THE ANTIMONIAL SILVER-LEAD VEINS OF THE ARABIA DISTRICT, NEVADA.

By Adolph Knopf.

INTRODUCTION.

The Arabia district, in Humboldt County, Nev., is an old mining camp which, long idle after its first period of activity in the late sixties, has again become active under the stimulus of the present high prices of lead, antimony, and silver. The first smelter erected in Nevada, at Oreana, on the Southern Pacific Railroad, was built in 1865 to reduce the ore of the Montezuma, the principal mine in the Arabia district. The ores of the district are notable in that they consist almost wholly of silver-bearing bindheimite, the so-called hydrous antimonate of lead.

The Arabia district is in the foothills of the Trinity Range, about 4 miles west of Oreana (Nenzel railroad station). The elevation of the district at the Montezuma mine is 4,600 feet—about 400 feet above Oreana. The topography is open, the hills are low and rounded, and the relief is from 200 to 300 feet. The district is wholly without water.

GENERAL GEOLOGY.

Granodiorite prevails throughout the district. Scattered through the granodiorite, however, are blocks and irregular masses of thoroughly contact-metamorphosed sedimentary rocks of the hornfels type. The granodiorite and hornfels are cut by numerous veins carrying bindheimite and quartz. Rhyolite, far younger in age than the ore deposits, in places caps the granodiorite and the inclosed masses of hornfels.

The granodiorite is a fine-grained, evenly granular rock consisting of feldspar, quartz, and biotite. It is as a rule thoroughly altered to a white granular rock resembling an aplite. Under the microscope this alteration is found to be due to conversion of the feldspar and biotite into sericite. As a result of this sericitization the quartz, which is inconspicuous in the better-preserved rock, has become prominent and emphasizes the aplitic appearance of the altered granodiorite. The alteration is so widespread throughout the district that no fresh material was found, and in consequence there is some doubt as to whether the rock is a granodiorite or the closely allied species quartz diorite.

The sedimentary rocks embedded in the granodiorite are chiefly metamorphosed shales. In places they show bedding. They are homogeneous, uniform rocks and contain no strata that are readily and certainly distinguishable from the rest. They are grayish black and extremely fine grained, ranging from microcrystalline to aphanitic, and under the microscope are found to consist mainly of an intimate intergrowth of quartz and biotite. The biotite makes up about one-third of the bulk, and the remainder is quartz, except for a subordinate amount of white mica. Rock of this kind is typical hornfels. The metamorphosed sediments northwest of the Montezuma mine differ from those just described, resembling faintly mottled cherts. Their high specific gravity, however, indicates that they are not cherts, and under the microscope they are seen to consist of quartz and finely granular pyroxene.

The blocks of hornfels occur not only at the surface but also rather unexpectedly in places underground—for example, where the surface exposures, consisting wholly of granodiorite, would lead one to expect only granodiorite in depth. It is clear that some of the blocks are wholly surrounded by granodiorite. The rocks are cut by dikes of granodiorite, which, so far as observed, range from an inch to 15 feet in thickness. The occurrence and distribution of these masses of contact-metamorphosed rocks show that erosion has cut down some distance below the irregular roof of an intrusive mass of granodiorite.

The age of the contact-metamorphic sediments is not certainly known, as no fossils were found in them. According to Arnold Hague [1] the only sedimentary rocks found in the Trinity Range are Jurassic slates, the Triassic rocks so common in the Humboldt Range, the next range to the east, being entirely absent. It is possible, therefore, that the metamorphosed sediments in the Arabia district are Jurassic, and that the granodiorite which intrudes them, instead of being of Archean age, as Hague thought, is early Cretaceous, its age conforming with what has been established in recent years for similar intrusions in other parts of Nevada.

The rhyolites resting on the granodiorite are gray, brown, and black varieties, which as a rule are conspicuously flow-streaked and in places are so thinly flow-laminated as to resemble shales. They contain porphyritic crystals of feldspar and of biotite in lustrous plates. Under the microscope the feldspar phenocrysts prove to be andesine, embedded in a glassy groundmass, and tridymite is found to occur

[1] Hague, Arnold, Descriptive geology: U. S. Geol. Expl. 40th Par. Rept., vol. 2, p. 753, 1877.

in some abundance in the pores of the rock. The absence of sanidine and quartz phenocrysts and the prevalence of andesine point to latitic affinities of the rhyolites. Black obsidian occurs in places at the base of the rhyolite lavas, but it is nowhere more than a few feet thick.

The rhyolites are probably of Miocene or Pliocene age.

THE VEINS.

The ore bodies are fissure veins in granodiorite and hornfels. Those in granodiorite are inclosed between well-defined walls, but within a short distance after entering the hornfels they fray out into narrow stringers. Some of the veins are traceable on the surface for more than 1,000 feet.

The principal ore mineral is argentiferous bindheimite, the so-called hydrous antimonate of lead. In the richer ore bodies it fills the veins from wall to wall in solid masses; in the leaner ore bodies considerable coarse milk-white quartz is associated with it. Under the microscope the quartz from the Montezuma mine is found to inclose numerous small prisms of tourmaline.

The bindheimite occurs in a variety of forms, but two of these are particularly characteristic of the district. One of them is a deep yellowish-brown amorphous variety of high, brilliant pitchy luster, and the other is a yellow compact earthy variety that has commonly a divergent columnar structure, and is obviously pseudomorphic after the sulphide from which the bindheimite is derived. Small particles of this sulphide are occasionally found in the bindheimite and prove to be fibrous jamesonite. The following analysis of bindheimite from the Montezuma mine is given by J. D. Hague:[1]

Analysis of bindheimite from the Montezuma mine, Nev.

[W. G. Mixter, analyst.]

Sb_2O_5	51.94
PbO	40.89
Ag	.33
Fe_2O_3	.60
Insoluble residue	1.66
Water	4.58
	100.00

The different varieties of bindheimite are irregularly commingled throughout the ore. The brown, highly pitchy variety is generally surrounded by a delicate banding, which consists of an alternation of the brown and yellow varieties. Bindheimite, as first pointed

[1] Hague, J. D., Mining industry: U. S. Geol. Expl. 40th Par. Rept., vol. 3, p. 299, 1870.

out by Cornu,[1] is a mineral gel,[2] and this banding appears obviously to be the result of the rhythmic precipitation of some diffusing compound before the bindheimite gel had set (the Liesegang effect). The diffusing compound was probably an iron salt, and its rhythmic precipitation was due to hydrolysis, a possibility that was shown experimentally by Liesegang.[3]

Under the microscope the pitchy bindheimite is seen to be a deep yellowish-brown translucent homogeneous substance. A highly birefringent mineral, possibly valentinite (Sb_2O_3), is intergrown with some of the bindheimite from the Montezuma mine.

Other oxidized minerals, which so far as now known occur only in the ore of the Montezuma mine, are plumbojarosite (basic sulphate of lead and ferric iron), scorodite, cerusite, and gypsum.

The ore of the Montezuma mine contained about 50 per cent of lead and antimony and 80 ounces of silver to the ton.[4] The ore left in the stopes of the Electric and Jersey mines contains about 10 per cent of lead, 10 per cent of antimony, and 15 ounces of silver and 0.10 ounce of gold to the ton.

MONTEZUMA MINE.

The Montezuma has been the chief productive mine in the district. In 1868 Raymond[5] estimated that it had produced 1,500 tons of ore and that the reserves in sight were 1,200 tons. To treat the ore of this mine the company built the smelter at Oreana, on Humboldt River, after earlier unsuccessful attempts had been made to reduce the ore in a stamp mill. At first only the silver was recovered during smelting, the antimony being sublimed and the lead cupeled. On the completion of the Central Pacific Railway, however, transportation costs were so much lowered that the lead and antimony could be profitably marketed, and the crude metal from the shaft furnace, an alloy of lead and antimony, was sold without further treatment to Selby & Co., of San Francisco, who paid $100 a ton for the base metal and $1 an ounce for the silver it contained. The ore from the mine carried from 40 to 50 per cent of lead and antimony and from 60 to 80 ounces of silver to the ton. In the spring of 1917 the old slags from the Oreana smelter were being shipped to the smelter at Midvale, Utah, to recover the lead, antimony, and silver in them. They averaged 7 per cent of lead, 5 per cent of antimony, and 2 ounces of silver to the ton. This accords with Hague's statement that the

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[1] Cornu, F., Ueber die Verbreitung gelartiger Körper im Mineralreich, ihre chemisch-geologische Bedeutung und ihre systematische Stellung: Centralbl. Mineralogie, Jahrg. 1909, p. 330.

[2] As a colloid mineral bindheimite can not be given a definite chemical formula, such as is denoted by the term hydrous antimonate of lead. Lacroix, in fact, writes yPbO. $x Sb_2O_5$. $z H_2O$.

[3] Liesegang, R. E., Geologische Diffusionen, p. 147, 1913.

[4] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains for 1868, pp. 130-131, 1869.

[5] Idem, p. 129.

slags were poor, the richer slags having been returned to the furnaces. The smelting works and methods of treatment are described in detail by Hague.[1] During the removal and shipment of the old slags in 1917 some of the tailings from the unsuccessful stamp mill were uncovered; they carry 18 per cent of antimony, 24.7 per cent of lead, and 17 ounces of silver to the ton.

The principal workings of the Montezuma mine consist of a large pit 90 feet long and 20 feet wide, whose floor is about 20 feet below the surface of the hill. In early days an incline was sunk 120 feet on the vein, but at 60 feet it passed out of ore. Subsequently a drift was run westward at the 60-foot level some 80 or 100 feet, and was reported as being in good ore for the whole distance.[2] At the present time the lower workings are inaccessible below a level 35 feet vertically below the floor of the pit.

The mine has been practically idle since 1875. In 1917 the old dumps were sorted for the bindheimite they contained, and some work was done toward reopening the mine, the intention being to explore it in depth.

The ore body occupies a fissure in the granodiorite; it trends east and dips 45° N. The walls are well defined and are strongly marked with groovings that dip westward at a moderate angle. The ore body formerly worked appears to have been a large lens that pitched westward, possibly in conformity with the groovings scored on the footwall. The footwall is in part a large block of metamorphic shale inclosed in the granodiorite. A crosscut that was driven through the shale shows that the shale is cut by a close network of quartz veins, so that the larger proportion of exposed rock consists of coarse-grained white quartz, which locally carries exceedingly coarse crystalline calcite.

The main ore body, at the level of the pit, was 14 feet thick and 90 feet long. The vein was "filled with ore, variable in quality but almost entirely free from gangue, and nearly all fit to send to the furnace without assortment." [3] Below the level of the pit the vein averages 6 feet in thickness. The ore formerly worked consisted, as the old records show, largely of bindheimite, containing traces of residual jamesonite. Cerusite, black manganiferous oxide of antimony, gypsum, and arsenopyrite partly oxidized to the green mineral scorodite can still be found locally. In the workings now accessible below the floor of the pit the vein filling consists of secondary "jasper" irregularly banded and mottled in yellow and red. Microscopic examination, supported by chemical tests, shows that the yellowish jasper contains considerable plumbojarosite in closely packed aggregates of hexagonal tablets. The plumbojarosite not uncommonly occurs in

[1] Hague, J. D., Mining industry: U. S. Geol. Expl. 40th Par. Rept., vol. 3, pp. 300-308, 1870.
[2] Idem, p. 299.
[3] Idem, p. 298.

perfectly formed crystals as a replacement of coarse quartz grains that are residual from the primary ore and are now inclosed in the secondary cryptocrystalline quartz forming the bulk of the jasper.

OTHER MINES AND PROSPECTS.

Considerable work was done in early days on the other veins of the district. These are narrow veins, considerably smaller than the Montezuma, and trend north and dip 30° – 60° E. The most development work has been done on the Electric and Jersey veins, which are 1,000 feet north of the Montezuma mine.

The Electric vein is opened by an incline 350 feet long, from which four levels have been turned off. A vertical depth of 210 feet is attained. The vein has been stoped, but about 1,000 tons of antimonial lead-silver ore is estimated to remain in the stopes. The vein ranges in thickness from 1 to 3 feet. On the upper levels it is inclosed in granodiorite and lies between remarkably even, regular walls, but in the hornfels, which it enters in the lower part of the mine, it splits up into thin barren stringers that almost pinch out. On the surface the Electric vein enters hornfels 60 feet south of the incline and abruptly narrows down. A formidable-looking postmineral fault, trending east and dipping 45° N., has been cut in the lower workings, but as it fails to displace the contact of the granodiorite and hornfels 400 feet east of the vein, it can not displace the vein more than a few feet at most.

The Jersey vein is 220 feet east of the Electric vein, to which it is roughly parallel. It is separately owned, being held by a claim, 10 feet wide and 1,200 feet long, which is wholly inclosed in the Electric claim. It is opened by a number of inclines, the main one of which is 150 feet long and reaches a depth of 71 feet. The upper levels are in granodiorite, but in depth the vein enters the hornfels, with results unfavorable to the quality and quantity of ore. A notable feature is a conspicuous postmineral fault, which despite its appearance suggestive of strong movement dislocates the vein not more than a few feet. South of the fault the most massive bindheimite ore left in the mine was seen; it occurs in bodies as much as 1 foot in diameter consisting solidly of the pitchy variety.

The Electric and Jersey veins show clearly, both along the strike and down the dip, that the hornfels has been highly unfavorable for vein formation. In both mines, however, there remains much territory in granodiorite which is probably worthy of exploration.

At depths greater than have yet been obtained the veins will be found to reenter the granodiorite and probably lose their stringered character, becoming simple fissure fillings. The depth at which this change will be reached can not be predicted, but it is probably not great and may be as little as a few feet.

There are numerous other narrow veins in the district that are of the same general character as the Electric and Jersey veins; they are on patented claims owned by the Electric Mining & Reduction Co.

The Aztec is a recent location in which the mineralization occurred along a fissure that is possibly the westward extension of the fissure on which the Montezuma ore body is situated. The vein is 6 inches thick and dips 60° N.; the hanging wall is sedimentary rock and the footwall is granodiorite. It carries bindheimite, which is pseudomorphic after jamesonite, and quartz inclosing a little chalcopyrite.

PERSISTENCE OF ORE IN DEPTH.

The main questions of practical interest with reference to the veins of the district are the probable tenor of the ore in the sulphide zone and the persistence of the ore in depth. Sulphides are rare in the ore bodies so far laid open to view, and it is probable that this highly oxidized ore may persist to depths of 400 or 500 feet, or down to the level of Humboldt River.

Because lead and antimony do not readily go into solution during the oxidation of their sulphides, it is probable that the primary sulphide ore will contain essentially as much lead and antimony as the oxidized ore. During oxidation, however, much sulphur was eliminated, doubtless in the form of sulphuric acid, and this process favored downward migration of the silver. The silver taken into solution in the zone of oxidation would be precipitated by the primary sulphides that occur at greater depth, and it is therefore not unreasonable to expect that rich secondary antimonial silver sulphides will be found just above the zone of primary sulphides.

Jamesonite, so far as its paragenesis is known, appears to occur more commonly in ore deposits formed at high temperatures, as is indicated, for example, by its occurrence as the principal ore mineral in the contact-metamorphic deposit at Zimapan, Mexico,[1] and in tin-bearing veins in Bolivia. The tourmaline content of the quartz in the Montezuma vein accords with this supposition. If, then, the veins of the Arabia district were formed under conditions of high temperature, this feature, considered together with the widespread, thorough hydrothermal alteration of the granodiorite inclosing the veins of the district, indicates that some of the stronger veins may carry ore in depth. This possibility, combined with the chance that a zone of enriched silver sulphides exists in depth, suggests that the district merits deeper exploration than has yet been attempted.

[1] Lindgren, Waldemar, and Whitehead, W. L., A deposit of jamesonite near Zimapan, Mexico: Econ. Geology, vol. 9, pp. 435–462, 1914.