,

[1] Wasson, Joseph, op. cit.

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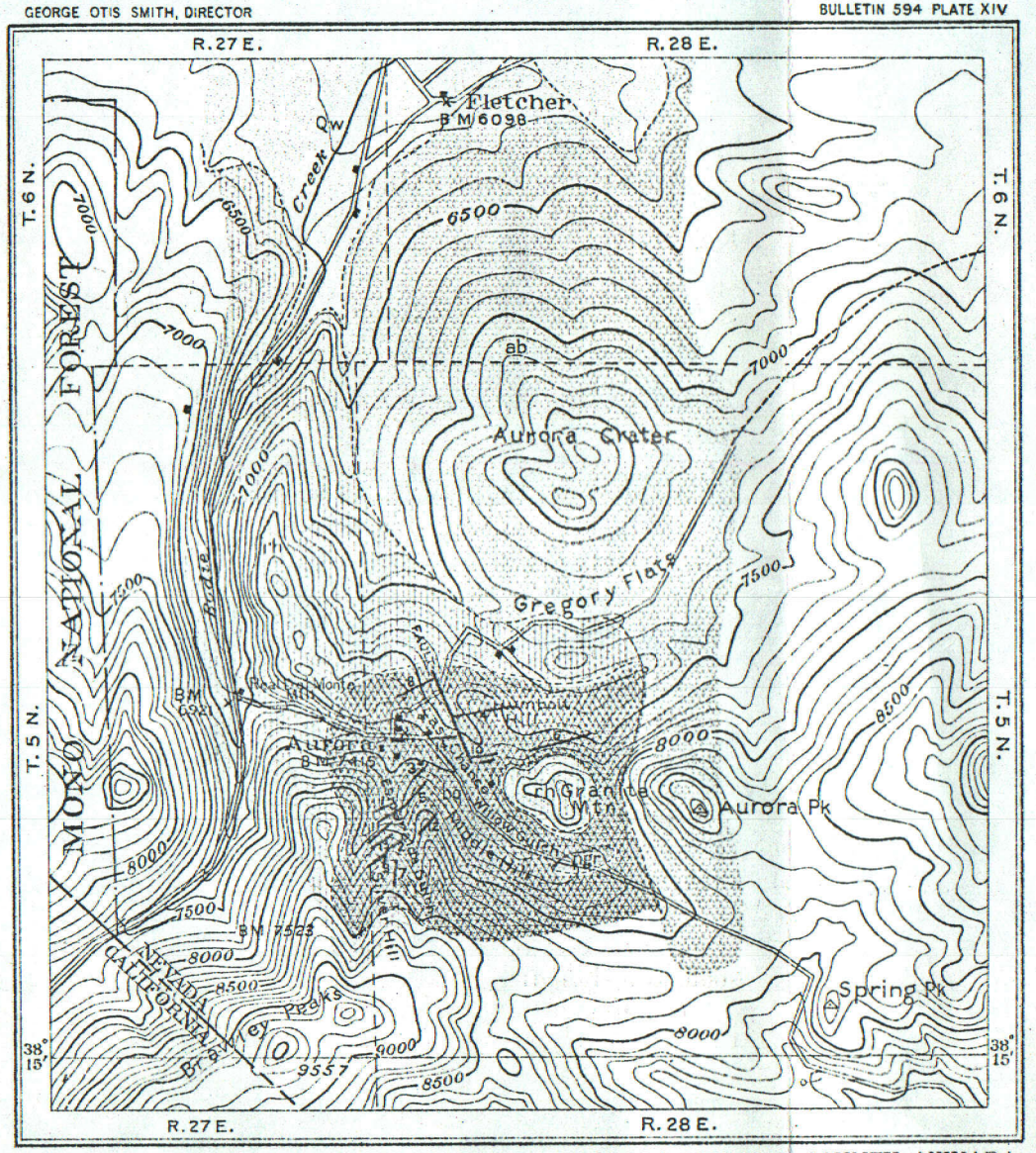
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 594 PLATE XIV



LEGEND

- Qw — Quaternary wash
- ab — Augite basalt (*Cap rock*)
- rh — Rhyolite tuffs and flows
- bq — Biotite-quartz latite and associated andesite porphyries
- pgr — Porphyritic granite
- 9/2 — Veins (*Numbers refer to list of names*)
- Fault

LIST OF VEINS

1 Antelope
2 Bald Eagle-Spotted Tiger
3 Durant
4 Humboldt-Silver Lining
5 Live Yankee
6 Martinez-Juanita
7 Old Esmeralda
8 Prospectus
9 Radical
10 Real Del Monte
11 Sonora
12 Summit
13 Utah-Cortez
14 Wide West-Last Chance

GEOLOGIC SKETCH MAP OF THE VICINITY OF AURORA, MINERAL COUNTY, NEVADA

Base from topographic map of the Hawthorne quadrangle

1 ½ 0 1 2 3 4 Miles

Contour interval 100 feet
Datum is mean sea level
1914

and Humboldt. The town has an elevation of 7,415 feet above sea level. Silver and Middle hills are separated by Esmeralda Gulch. They are long, northward-sloping spurs from the Brawley Peaks, which rise to a height of 9,557 feet about 2¼ miles south of the town. Last Chance Hill, east of Aurora, is a low divide, less than 150 feet above the valley, which separates Willow Creek from the Gregory Flat drainage basin. Humboldt Hill, a low rounded knob about three-fourths of a mile northeast of Aurora, rises to a height of a little over 7,600 feet. The mines of the Aurora district are located on these four hills, though at the east end of the flat north of town and about 150 feet higher there are a few veins near Humboldt and Last Chance hills.

GEOLOGY.

CHARACTER AND DISTRIBUTION OF THE ROCKS.

The rocks exposed in the Esmeralda district are, with a single exception, of volcanic origin. In the bottom of Willow Gulch, about 2 miles southwest of Aurora (see Pl. XIV), there is a small, indistinct exposure of a rock that appears to be the basement on which the flows were extruded. It is a coarsely porphyritic, granular rock, and is probably to be correlated with the granodiorite and associated rocks of the Sierra Nevada. At least three series of flows overlie this granular rock. The oldest of these flows consists of grayish-green altered rocks that are largely biotite-quartz latites, together with some andesites. This series is exposed on Silver, Middle, Last Chance, and Humboldt hills, and extends southeast up Willow Gulch for an unknown distance. These rocks, which are at least 900 feet thick, inclosed all the veins of the district, none being found in the younger rocks.

Above these flows of intermediate chemical composition lies a series of light-gray to brownish-gray rhyolites that are particularly well exposed on the flats north and northwest of Aurora along Bodie Creek, where they are 1,000 feet thick, and also on Granite Mountain, about 1 mile southeast of town, where there is a remnant of the series about 300 feet thick. Above both the andesites and rhyolites lies a black vesicular basalt that forms Aurora Crater (see Pl. XIV) and covers a large expanse of country to the west of Granite Mountain. It ranges from about 10 to over 600 feet in thickness. Its weathered surfaces are brown.

All these flows appear to have a gentle dip to the north-northwest. It seems probable that there was a time of erosion between the andesite and rhyolite eruptions, as the rhyolite flows rest on an uneven surface that looks like an erosion surface.

There was unquestionably an interval of considerable length between the rhyolite and basalt eruptions, for the base of the later

flows rests in the bottoms of gulches in some places and on the tops of ridges at other places.

The latites and associated andesites seem to have been exposed by the erosion of the capping rhyolite along the Willow Creek drainage basin, and Granite Mountain seems to be a remnant of this capping which escaped erosion. It does not seem probable that the basalt ever extended much beyond its present limits, as shown on Plate XIV, for the edges of the flows are fresh and in some places along the gulch northeast of Gregory Flats show the piled-up, overturned marginal portions of quickly cooled lava sheets.

TOPOGRAPHIC EXPRESSION OF THE DIFFERENT ROCKS.

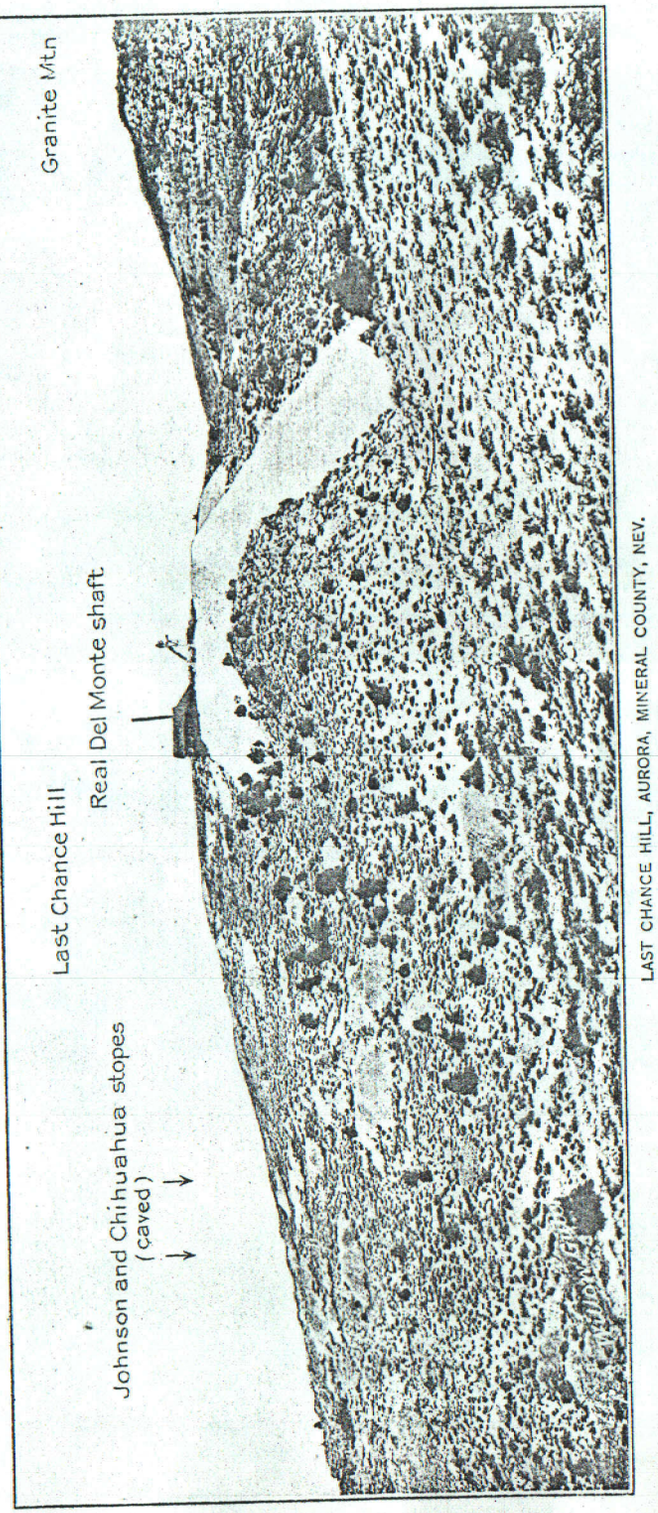
The oldest flow rocks are all much altered and are rather easily eroded, except where they have been silicified near the veins. As a consequence the mineralized hills have, as a rule, even and rather gentle slopes, as is shown in the view of Last Chance Hill (Pl. XV). At the southern end of Silver Hill, where the rock is much silicified near the Bald Eagle, Spotted Tiger, and Radical veins, the generally smooth andesite surfaces are interrupted by steep cliffs, as shown in Plate XVI, *A*.

The rhyolite series weathers in rough cliffs and the surfaces of the flows are marked by small steep-sided gullies. On the long ridge northwest of Aurora, near Bodie Creek, the topography suggests the badland forms at many points, especially on the northeast side of the ridge.

The surface of the basalt flows is very rough, making the crossing of these areas difficult, even on foot. Aurora Crater is a basaltic vent, the northwest rim of which has been cut through by erosion. It is a beautiful example of a small volcano, with the successive flows clearly traceable on its rough scarred sides.

PETROGRAPHY.

Porphyritic granite.—The single exposure of porphyritic granite in the district lies in the bottom of Willow Gulch, about 1¼ miles southwest of Aurora. Its boundaries are not well shown on account of the wash, but the andesitic flows clearly rest on this basement. The outcrop is small and deeply weathered, practically no fresh rock being visible. Numerous large pink orthoclase crystals, the maximum length being 2 inches, are present in the residual sand covering part of the area. The weathered surfaces have a light greenish-gray color, owing to the alteration of the constituents. The rock is rather coarsely granular throughout and contains very large, zonally built, pink orthoclase phenocrysts.



LAST CHANCE HILL, AURORA, MINERAL COUNTY, NEV.

Shows gentle slopes of andesitic flows.

In thin sections the groundmass of this coarse porphyry is seen to be inequigranular. None of the minerals, except the phenocrysts and accessory minerals, show any crystal form. The minerals present in this rock, named in the order of their abundance, are orthoclase, quartz, microperthite, green hornblende, brown biotite, microcline, muscovite, and oligoclase. The accessory minerals are titanite, magnetite, and apatite. The ferromagnesian minerals are somewhat chloritized, and the feldspars are more or less kaolinized. Some of the muscovite appears to be primary, but part, at least, is bleached biotite. The titanite and magnetite are closely associated and intergrowths of these two minerals are common.

Biotite-quartz latite.—The general country rock on the hills in the vicinity of Aurora, in which the veins are found, is a greenish-gray to gray altered porphyry which ranges from rather fine to medium grain. Few of the phenocrysts are more than an eighth of an inch in diameter, and most of them are less. The most widely distributed type of rock has a fine-grained greenish-gray groundmass, thickly studded with small white lath-shaped phenocrysts. All the rock of this type carries some disseminated pyrite, which is particularly abundant near the veins.

The thin sections show that this rock originally consisted of phenocrysts of andesine, biotite, and possibly pyroxene, set in a fine-grained matrix of andesine, with some ferromagnesian minerals. Small interstices of the groundmass contain intergrowths of quartz and orthoclase. The rock is a biotite-quartz latite. All the rocks are very much altered, presumably by the hot calcareous solutions which deposited the veins. The andesine phenocrysts are altered to calcite, sericite, some quartz, and some of them show a little green epidote. The ferromagnesian minerals are completely altered to chlorite and some magnetite. The groundmass is altered to an aggregate of sericite, chlorite, and quartz. Near the veins the alteration has been much more intense than at a distance of 150 to 200 feet from them. In these highly altered zones quartz has been added to the body of the rock, which is also cut by stringers of quartz and calcite. Sericite and epidote are also much more abundant in the rock near the veins, whereas chlorite is more commonly developed in the rock at a distance from the veins.

Andesite.—Near the bottom of Esmeralda Gulch, 1 mile south of Aurora, there is a fine-grained light-green porphyry apparently intrusive into the biotite-quartz latite, though it may be an underlying flow. This fine-grained dark rock is exposed in several other localities in the district, and it is probably rather widespread in distribution.

This rock is much altered and contains disseminated pyrite in small quantities and is cut by quartz and calcite stringers.

Thin sections of this rock show that its groundmass is composed of microscopic lath-shaped crystals of andesine and augite, the latter mineral altered to chlorite. In this groundmass are set small well-developed phenocrysts of zonally built andesine and of augite, both of which are altered, the augite to green chlorite and the feldspars to grayish aggregates of sericite and chlorite.

Rhyolites.—The rhyolite series is made up of a number of relatively thin flows, all of which are glassy. They range in color from gray through green to purple. Some of them appear to be tuffaceous, but the majority are typical flow rhyolites. On the flat north of Aurora some pearl-gray perlitic rhyolites are seen near the top of the series. Flakes of biotite are seen in all of these rocks, and quartz can usually be detected with the unaided eye. Thin sections show that the rock consists of a glassy base having, as a rule, distinct flow structure, which contains a few phenocrysts of quartz, orthoclase, and biotite. Some of the slides show that the groundmass suffered some devitrification, accompanied by the development of chlorite and sericite.

About one-fourth of a mile southeast of the Old Esmeralda Tunnel a small, indistinct body of rhyolite has been altered to a soft white mass by hydrothermal action, but the flows at other places show no alteration by hot waters.

Basalt.—The basalt of Aurora Crater is a very fresh vesicular black rock showing a few small green olivine crystals to the unaided eye. Under the microscope the groundmass is seen to be composed of microscopic labradorite laths and grains of nearly colorless augite set in a black glass paste. The flow structure is well shown by the rough parallel orientation of the long dimensions of the plagioclase laths, many of which bend around the vesicular openings.

QUATERNARY GRAVELS.

The Quaternary deposits on lower Bodie Creek, shown at the top of Plate XIV, consist of unconsolidated sands, gravels, and silts, which a little north of the area shown on the map are quite thick and extensive. The surface is covered by fine sandy loam, which under irrigation has produced excellent crops.

On Last Chance Hill there is a small area underlain by roughly stratified volcanic material, shown in the caved Chihuahua stope. (See Pl. XVI, *B*, p. 148.) This material ranges from a few feet to a maximum of 20 feet in thickness and appears to have been reworked by streams.

In the canyon northwest of Gregory Flats and about 1½ miles due north of Aurora a warm spring issues from beneath the basalt

of Aurora Crater. This spring deposits limonite and aragonite. The aragonite forms crusts from one-fourth inch to 4 inches in thickness, though most of the crusts are less than 2 inches thick. The entire deposit covers an area about 150 feet square to a maximum depth of 15 feet.

ORE DEPOSITS.

Distribution of the veins.—The ore deposits of the Esmeralda district occur as veins that cut the biotite-quartz latite and associated andesite over an area extending in a northeast-southwest direction, about 2 miles in length by 1¼ miles in width. Aurora is near the center of the northwest side of the productive area. On Silver and Middle hills the veins are rather closely spaced and have, with one exception, a persistent strike of about N. 45° E., though strikes between N. 40° E. and N. 50° E. are seen in many places, even along veins whose average course is N. 45° E. These veins all dip to the southeast but at different angles. The largest and apparently the strongest veins—that is, the Eureka, the Antelope and Lady Jane, the Cortez and Utah, and the Spotted Tiger and Bald Eagle veins—all dip between 45° and 60° SE. into the hill, but some of the smaller veins slope southeast at much flatter angles. An exceptional vein system on Silver Hill is represented by the Old Esmeralda and Radical veins, which strike about N. 10° E. and stand nearly vertical. The outcrops of these veins are wider than any of the northeast-southwest system, the Old Esmeralda being 60 feet wide and the Radical between 20 and 30 feet in maximum width.

On Last Chance and Humboldt hills the veins strike more nearly east and west, ranging between N. 60° E. and N. 80° E., and with the exception of the Humboldt and Prospectus veins, which dip 80° N., they dip to the west-southwest at angles ranging between 65° and 75°. Some of the smaller veins have flatter dips, but the strong, well-defined ones stand more nearly vertical. The veins on these two hills have been displaced by a nearly vertical fault, whose strike ranges from N. 20° E. at the Humboldt vein to N. 30° W. at the Real Del Monte vein. The horizontal displacement along this fault has amounted to over 600 feet, the veins west of the fault being at least that far north of their continuation on the eastern side. Thus the Humboldt vein on the east side of the fault along the crest of Humboldt Hill is the Prospectus west of the fault. (See Pl. XIV, p. 142.)

It is said that about 6 miles northeast of Aurora lies a small area of andesite in which there are some veins, but the locality was not visited.

Character of the veins.—The veins of the Esmeralda district range from a fraction of an inch to 70 or even 80 feet in width. They are

as a rule between 18 inches and 4 feet wide, and can generally be traced for several hundred feet along the strike. They are not simple, clean-cut veins, but send off numerous small interlacing branches into the walls, particularly on the footwall side. This tendency of the veins is well seen on the edge of the Old Chihuahua stope on Last Chance Hill. (See Pl. XVI, *B*.)

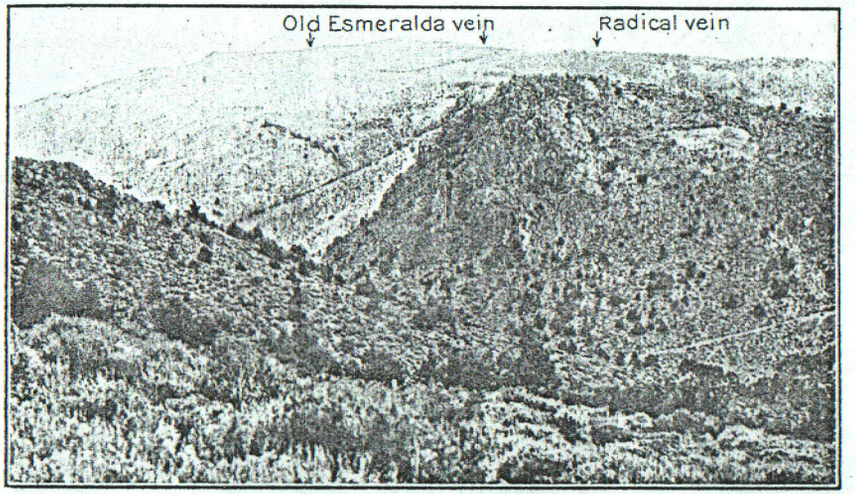
Along some of the veins there has been postmineral movement. This movement has usually taken place along the hanging wall and has been slight, producing in most places a thin clay parting between the country rock and quartz.

The veins consist in great part of finely granular, white, barren-looking quartz. In some places the quartz is so fine grained that it has a milky-white porcelain-like appearance. The veins are banded by crustification, the different bands being due to the difference in size of the quartz grains. In all the veins there are small druses lined with minute clear quartz crystals. The rich ore is always marked by irregular wavy streaks of what appears to be dark quartz, cutting the white low-grade or barren vein filling. (See Pl. XVII, *A*.) In reality these rich streaks are made up of quartz, adularia, argentiferous tetrahedrite, and small amounts of pyrite and chalcopyrite, together with a soft bluish-gray mineral supposed to be a combination of gold and possibly silver with selenium. Some free gold is found here and there in the richest ore now mined, and the old stopes are said to have contained large quantities of free gold.

The adularia is notably absent from most of the white barren quartz, but was found in soft, narrow kaolinized bands in white quartz ore from the Humboldt shaft. In practically every thin section of the ores studied there is a small amount of sericite in thin flakes cutting the quartz crystals. In all the thin sections of very rich ore adularia is abundant, being associated with the quartz and commonly inclosed in the interlocking quartz grains. As a rule the rhombic forms of adularia are not seen, the mineral occurring in irregular masses.

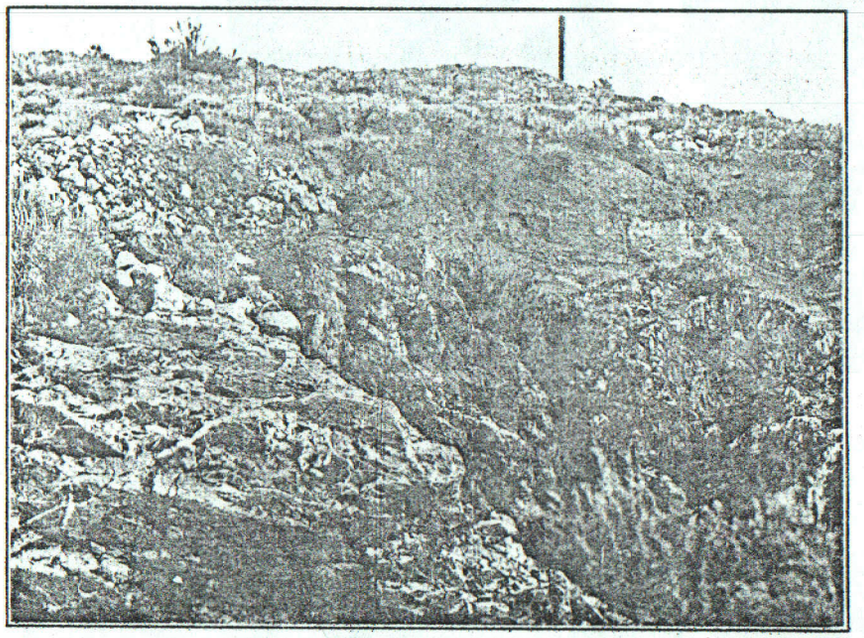
Qualitative tests of a small piece of rich ore from the 350-foot level of the Durant vein at Aurora show the presence of selenium but no tellurium. It also contains a rather large quantity of iron and copper, smaller quantities of silver and gold, and some antimony. A polished section and thin section of this ore show the undoubted presence of pyrite, chalcopyrite, tetrahedrite, and free gold. There is also a small quantity of a soft bluish-gray mineral, that is distinct from the tetrahedrite, which is thought to be a selenium-gold and possibly silver compound. This mineral occurs in minute specks and could not be separated from the other constituents.

U. S. GEOLOGICAL SURVEY BULLETIN 594 PLATE XVI



A. SOUTH END OF SILVER HILL, AURORA, MINERAL COUNTY, NEV.

Shows croppings of Old Esmeralda vein and cliffs where andesitic flows are silicified at the junction of several veins.

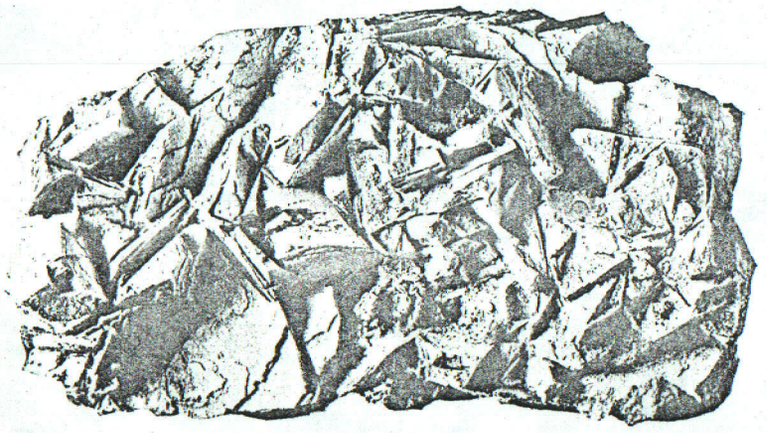


B. CHIHUAHUA STOPE ON LAST CHANCE HILL, MINERAL COUNTY, NEV.

Branching veins in footwall of main vein at left and stratified volcanic material in right center.

A. STREAK OF RICH ORE FROM SPOTTED TIGER VEIN.

Natural size.



B. ORE FROM A SMALL VEIN CUT BY THE MONARCH TUNNEL.

Shows typical quartz-adularia mineralization after calcite.

The presence of selenium without tellurium sets these veins apart, for there are only a very few mining districts in the United States where this combination of ores is found.

Spurr[1] says that at Tonopah the veins are chiefly due to replacement of the andesite by quartz and the ore minerals along zones of fracture. Crustified veins clearly due to filling of open spaces are exceptional at Tonopah. The mineralizing agent he considers to be "volcanic waters that were hot and ascending." The primary ores at Tonopah, according to Spurr, contained quartz, adularia, carbonates of lime, iron, magnesia and manganese, silver sulphite, probably polybasite or stephanite, and argentite, silver chloride, chalcopyrite, pyrite, galena, sphalerite, and gold in an undetermined form, and silver selenide.

At Republic the veins which seem to bear more resemblance to those at Aurora, according to Umpleby,[2] occur along fissure fillings that have an average width of 3½ feet. The unaltered vein material is a firm white quartz with wavy ribbons of a bluish-gray cast. The veins are made up of quartz, chalcedony, opal, calcite, and adularia, carrying inconspicuous amounts of pyrite and chalcopyrite, with silver and possibly gold, in association with antimony, sulphur, and selenium. The most striking feature of the Republic ores is the extremely barren appearance of the quartz. Fluorite was noted in the slides. The silver is thought to be partly in the form of silver selenide and partly as a component of gray copper. Some gold is free, but most of it is probably combined with selenium and tellurium.

Lindgren[3] says of the Republic veins that the banding is due to the difference in size of the quartz grains; that the ore minerals occur in extremely fine distribution in thin black streaks, generally near the walls. In the rich portion of the veins tetrahedrite and chalcopyrite have been identified, but the principal ore mineral, presumably a selenide of gold and silver, occurs in such fine distribution that it has not yet been isolated.

As it was impossible, on account of the condition of most of the mine workings, to study the veins at Aurora at depth, a satisfactory understanding of the distribution of the good and poor ore was not reached during this reconnaissance. From what could be learned, however, it would seem that the rich ore occurred in relatively small

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 83–104, 1905.

[2] Umpleby, J. B., Geology and ore deposits of the Republic mining district: Washington Geol. Survey Bull. 1, p. 37, 1910.

[3] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, 1914.

shoots in the large barren veins. There were five such shoots, which were exceptionally large on the Wide West vein on Last Chance Hill.

In the majority of the veins it is understood that the rich ore streaks, ranging from a fraction of an inch to 6 inches in width, were as a rule found near the walls, particularly the hanging wall, and that they were not continuous along the veins for any considerable distance. It is almost certain, however, that the barren-looking white quartz, where it shows even a slight suggestion of the bluish color, carries gold.

The veins are said to have been in general considerably wider in the richer portions. This was particularly the case on the Wide West vein, where some of the stopes were as much as 60 feet wide, though the leaner portion of the vein between the stopes ranged from 6 to 10 feet in width.

As only the surface workings and outcrops of these deposits could be studied it is not possible to give detailed descriptions of the veins.

Tenor of the ore.—The average ore from any vein is probably of low grade. Ore which is taken from rich shoots may run up to $1,000 a ton. The average gross value of the ore is reported to be about $6 to $8 a ton, the ratio of gold to silver being 1 to 2 or 1 to 5. It is said that in the ore mined in the early days from the rich stopes on Last Chance Hill the ratio of gold to silver was as 4 to 2.

Origin of the veins.—The veins of the Esmeralda district were formed in open fissures by hot ascending, very siliceous solutions. These solutions were capable of altering the inclosing biotite-quartz latite for considerable distances from the veins. In one or two small veins cut by the Monarch tunnel on Silver Hill the quartz shows the typical form of replacement after calcite, common to the quartz-adularia type of veins (Pl. XVII, *B*). Pure white calcite was found on the dump of the Humboldt shaft that was said to come from the 450-foot level, though none was found above the 100-foot level in the mine. This ore seems to show that calcite was deposited before the quartz, which appears to replace the carbonate. It is questionable, however, if any considerable time intervened between the deposition of the calcite and the entrance of the silica-bearing solutions. Certainly in most of the ore there is little suggestion that the quartz is secondary after calcite, except that none of the quartz shows the crystal forms of this mineral usually seen where it is deposited alone in open fissures.

The age of the formation of these veins is not certainly known, though they were formed after the eruption of the biotite-quartz latite and associated andesite and before the succeeding flows of rhyolite. It is probable that they are representatives of the late Tertiary mineralization common to the Great Basin region.

HAWTHORNE DISTRICT, MINERAL COUNTY, NEV.

LOCATION AND ACCESSIBILITY.

The Hawthorne district comprises a large area, tributary to the town of that name, on the east side of the Wassuk (Walker River) Range and on the northwest side of the Excelsior Mountains. The town of Hawthorne is situated at the south end of Walker Lake, 7 miles south-southwest of Thorne, a station on the Hazen-Tonopah branch of the Southern Pacific Railroad. The region is shown in the west-central part of the Hawthorne topographic sheet of the United States Geological Survey. The mines visited by the writer were in the immediate vicinity of the town of Lucky Boy, 3 miles southwest of Hawthorne in an air line. (See No. 15, Pl. I, p. 18.)

PRODUCTION.

The figures showing the production for this region are not accurate, as in some years the production of the mines at Buckley Camp and Garfield was combined with that of the mines near Hawthorne. The Survey has recorded a total production since 1904 from the district of $1,090,867, extracted from 17,782 tons of crude ore. From 1907, when the veins near Lucky Boy were discovered, to 1911, inclusive, 13,968 tons of ore have been mined from these veins, carrying $21,387 in gold, 1,770,279 ounces of silver, 54,206 pounds of copper, and 2,982,041 pounds of lead, having a total value of $1,076,235.

TOPOGRAPHY.

Hawthorne, which lies at an elevation of 4,326 feet above sea level, is situated near the center of the flats at the south end of Walker Lake. About 4 miles west of the town the Wassuk Range rises in a distance of less than 2 miles from the level valley floor to a height of 7,500 feet. The highest peak of this range, Mount Grant, 10 miles northwest of Hawthorne, has an elevation of 11,303 feet, and Cory Peak, about the same distance southwest of the town, an elevation of 10,516 feet. The old Bodie stage road goes over the range about 2 miles south of Cory Peak through a pass whose summit is 8,000 feet above sea level. The Lucky Boy mines are located in rather low hills, which have an elevation of 6,225 feet, about one-half mile west of the place where the Bodie stage road begins the ascent from Walker Lake valley.

GEOLOGY.

Sedimentary rocks.—In the vicinity of Lucky Boy a series of metamorphosed light-colored thin-bedded, slightly cherty limestones, associated with calciferous sandstones and some dark shales,

contains the greatest number of quartz veins, into a fine-grained substance, composed mainly of quartz, calcite, brown mica, and chlorite, by the addition of potash.

Knopf[1] has noted a similar alteration of the igneous rocks in the northern end of the Juneau belt by a large introduction of albite, the conversion of the hornblende and other amphiboles into biotite, and the introduction of apatite. This alteration shows a large addition of soda and potash demanded by the formation of albite and biotite, and a heavy loss of magnesia, lime, and iron. Knopf concludes that the mineralizing solutions were rich in soda and potash and that they were hot, ascending waters of deep-seated origin.

Spencer[2] has recently found a similar alteration of quartz monzonite in the Ely district, Nev. He finds the most intense alteration along zones of crushing and concludes that the alteration was produced by hot aqueous solutions carrying soda and potash which have changed the hornblende, plagioclase, and magnetite of the original rock into sericite and biotite and have deposited pyrite, chalcopyrite, calcite, and possibly quartz.

Rockland mine.—The Rockland mine, situated about 3 miles southeast of Pine Grove, though not visited, is presumably of the same type of ore deposits as the Wheeler and Wilson mines and may be on a continuation of the same fault zone, though it seems more probable that it lies in another zone of fracture. The "vein" is said to strike northwest and to dip 45°–55° NE. The footwall is the dark altered quartz monzonite and the hanging wall a "light-colored porphyry," presumably the intrusive granite porphyry, though it may be the rhyolite. The property is developed by three drift tunnels. The ore is said to contain very little copper, the value being chiefly gold and silver, the bullion having a value of $15 an ounce.

There is said to be a 20-stamp amalgamation mill on the property, lately installed to replace a dry process mill, which was unsuccessful on account of the large quantity of clay in the ore.

FUTURE OF THE DISTRICT.

This type of ore has probably been formed at considerable depth, for the accompanying alteration, as pointed out by Lindgren,[3] is such as to preclude the theory of shallow deposition. It seems probable, therefore, that the mineralization along the fault zone will continue for a considerable distance below the surface. It is to be expected, and is already shown in the lower workings of the Wilson, that the

[1] Knopf, Adolph, The Eagle River region, southeastern Alaska: U. S. Geol. Survey Bull. 502, pp. 36–41, 1912.

[2] Unpublished manuscript.

[3] Lindgren, Waldemar, Metasomatic processes in fissure veins: Am. Inst. Min. Eng. Trans., vol. 30, pp. 609–645, 1901.

grade of the ore will not be as high as at the surface, but the unaltered sulphides at a depth of 250 feet carry $10 a ton, and ore of even lower grade has been successfully worked at numerous places. This pyritic ore, with such a small proportion of copper minerals, is amenable to cyanide treatment, and it seems entirely possible that if a sufficient quantity of ore can be treated the properties could again be producers. In fact, reports in the mining journals indicate that these mines are to resume production in the near future.

AURORA (ESMERALDA) DISTRICT, MINERAL COUNTY, NEV.

LOCATION AND ACCESSIBILITY.

The old Esmeralda mining district at Aurora, Nev. (No. 14, Pl. I, p. 18), is 28 miles in an air line southwest of Thorne, a town on the Hazen-Tonopah branch of the Southern Pacific and its nearest railroad point. The town of Aurora is 3 miles east of the California-Nevada boundary, 16 miles north of Mono Lake and 1½ miles east of Bodie Canyon. The region is shown near the center of the west side of the Hawthorne topographic sheet of the United States Geological Survey.

The district is most easily reached by the automobile stage which runs daily between Hawthorne, Nev., and Bodie, Cal. It is possible to enter this part of Nevada by way of Minden, the southern terminus of the Virginia & Truckee Railway. Stages operate between that town and Wellington and thence south to Bodie, Cal., but the trip requires three days in contrast to the half-day run from Hawthorne.

HISTORY AND PRODUCTION.

The Old Esmeralda, near the southern limit of the productive area (see Pl. XVI, *A*, p. 148), was the first vein discovered in the Aurora district. According to Wasson,[1] James M. Brawley, J. M. Cory, and E. R. Hicks made the discovery on August 22, 1860, and immediately located four claims. The town of Esmeralda was built in the gulch just east of the discovery, but later in the year the present town site of Aurora, 1½ miles north, was laid out. The first mill, owned by Edmund Green, was put in operation in 1861, and was followed shortly by several arrastres and mills. In 1864 there were 17 amalgamation mills in the district, the largest, which had 30 stamps, being the Real Del Monte in Bodie Canyon. Up to the year 1864 the camp was very prosperous. Aurora had a population of about 10,000 and was the county seat of Mono County, Cal. During the year 1864, however, misfortunes befell the camp. The California-Nevada boundary was run and showed that the Esmeralda district lay in Nevada;

[1] Wasson, Joseph, Bodie and Esmeralda: a pamphlet published in 1878 by the Mining and Scientific Press, San Francisco, Cal.

the rich bonanzas in the Wide West vein on Last Chance Hill became exhausted and bitter litigation over the ownership of the veins on Last Chance Hill developed. The camp, however, continued to prosper until 1882, though the supply of $75 ore, which in earlier times could not be mined, was then becoming depleted. In 1880 an English company acquired possession of the main group of claims on Last Chance Hill. It began operations in 1887, starting the Real Del Monte shaft and connections with the Durant vein on Middle Hill, but suspended work in 1892 after a vain effort to keep the lower workings of the 800-foot shaft free from water.

Most of the claims in the Esmeralda district were owned in July, 1913, by two companies, the Cain Consolidated Co. and the Aurora Mines Co. The Aurora Mines Co.'s chief group, containing 11 claims, lies on Silver Hill, though they own 5 claims on Aurora Hill. The Cain Consolidated Co. controls about 40 claims, among which are some of the famous producers of the district. In the summer of 1912 these holdings were under option to certain financiers of Tonopah, Nev., who have, according to reports of the mining journals, taken up the ground and started operations.

Most of the productive ground of the district has now been acquired by the Goldfield Consolidated Mining Co. A 500-ton cyanide mill has been built, and there is every prospect that Aurora will again be a producing camp.

The records of production are incomplete. According to a statement of Wells, Fargo & Co. the bullion shipped through them up to 1869 had a value of $27,000,000. Mr. Wasson[1] gives the following table of gold bullion shipped without insurance:

Bullion shipped from Aurora without insurance from 1861 to 1869, inclusive.

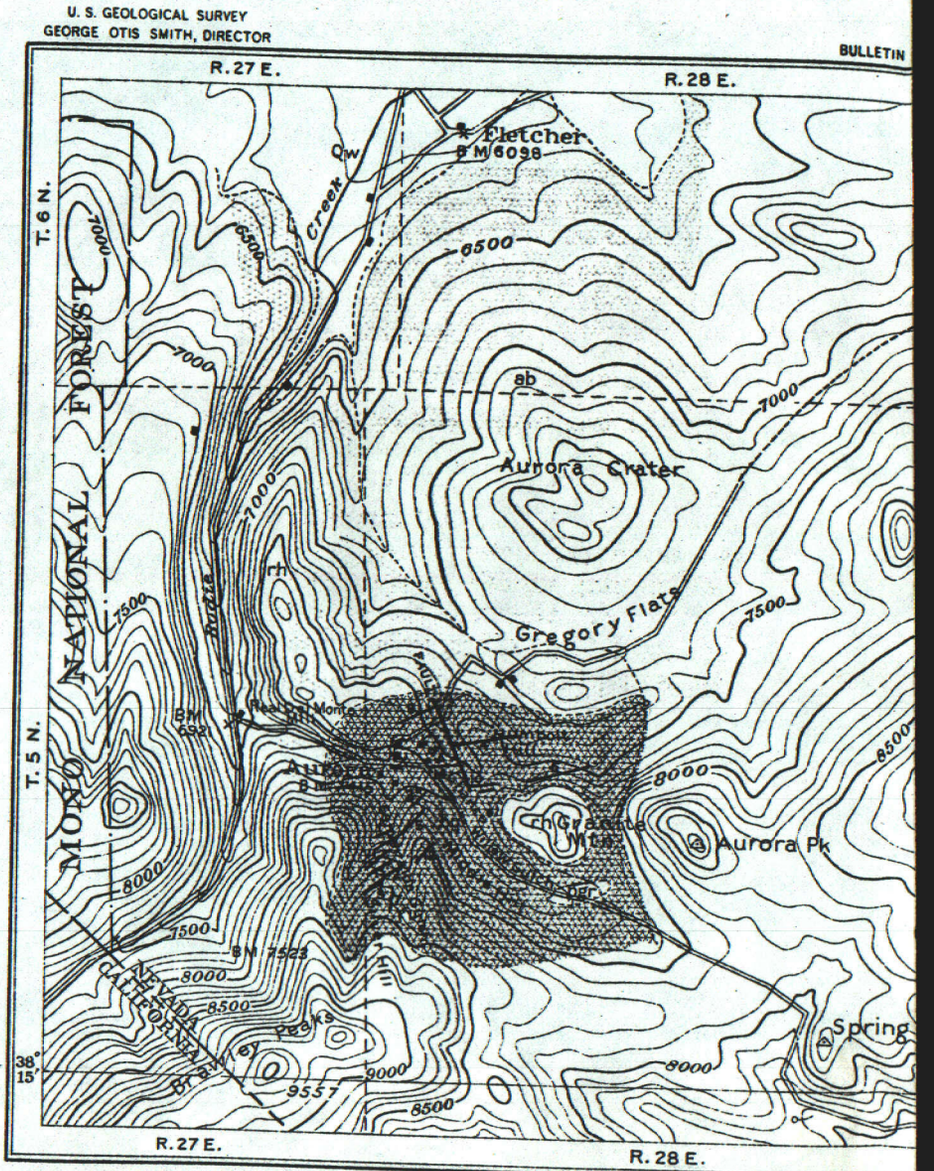
1861	$43,417.28	1867	$130,656.89
1862	173,148.82	1868	98,188.88
1863	546,019.16	1869	28,166.50
1864	952,023.29		
1865	237,185.23		2,365,968.82
1866	158,162.77		

He further says that between seven and eight million dollars' worth of bullion was shipped by express in 1864 and about $12,000,000 prior to the year 1869. If the reports of production of some of the stopes are taken into consideration, even so large a sum as $27,000,000 seems a small showing for the camp.

TOPOGRAPHY.

There are four rather low hills south and east of the town of Aurora (see Pl. XIV), known as Silver, Middle, Last Chance,

[1] Wasson, Joseph, op. cit.



GEOLOGIC SKETCH MAP OF THE VICINITY OF AURORA, MINERAL COUNTY, N

Base from topographic map of the Hawthorne quadrangle

1 ½ 0 1 2 3 4 Miles

Contour interval 100 feet
Datum is mean sea level
1914

LEGEND

Qw — Quaternary wash

ab — Augite basalt (*Cap rock*)

rh — Rhyolite tuffs and flows

Biotite-quartz latite and associated andesite porphyries

pgr — Porphyritic granite

Veins (*Numbers refer to list of names*)

Fault

LIST OF VEINS

1 Antelope
2 Bald Eagle-Spotted Tiger
3 Durant
4 Humboldt-Silver Lining
5 Live Yankee
6 Martinez-Juanita
7 Old Esmeralda
8 Prospectus
9 Radical
10 Real Del Monte
11 Sonora
12 Summit
13 Utah-Cortez
14 Wide West-Last Chance

NEVADA

and Humboldt. The town has an elevation of 7,415 feet above sea level. Silver and Middle hills are separated by Esmeralda Gulch. They are long, northward-sloping spurs from the Brawley Peaks, which rise to a height of 9,557 feet about 2¼ miles south of the town. Last Chance Hill, east of Aurora, is a low divide, less than 150 feet above the valley, which separates Willow Creek from the Gregory Flat drainage basin. Humboldt Hill, a low rounded knob about three-fourths of a mile northeast of Aurora, rises to a height of a little over 7,600 feet. The mines of the Aurora district are located on these four hills, though at the east end of the flat north of town and about 150 feet higher there are a few veins near Humboldt and Last Chance hills.

GEOLOGY.

CHARACTER AND DISTRIBUTION OF THE ROCKS.

The rocks exposed in the Esmeralda district are, with a single exception, of volcanic origin. In the bottom of Willow Gulch, about 2 miles southwest of Aurora (see Pl. XIV), there is a small, indistinct exposure of a rock that appears to be the basement on which the flows were extruded. It is a coarsely porphyritic, granular rock, and is probably to be correlated with the granodiorite and associated rocks of the Sierra Nevada. At least three series of flows overlie this granular rock. The oldest of these flows consists of grayish-green altered rocks that are largely biotite-quartz latites, together with some andesites. This series is exposed on Silver, Middle, Last Chance, and Humboldt hills, and extends southeast up Willow Gulch for an unknown distance. These rocks, which are at least 900 feet thick, inclosed all the veins of the district, none being found in the younger rocks.

Above these flows of intermediate chemical composition lies a series of light-gray to brownish-gray rhyolites that are particularly well exposed on the flats north and northwest of Aurora along Bodie Creek, where they are 1,000 feet thick, and also on Granite Mountain, about 1 mile southeast of town, where there is a remnant of the series about 300 feet thick. Above both the andesites and rhyolites lies a black vesicular basalt that forms Aurora Crater (see Pl. XIV) and covers a large expanse of country to the west of Granite Mountain. It ranges from about 10 to over 600 feet in thickness. Its weathered surfaces are brown.

All these flows appear to have a gentle dip to the north-northwest. It seems probable that there was a time of erosion between the andesite and rhyolite eruptions, as the rhyolite flows rest on an uneven surface that looks like an erosion surface.

There was unquestionably an interval of considerable length between the rhyolite and basalt eruptions, for the base of the later

flows rests in the bottoms of gulches in some places and on the tops of ridges at other places.

The latites and associated andesites seem to have been exposed by the erosion of the capping rhyolite along the Willow Creek drainage basin, and Granite Mountain seems to be a remnant of this capping which escaped erosion. It does not seem probable that the basalt ever extended much beyond its present limits, as shown on Plate XIV, for the edges of the flows are fresh and in some places along the gulch northeast of Gregory Flats show the piled-up, overturned marginal portions of quickly cooled lava sheets.

TOPOGRAPHIC EXPRESSION OF THE DIFFERENT ROCKS.

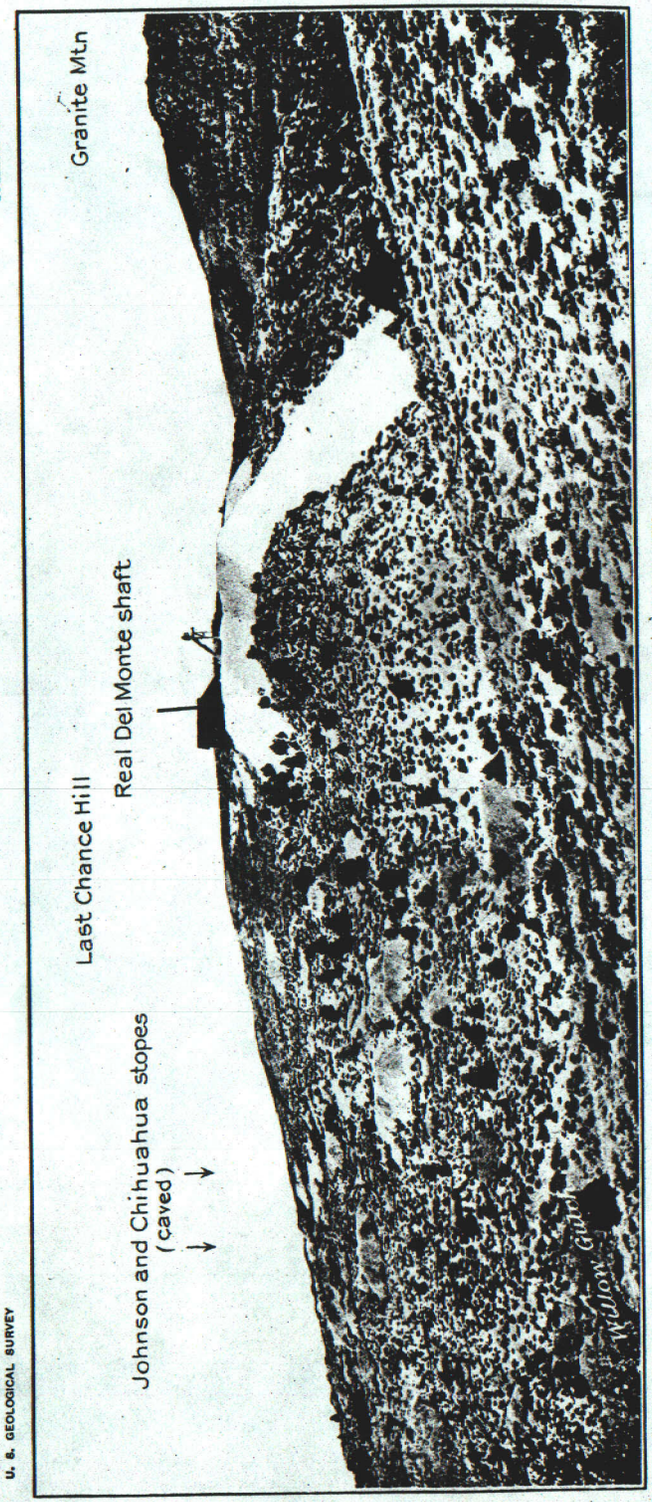
The oldest flow rocks are all much altered and are rather easily eroded, except where they have been silicified near the veins. As a consequence the mineralized hills have, as a rule, even and rather gentle slopes, as is shown in the view of Last Chance Hill (Pl. XV). At the southern end of Silver Hill, where the rock is much silicified near the Bald Eagle, Spotted Tiger, and Radical veins, the generally smooth andesite surfaces are interrupted by steep cliffs, as shown in Plate XVI, *A*.

The rhyolite series weathers in rough cliffs and the surfaces of the flows are marked by small steep-sided gullies. On the long ridge northwest of Aurora, near Bodie Creek, the topography suggests the badland forms at many points, especially on the northeast side of the ridge.

The surface of the basalt flows is very rough, making the crossing of these areas difficult, even on foot. Aurora Crater is a basaltic vent, the northwest rim of which has been cut through by erosion. It is a beautiful example of a small volcano, with the successive flows clearly traceable on its rough scarred sides.

PETROGRAPHY.

Porphyritic granite.—The single exposure of porphyritic granite in the district lies in the bottom of Willow Gulch, about 1¼ miles southwest of Aurora. Its boundaries are not well shown on account of the wash, but the andesitic flows clearly rest on this basement. The outcrop is small and deeply weathered, practically no fresh rock being visible. Numerous large pink orthoclase crystals, the maximum length being 2 inches, are present in the residual sand covering part of the area. The weathered surfaces have a light greenish-gray color, owing to the alteration of the constituents. The rock is rather coarsely granular throughout and contains very large, zonally built, pink orthoclase phenocrysts.



LAST CHANCE HILL, AURORA, MINERAL COUNTY, NEV.

Shows gentle slopes of andesitic flows.

In thin sections the groundmass of this coarse porphyry is seen to be inequigranular. None of the minerals, except the phenocrysts and accessory minerals, show any crystal form. The minerals present in this rock, named in the order of their abundance, are orthoclase, quartz, microperthite, green hornblende, brown biotite, microcline, muscovite, and oligoclase. The accessory minerals are titanite, magnetite, and apatite. The ferromagnesian minerals are somewhat chloritized, and the feldspars are more or less kaolinized. Some of the muscovite appears to be primary, but part, at least, is bleached biotite. The titanite and magnetite are closely associated and intergrowths of these two minerals are common.

Biotite-quartz latite.—The general country rock on the hills in the vicinity of Aurora, in which the veins are found, is a greenish-gray to gray altered porphyry which ranges from rather fine to medium grain. Few of the phenocrysts are more than an eighth of an inch in diameter, and most of them are less. The most widely distributed type of rock has a fine-grained greenish-gray groundmass, thickly studded with small white lath-shaped phenocrysts. All the rock of this type carries some disseminated pyrite, which is particularly abundant near the veins.

The thin sections show that this rock originally consisted of phenocrysts of andesine, biotite, and possibly pyroxene, set in a fine-grained matrix of andesine, with some ferromagnesian minerals. Small interstices of the groundmass contain intergrowths of quartz and orthoclase. The rock is a biotite-quartz latite. All the rocks are very much altered, presumably by the hot calcareous solutions which deposited the veins. The andesine phenocrysts are altered to calcite, sericite, some quartz, and some of them show a little green epidote. The ferromagnesian minerals are completely altered to chlorite and some magnetite. The groundmass is altered to an aggregate of sericite, chlorite, and quartz. Near the veins the alteration has been much more intense than at a distance of 150 to 200 feet from them. In these highly altered zones quartz has been added to the body of the rock, which is also cut by stringers of quartz and calcite. Sericite and epidote are also much more abundant in the rock near the veins, whereas chlorite is more commonly developed in the rock at a distance from the veins.

Andesite.—Near the bottom of Esmeralda Gulch, 1 mile south of Aurora, there is a fine-grained light-green porphyry apparently intrusive into the biotite-quartz latite, though it may be an underlying flow. This fine-grained dark rock is exposed in several other localities in the district, and it is probably rather widespread in distribution.

This rock is much altered and contains disseminated pyrite in small quantities and is cut by quartz and calcite stringers.

Thin sections of this rock show that its groundmass is composed of microscopic lath-shaped crystals of andesine and augite, the latter mineral altered to chlorite. In this groundmass are set small well-developed phenocrysts of zonally built andesine and of augite, both of which are altered, the augite to green chlorite and the feldspars to grayish aggregates of sericite and chlorite.

Rhyolites.—The rhyolite series is made up of a number of relatively thin flows, all of which are glassy. They range in color from gray through green to purple. Some of them appear to be tuffaceous, but the majority are typical flow rhyolites. On the flat north of Aurora some pearl-gray perlitic rhyolites are seen near the top of the series. Flakes of biotite are seen in all of these rocks, and quartz can usually be detected with the unaided eye. Thin sections show that the rock consists of a glassy base having, as a rule, distinct flow structure, which contains a few phenocrysts of quartz, orthoclase, and biotite. Some of the slides show that the groundmass suffered some devitrification, accompanied by the development of chlorite and sericite.

About one-fourth of a mile southeast of the Old Esmeralda Tunnel a small, indistinct body of rhyolite has been altered to a soft white mass by hydrothermal action, but the flows at other places show no alteration by hot waters.

Basalt.—The basalt of Aurora Crater is a very fresh vesicular black rock showing a few small green olivine crystals to the unaided eye. Under the microscope the groundmass is seen to be composed of microscopic labradorite laths and grains of nearly colorless augite set in a black glass paste. The flow structure is well shown by the rough parallel orientation of the long dimensions of the plagioclase laths, many of which bend around the vesicular openings.

QUATERNARY GRAVELS.

The Quaternary deposits on lower Bodie Creek, shown at the top of Plate XIV, consist of unconsolidated sands, gravels, and silts, which a little north of the area shown on the map are quite thick and extensive. The surface is covered by fine sandy loam, which under irrigation has produced excellent crops.

On Last Chance Hill there is a small area underlain by roughly stratified volcanic material, shown in the caved Chihuahua stope. (See Pl. XVI, *B*, p. 148.) This material ranges from a few feet to a maximum of 20 feet in thickness and appears to have been reworked by streams.

In the canyon northwest of Gregory Flats and about 1½ miles due north of Aurora a warm spring issues from beneath the basalt

of Aurora Crater. This spring deposits limonite and aragonite. The aragonite forms crusts from one-fourth inch to 4 inches in thickness, though most of the crusts are less than 2 inches thick. The entire deposit covers an area about 150 feet square to a maximum depth of 15 feet.

ORE DEPOSITS.

Distribution of the veins.—The ore deposits of the Esmeralda district occur as veins that cut the biotite-quartz latite and associated andesite over an area extending in a northeast-southwest direction, about 2 miles in length by 1¼ miles in width. Aurora is near the center of the northwest side of the productive area. On Silver and Middle hills the veins are rather closely spaced and have, with one exception, a persistent strike of about N. 45° E., though strikes between N. 40° E. and N. 50° E. are seen in many places, even along veins whose average course is N. 45° E. These veins all dip to the southeast but at different angles. The largest and apparently the strongest veins—that is, the Eureka, the Antelope and Lady Jane, the Cortez and Utah, and the Spotted Tiger and Bald Eagle veins—all dip between 45° and 60° SE. into the hill, but some of the smaller veins slope southeast at much flatter angles. An exceptional vein system on Silver Hill is represented by the Old Esmeralda and Radical veins, which strike about N. 10° E. and stand nearly vertical. The outcrops of these veins are wider than any of the northeast-southwest system, the Old Esmeralda being 60 feet wide and the Radical between 20 and 30 feet in maximum width.

On Last Chance and Humboldt hills the veins strike more nearly east and west, ranging between N. 60° E. and N. 80° E., and with the exception of the Humboldt and Prospectus veins, which dip 80° N., they dip to the west-southwest at angles ranging between 65° and 75°. Some of the smaller veins have flatter dips, but the strong, well-defined ones stand more nearly vertical. The veins on these two hills have been displaced by a nearly vertical fault, whose strike ranges from N. 20° E. at the Humboldt vein to N. 30° W. at the Real Del Monte vein. The horizontal displacement along this fault has amounted to over 600 feet, the veins west of the fault being at least that far north of their continuation on the eastern side. Thus the Humboldt vein on the east side of the fault along the crest of Humboldt Hill is the Prospectus west of the fault. (See Pl. XIV, p. 142.)

It is said that about 6 miles northeast of Aurora lies a small area of andesite in which there are some veins, but the locality was not visited.

Character of the veins.—The veins of the Esmeralda district range from a fraction of an inch to 70 or even 80 feet in width. They are

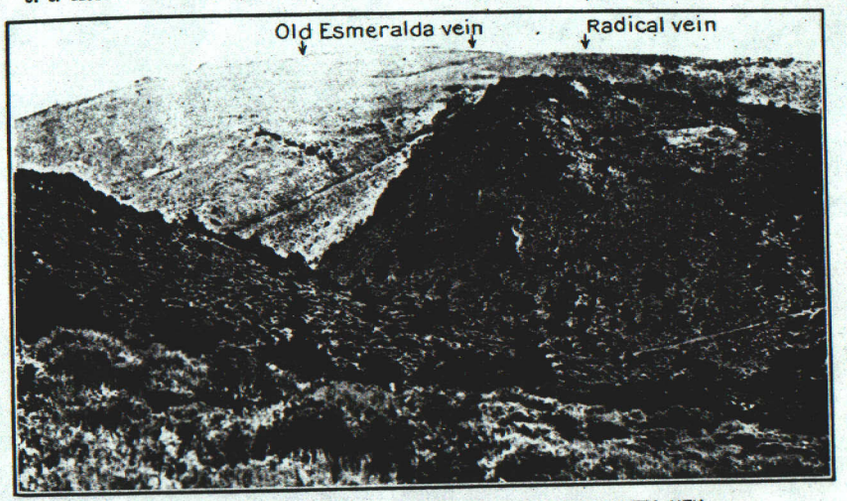
as a rule between 18 inches and 4 feet wide, and can generally be traced for several hundred feet along the strike. They are not simple, clean-cut veins, but send off numerous small interlacing branches into the walls, particularly on the footwall side. This tendency of the veins is well seen on the edge of the Old Chihuahua stope on Last Chance Hill. (See Pl. XVI, *B*.)

Along some of the veins there has been postmineral movement. This movement has usually taken place along the hanging wall and has been slight, producing in most places a thin clay parting between the country rock and quartz.

The veins consist in great part of finely granular, white, barren-looking quartz. In some places the quartz is so fine grained that it has a milky-white porcelain-like appearance. The veins are banded by crustification, the different bands being due to the difference in size of the quartz grains. In all the veins there are small druses lined with minute clear quartz crystals. The rich ore is always marked by irregular wavy streaks of what appears to be dark quartz, cutting the white low-grade or barren vein filling. (See Pl. XVII, *A*.) In reality these rich streaks are made up of quartz, adularia, argentiferous tetrahedrite, and small amounts of pyrite and chalcopyrite, together with a soft bluish-gray mineral supposed to be a combination of gold and possibly silver with selenium. Some free gold is found here and there in the richest ore now mined, and the old stopes are said to have contained large quantities of free gold.

The adularia is notably absent from most of the white barren quartz, but was found in soft, narrow kaolinized bands in white quartz ore from the Humboldt shaft. In practically every thin section of the ores studied there is a small amount of sericite in thin flakes cutting the quartz crystals. In all the thin sections of very rich ore adularia is abundant, being associated with the quartz and commonly inclosed in the interlocking quartz grains. As a rule the rhombic forms of adularia are not seen, the mineral occurring in irregular masses.

Qualitative tests of a small piece of rich ore from the 350-foot level of the Durant vein at Aurora show the presence of selenium but no tellurium. It also contains a rather large quantity of iron and copper, smaller quantities of silver and gold, and some antimony. A polished section and thin section of this ore show the undoubted presence of pyrite, chalcopyrite, tetrahedrite, and free gold. There is also a small quantity of a soft bluish-gray mineral, that is distinct from the tetrahedrite, which is thought to be a selenium-gold and possibly silver compound. This mineral occurs in minute specks and could not be separated from the other constituents.



A. SOUTH END OF SILVER HILL, AURORA, MINERAL COUNTY, NEV.

Shows croppings of Old Esmeralda vein and cliffs where andesitic flows are silicified at the junction of several veins.

B. CHIHUAHUA STOPE ON LAST CHANCE HILL, MINERAL COUNTY, NEV.

Branching veins in footwall of main vein at left and stratified volcanic material in right center.

A. STREAK OF RICH ORE FROM SPOTTED TIGER VEIN.

Natural size.

B. ORE FROM A SMALL VEIN CUT BY THE MONARCH TUNNEL.

Shows typical quartz-adularia mineralization after calcite.

The presence of selenium without tellurium sets these veins apart, for there are only a very few mining districts in the United States where this combination of ores is found.

Spurr[1] says that at Tonopah the veins are chiefly due to replacement of the andesite by quartz and the ore minerals along zones of fracture. Crustified veins clearly due to filling of open spaces are exceptional at Tonopah. The mineralizing agent he considers to be "volcanic waters that were hot and ascending." The primary ores at Tonopah, according to Spurr, contained quartz, adularia, carbonates of lime, iron, magnesia and manganese, silver sulphite, probably polybasite or stephanite, and argentite, silver chloride, chalcopyrite, pyrite, galena, sphalerite, and gold in an undetermined form, and silver selenide.

At Republic the veins which seem to bear more resemblance to those at Aurora, according to Umpleby,[2] occur along fissure fillings that have an average width of 3½ feet. The unaltered vein material is a firm white quartz with wavy ribbons of a bluish-gray cast. The veins are made up of quartz, chalcedony, opal, calcite, and adularia, carrying inconspicuous amounts of pyrite and chalcopyrite, with silver and possibly gold, in association with antimony, sulphur, and selenium. The most striking feature of the Republic ores is the extremely barren appearance of the quartz. Fluorite was noted in the slides. The silver is thought to be partly in the form of silver selenide and partly as a component of gray copper. Some gold is free, but most of it is probably combined with selenium and tellurium.

Lindgren[3] says of the Republic veins that the banding is due to the difference in size of the quartz grains; that the ore minerals occur in extremely fine distribution in thin black streaks, generally near the walls. In the rich portion of the veins tetrahedrite and chalcopyrite have been identified, but the principal ore mineral, presumably a selenide of gold and silver, occurs in such fine distribution that it has not yet been isolated.

As it was impossible, on account of the condition of most of the mine workings, to study the veins at Aurora at depth, a satisfactory understanding of the distribution of the good and poor ore was not reached during this reconnaissance. From what could be learned, however, it would seem that the rich ore occurred in relatively small

[1] Spurr, J. E., Geology of the Tonopah mining district, Nev.: U. S. Geol. Survey Prof. Paper 42, pp. 83–104, 1905.

[2] Umpleby, J. B., Geology and ore deposits of the Republic mining district: Washington Geol. Survey Bull. 1, p. 37, 1910.

[3] Bancroft, Howland, The ore deposits of northeastern Washington: U. S. Geol. Survey Bull. 550, 1914.

shoots in the large barren veins. There were five such shoots, which were exceptionally large on the Wide West vein on Last Chance Hill.

In the majority of the veins it is understood that the rich ore streaks, ranging from a fraction of an inch to 6 inches in width, were as a rule found near the walls, particularly the hanging wall, and that they were not continuous along the veins for any considerable distance. It is almost certain, however, that the barren-looking white quartz, where it shows even a slight suggestion of the bluish color, carries gold.

The veins are said to have been in general considerably wider in the richer portions. This was particularly the case on the Wide West vein, where some of the stopes were as much as 60 feet wide, though the leaner portion of the vein between the stopes ranged from 6 to 10 feet in width.

As only the surface workings and outcrops of these deposits could be studied it is not possible to give detailed descriptions of the veins.

Tenor of the ore.—The average ore from any vein is probably of low grade. Ore which is taken from rich shoots may run up to $1,000 a ton. The average gross value of the ore is reported to be about $6 to $8 a ton, the ratio of gold to silver being 1 to 2 or 1 to 5. It is said that in the ore mined in the early days from the rich stopes on Last Chance Hill the ratio of gold to silver was as 4 to 2.

Origin of the veins.—The veins of the Esmeralda district were formed in open fissures by hot ascending, very siliceous solutions. These solutions were capable of altering the inclosing biotite-quartz latite for considerable distances from the veins. In one or two small veins cut by the Monarch tunnel on Silver Hill the quartz shows the typical form of replacement after calcite, common to the quartz-adularia type of veins (Pl. XVII, *B*). Pure white calcite was found on the dump of the Humboldt shaft that was said to come from the 450-foot level, though none was found above the 100-foot level in the mine. This ore seems to show that calcite was deposited before the quartz, which appears to replace the carbonate. It is questionable, however, if any considerable time intervened between the deposition of the calcite and the entrance of the silica-bearing solutions. Certainly in most of the ore there is little suggestion that the quartz is secondary after calcite, except that none of the quartz shows the crystal forms of this mineral usually seen where it is deposited alone in open fissures.

The age of the formation of these veins is not certainly known, though they were formed after the eruption of the biotite-quartz latite and associated andesite and before the succeeding flows of rhyolite. It is probable that they are representatives of the late Tertiary mineralization common to the Great Basin region.

HAWTHORNE DISTRICT, MINERAL COUNTY, NEV.

LOCATION AND ACCESSIBILITY.

The Hawthorne district comprises a large area, tributary to the town of that name, on the east side of the Wassuk (Walker River) Range and on the northwest side of the Excelsior Mountains. The town of Hawthorne is situated at the south end of Walker Lake, 7 miles south-southwest of Thorne, a station on the Hazen-Tonopah branch of the Southern Pacific Railroad. The region is shown in the west-central part of the Hawthorne topographic sheet of the United States Geological Survey. The mines visited by the writer were in the immediate vicinity of the town of Lucky Boy, 3 miles southwest of Hawthorne in an air line. (See No. 15, Pl. I, p. 18.)

PRODUCTION.

The figures showing the production for this region are not accurate, as in some years the production of the mines at Buckley Camp and Garfield was combined with that of the mines near Hawthorne. The Survey has recorded a total production since 1904 from the district of $1,090,867, extracted from 17,782 tons of crude ore. From 1907, when the veins near Lucky Boy were discovered, to 1911, inclusive, 13,968 tons of ore have been mined from these veins, carrying $21,387 in gold, 1,770,279 ounces of silver, 54,206 pounds of copper, and 2,982,041 pounds of lead, having a total value of $1,076,235.

TOPOGRAPHY.

Hawthorne, which lies at an elevation of 4,326 feet above sea level, is situated near the center of the flats at the south end of Walker Lake. About 4 miles west of the town the Wassuk Range rises in a distance of less than 2 miles from the level valley floor to a height of 7,500 feet. The highest peak of this range, Mount Grant, 10 miles northwest of Hawthorne, has an elevation of 11,303 feet, and Cory Peak, about the same distance southwest of the town, an elevation of 10,516 feet. The old Bodie stage road goes over the range about 2 miles south of Cory Peak through a pass whose summit is 8,000 feet above sea level. The Lucky Boy mines are located in rather low hills, which have an elevation of 6,225 feet, about one-half mile west of the place where the Bodie stage road begins the ascent from Walker Lake valley.

GEOLOGY.

Sedimentary rocks.—In the vicinity of Lucky Boy a series of metamorphosed light-colored thin-bedded, slightly cherty limestones, associated with calciferous sandstones and some dark shales,

are exposed. Their structure is very much complicated by faulting and intrusion. In general these sediments seem to strike nearly east and to dip south at medium to high angles. These sedimentary rocks, interspersed in many places with intrusive rocks, extend south and southeast of the stage road for about 1½ miles. No fossils were found by the writer in these metamorphosed sediments, which are probably Mesozoic or younger in age, as it has been rather definitely shown that there are only small isolated areas of Paleozoic sediments between a nearly north-south line just west of Battle Mountain and the crest of the Sierra Nevada. This fact was first noted by the geologists of the Fortieth Parallel Survey.[1]

The Walker Lake valley is underlain by roughly stratified gravels and silts deposited during Pleistocene time in an arm of Lake Lahontan, as described by Russell.[2] Spurr[3] has noted rock-cut benches and gravels 400 feet above those described by Russell. He also noted gravels which he considers to be Pliocene in age on the Bodie road, at an elevation of 7,100 feet west of the summit.

Igneous rocks.—The limestones are intruded in a most intricate manner by a light to a medium gray granular rock, which is in turn cut by narrow dikes, some of which are dark colored, though many are light. The granular rock is composed of orthoclase, microcline, quartz, biotite, plagioclase, and hornblende, named in the order of decreasing abundance. It is as a rule quite fresh, though some secondary chlorite and sericite were noted in thin sections. Magnetite and apatite are accessory. The feldspars show as fairly large anhedral areas with smaller irregular areas of quartz between them. The plagioclase feldspar is between oligoclase and andesine, to judge from the extinction angles. This granodiorite is probably near granite in chemical composition.

The dark-colored basic dikes were seen in only a few places on the surface; the specimens are too much altered for determination, though they are seen to be basic phases of the granodiorite. The light-colored dikes are aplite, a fine-grained granular mica-free rock, composed of feldspar and quartz, and alaskite, a very coarsely crystalline feldspar and quartz.

Contact metamorphism.—The contacts between the granodiorite and limestone are sharp, and there has been considerable contact metamorphism along them, though this process has not formed distinctly marked zones. The limestones near the contact are altered to granular aggregates consisting of white garnet (grossular), tremolite, diopside, quartz, calcite, and a white chloritic material. The

[1] King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par., vol. 1, pp. 266–267, 1878.

[2] Russell, I. C., Geological history of Lake Lahontan: U. S. Geol. Survey Mon. 11. 1885.

[3] Spurr, J. E., Descriptive geology of Nevada south of the fortieth parallel: U. S. Geol. Survey Bull. 208, p. 117, 1903.

more or less parallel orientation of the minerals gives a slightly schistose appearance to some of the rocks immediately at the contact. Some distance north of the main contact there are small masses of epidotized limestone. As a rule the sandy sediments appear to have escaped much alteration, though in one slide of a calcareous sandstone the matrix shows some change.

ORE DEPOSITS.

LUCKY BOY VEIN.

History and ownership.—The veins at Lucky Boy were discovered in 1906 by men engaged in repairing the Hawthorne-Bodie stage road. The main claims, the Mountain King, Lucky Boy, and several others, were early acquired by the Goldfield-Alamo Mining Co., controlled by Messrs. Adams and Miller, merchants of Hawthorne. The greater part of the development has been done by lessees. The deep shaft, the Mountain King, in 1912 was leased to Mr. Charles E. Knox, of Tonopah.

Development.—The Lucky Boy vein is developed by several shafts, the deepest of which is on the Mountain King claim at the west end of the productive part of the vein. In July, 1912, this shaft was over 900 feet deep and sinking was under way to the 1,000-foot level. There are drifts both east and west of the vein at 100-foot intervals and a large part of the ore from the main shoot above the 900-foot level has been stoped. The 100 and 200 foot levels connect with the surface through eastward drift tunnels. The shaft is an incline on the vein to the 100-foot level, below which it lies 2 to 4 feet above the vein in the hanging wall. It is equipped with a 1-ton skip and all hoisting is done by electric power, generated near Bodie, Cal.

On the Lucky Boy claim, east of the Mountain King, there are several smaller shafts, the deepest of which is on the Haller lease. It is an incline on the vein and reaches a depth of 400 feet. A winze in the west drift on the lowest level was 80 feet deep. In 1913 a long crosscut had been driven from the Walker Lake valley to undercut all of the old workings.

Occurrence and general features of the vein.—The vein occurs in a rather irregular fracture, which strikes N. 80°–85° E. and dips 65°–75° S. This fracture lies near the north contact of a body of intrusive granodiorite in limestone, which shows the effects of contact metamorphism. The fracture took place after the intrusion and cuts indiscriminately the limestone, the granite, and the contact, though in general it has followed the contact rather closely. As a rule the hanging wall of the vein is granite and the footwall metamorphosed limestone, though there are many exceptions to this generalization. It was not a simple fracture. There are numerous

splits in the vein, both in the hanging and foot walls, though the majority of the branches come in from the footwall side. In places there are lenses of somewhat mineralized, metamorphosed country rock between branches which reunite along both the strike and dip of the vein. The width of the vein ranges from 4 inches to 8 feet. At some places a difference of a few inches to several feet occurs in the space of 10 feet along the strike. The average width, however, is between 2 and 3½ feet.

Postmineral movement has produced gouge along the hanging wall, has crushed the vein material, and has formed a gouge on the footwall in a few places. This movement appears to have been nearly horizontal, though striæ which pitch to the east at low angles are seen here and there on the walls.

Occurrence and character of the ore.—The ore is not evenly distributed throughout the vein but occurs in small lenses and large shoots. These bodies have a persistent pitch to the west at rather steep angles and seem to be closely related to branch veins. The character of the wall rock apparently has little influence on the localization of the shoots. In the Mountain King ground the main ore shoot, about 120 feet long, was found at a depth of about 300 feet, though there were a few small lenses of ore in the upper workings. From the third level to a little below the fifth level the ore in this shoot was high grade. Between the sixth and eighth levels the vein was not heavily mineralized, though some small lenses were stoped. A short distance above the 900-foot level a second ore shoot has been opened, apparently at the junction of a branch vein with the main vein about 15 feet west of the shaft. The shoots and lenses do not end abruptly but pinch out to narrow streaks of good ore, which finally give out. The richer ore in the shoots occurs as bands, which are more often seen near the walls, particularly the hanging wall, than in the center of the vein. These bands range from 1 inch to 10 inches in width, but are between 2 and 4 inches at most places.

The low-grade ore, not mined at present, consists of crushed silicified wall rock, carrying more or less widely disseminated galena, tetrahedrite (gray copper), sphalerite, and pyrite. At the 900-foot level a lens of metamorphosed limestone between two branch veins contains a small quantity of the same minerals.

The medium-grade ore, which carries 50 to 400 ounces of silver to the ton, consists of fine-grained galena and tetrahedrite, together with a little pyrite. It occurs in bands up to 18 inches in width and in quite large bodies. The galena and tetrahedrite are finely granular, but in the richer ore they have been crushed, forming the "steel galena" and small fragments of tetrahedrite. As a rule the tetrahedrite is the common dark-gray to nearly black mineral, but in some stopes

it has a light steel-gray color. The lighter-colored "gray copper" apparently contains a large proportion of silver in comparison with the copper content. The most valuable ore, which carries 2,000 to 3,000 ounces of silver to the ton, consists of light-colored tetrahedrite in a matrix of quartz and barite and occurs in veinlets in the ore shoots. In this grade of ore some of the tetrahedrite is coated with a thin black film which seems to be silver sulphide (argentite), and copper carbonate stains are also noted. One veinlet of this sort of ore on the 900-foot level shows also a little native silver. This is 300 feet below the ground-water level, which is at about the 600-foot level. Native silver has not been found above the 900-foot level, according to Mr. G. F. Badgett, superintendent of the mine.[1]

Enrichment of the ore bodies below the 300-foot level.—The Lucky Boy vein probably originally consisted of argentiferous galena and tetrahedrite irregularly distributed through a siliceous gangue. Postmineral movement fractured the ore and produced the well-marked gouge seen particularly on the hanging wall. Later the silver and copper content of the ores near the surface were taken into solution by atmospheric waters and carried down along the crushed veins to be redeposited by the tetrahedrite and galena in the vicinity of and below ground-water level. The theory of downward enrichment in silver veins has recently been added to by Messrs. Palmer and Bastin,[2] who have shown the precipitating effect of certain sulphides on silver carried in solutions such as are ordinarily found in mine waters.

Age of the vein.—The Lucky Boy vein cuts limestones of supposedly Mesozoic or younger age and granodiorite that has intruded these sediments. The granodiorite intrusion is probably to be correlated with the intrusion of similar rock which occurred on an extensive scale along the Sierra Nevada in late Cretaceous or early Tertiary time.

Milling.—The ore from the Mountain King vein is treated in a 10-stamp mill equipped with three Pinder concentrating tables, on which most of the lead is saved, and two Diester slime tables, which catch part of the gray copper that has a strong tendency to slime when crushed. Mine water is used in the mill, the available supply being about 55 gallons a minute.

OTHER PROPERTIES.

A number of less important lead-silver veins near the Lucky Boy were not studied in detail. Most of them are east-west fissures with southerly dip and have a mineralization similar to the main vein.

[1] Personal communication.

[2] Palmer, Chase, and Bastin, E. S., Metallic minerals as precipitants of silver and gold: Econ. Geology, vol. 8, pp. 140–170, 1913.

In the granodiorite mountains north of the Bodie stage road there are a number of prospects that could not be visited.

Cory Creek canyon.—Near the head of Cory Creek canyon, north of Cory Peak, there are said to be several eastward-striking veins in granite, none of which were being worked in 1912. Probably the "granite" is the granodiorite, the common rock on the west side of the Wassuk Range. Some of these veins carry lead and silver; others carry gold. There is said to be a 15-stamp concentrating mill at the Big Indian mine in Cory Creek.

Cat Canyon.—Near the forks of Cat Creek, about 7 miles north of west of Hawthorne, there is said to be about 1,500 feet of work on a copper deposit belonging to the Nevada Consolidated Mines & Selling Co. The deposit was discovered in the early eighties, and a little gold was extracted from surface ore. The country rock is granodiorite, cut by dikes of basic granodiorite and aplite. The ore occurs along an easterly striking zone of crushed rock that is reported to range from 25 to 100 feet in width, carrying from 1 to 4 feet of gouge on both walls. The material of this zone is somewhat siliceous and contains more or less disseminated pyrite and chalcopyrite; it is said to average 2½ per cent copper and $4 in gold to the ton. The development consists of three crosscut tunnels 60, 256, and 440 feet below the outcrop. In the upper crosscut a little chalcocite and bornite is reported. Between the 256 and 440 foot levels there is said to be a more or less open fracture next the hanging wall in which native copper is at present being deposited by the rather abundant water coming down along this zone. The vein is said to have been lost in the lowest tunnel at the west end of the drifts at a fault that has a northward strike.

La Panta and Pamlico mines.—South and east of Hawthorne there are many scattered mines and prospects, none of which were visited, and the few notes given below are gathered from various sources.

The La Panta and Pamlico mines, 10 miles east-southeast of Hawthorne, not visited by the writer, were actively worked in the eighties, and since that time considerable gold is said to have been recovered by various lessees. In 1912 a small amount of work was being done at each mine. Both properties belong to the Esmeralda Consolidated Mining Co., of Buffalo, N. Y. According to Messrs. Stannard and House, of Hawthorne, both veins occur in rhyolite near limestone and have a northeast strike. The mountains south of the mines are made up of light gray-blue and white limestones for a considerable distance. The ores from the two veins are similar, consisting of red and yellow stained sugary quartz, which carries rather coarse free gold as nuggets and wires, and some argentiferous galena. The galena, together with cerusite, is said to be found near bodies of high-grade free-milling gold ore. The gold is said to occur in relatively small bodies irregularly scattered through the veins.

The La Panta vein is said to range from a narrow stringer to 30 feet in width, averaging about 5 feet. It dips 35°–45° N. and is developed by a 300-foot vertical shaft and numerous drifts. The ore is said to occur in shoots and to be worth $15 to $17.50 a ton. It is said that this property has produced about $200,000.

The Pamlico vein, said to be nearly vertical, is developed by drifts, raises, shafts, and crosscuts aggregating between 4 and 5 miles in length. Its width is reported to be rather constant, but in some places it attains a maximum of 24 feet. The estimated gross production from the property is $500,000.

At the Pamlico there is a 20-stamp amalgamation mill of about 60 tons daily capacity. Water is piped from Cottonwood Creek, which heads near Buller Mountain in the Wassuk Range, 8 miles west of the mine.

Excelsior Mountain claims.—The Excelsior Mountain Copper Co. owns a group of claims 18 miles south of Hawthorne, at the south end of Whisky Flat. These claims were not visited by the writer, but the following notes, furnished by Mr. House, of Hawthorne, are of interest. The deposit was first worked in 1882 for copper ores, which were rich in silver and carried a little gold. The ores were smelted for a time in a 400-pound Mexican furnace on the ground. They occurred along a vertical eastward-striking contact of "granite" (probably granodiorite) intrusive into light-gray to white limestones that stand nearly vertical. The contact zone, said to be about 400 feet wide, shows a rough banding of constituents. Immediately at the contact there is said to be a narrow zone of very rich silver ore associated with chalcocite. For the 140 feet next north the metamorphosed limestones have little value. An 11-foot belt of copper carbonate ore associated with chalcocite and pyrite occurs next north, followed by about 80 feet of sulphide ore, pyrite and chalcopyrite, said to run between 3½ and 5½ per cent copper. Between the sulphide belt and the unmetamorphosed limestones there is a 200-foot belt of garnetiferous ore that is said to average 1½ per cent of copper a ton throughout, together with a little silver. This ore body is developed by several shafts and crosscuts.

SANTA FE DISTRICT, MINERAL COUNTY, NEV.

LOCATION AND ACCESSIBILITY.

The Santa Fe district (No. 16, Pl. I, p. 18), as the name is used in this report, comprises the part of the Pilot Mountains between New York Canyon and the Luning-Lodi road, and a small area in the