Geology and Ore Deposits of Mohave County, Arizona*

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Introduction

The present sketch is submitted by request in the hope that it may serve as a basis for geologic discussion of the mining camps in Mohave County, which is experiencing a marked revival of activities.

The region, commonly known as the Mohave district and Kingman district, lies in western Arizona in the southern part of Mohave County, bordering California and Nevada on the west (Fig. 1). Kingman, the principal town, is situated near the center of the area on the Atchison, Topeka & Sante Fe Transcontinental Railway.

This region is composed of naked desert ranges of mountains and broad detritus-filled valleys, the southern extension of the characteristic topography of the Great Basin. In altitude it varies from 500 ft. in the southwest to 8,300 ft. on Hualpai Peak southeast of Kingman.

The mountains trend north-northwest. They rise about 3,000 ft. above the valleys, are generally rugged and were formed mainly by erosion. They are composed in the main of a complex of pre-Cambrian granitoid rocks which underlies the area as a whole. Like the valleys, they average about 10 miles in width. Beginning on the east, they are the Grand Wash Cliffs, the Cerbat Range, the Black Mountains or River Range, and the Eldorado Range.

The upper or dominantly cliff half of the Grand Wash Cliffs, marking the edge of the Colorado Plateau, is composed of nearly horizontal sedimentary Paleozoic strata of the Grand Canyon section, and the lower half of the underlying pre-Cambrian complex.

The Cerbat Mountains situated in the central part of the area, and the Black Mountains situated between Detrital-Sacramento Valley on the east and Mohave Valley, the great trough of the Colorado River, on the west, are locally flanked or overlain by Tertiary volcanics (Fig. 2). The latter consist of five groups of mountains of which the most important is the Black Mesa group on the south.

The Eldorado Range, rising from the great trough of the Colorado on the west and containing Searchlight, Eldorado Canyon, and other camps, is topographically and geologically similar to the Black Mountains.

Geology of the District[1]

The rock groups beginning with the oldest are the pre-Cambrian complex, Paleozoic sediments, pre-Tertiary intrusives, Tertiary volcanics, and Tertiary (?) and Quaternary sediments (Fig. 1). The first and third of the divisions named are the most important.

The pre-Cambrian complex consists of gray gneissoid granites, coarse,

[1] A fuller description of the rocks appears in *Bulletin* No 397, *U. S. Geological Survey* (1909).

porphyritic granitoids and their related schists, all of igneous origin and with varying degrees of metamorphism. It is traversed by a schistose

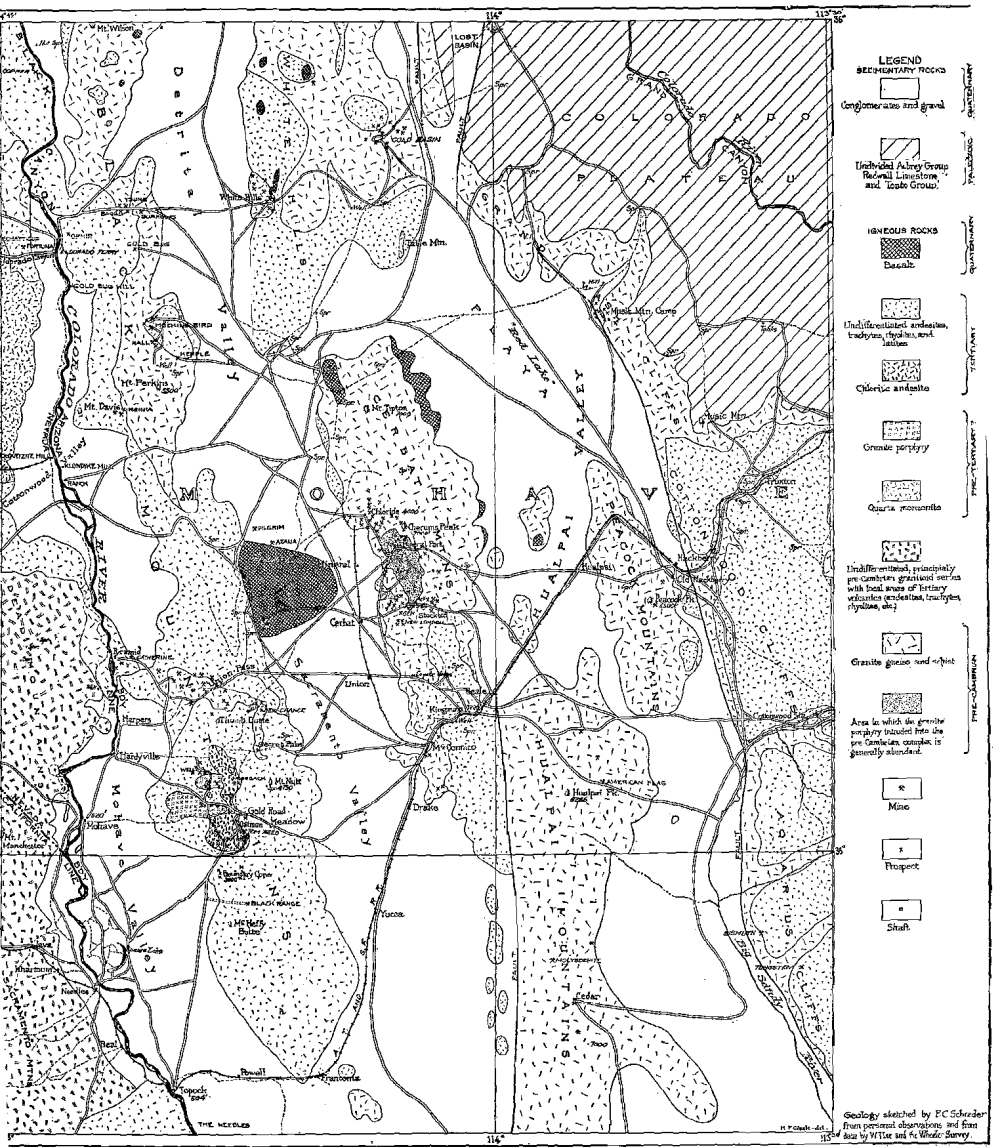

FIG. 1.

structure trending N. 30° E., and contains nearly all the mineral deposits of the Cerbat Range and Grand Wash Cliffs.

The Tertiary (?) and Quaternary sediments consist of several placer

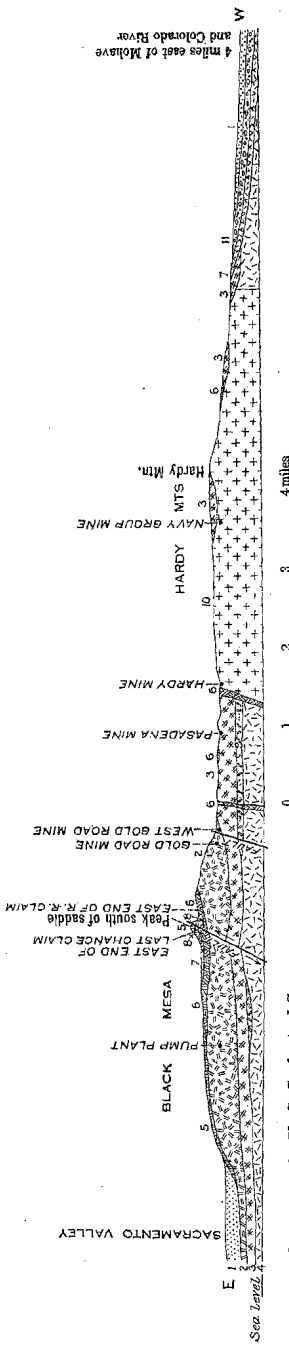

FIG. 2.—GENERALIZED SECTION ACROSS BLACK MOUNTAINS. 1, Sands and gravels; 2, undifferentiated volcanic rocks; 3, green chloritic andesite; 4, gneissoid granite; 5, basalt; 6, rhyolite; 7, young andesite; 8, rhyolite tuffs; 9, andesite and andesite tuffs; 10, granite porphyry and micropegmatite; 11, conglomerate.

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gold-bearing detrital formations or "wash", locally 2,000 ft. in thickness, partially filling the intermontane valleys.

Locally intruding the pre-Cambrian rocks are pre-Tertiary igneous masses and dikes thought to be of late Jurassic or early Cretaceous age. They occur chiefly in the Cerbat Mountains and are connected with the genesis of the deposits. The most important are granite porphyry, a light gray medium-grained rock, and lamprophyric rocks, the latter occurring mainly as dark, complementary, narrow dikes accompanying the acidic intrusives.

The Tertiary volcanics consist mainly of andesites, trachytes, rhyolites, and latites, lying in broad superimposed sheets, flows and beds locally aggregating 3,000 ft. in thickness (Fig. 2). They are best developed in the Black Mountains, particularly in the southern part (Fig. 3). They contain most of the mineral deposits of the range and played an important part in their genesis.

ORE DEPOSITS OF THE DISTRICT

General Description

The discovery of mineral and the beginning of mining in the Mohave area date from the finding of ore at the Moss mine, 4 miles northwest of Gold Road in the early sixties. From 1904 to 1914[2] the production was nearly $16,000,000, of which $11,500,000 is in gold, nearly all derived from the Tom Reed and Gold Road mines. Besides gold and silver, zinc, lead, copper, tungsten, molybdenum, and bismuth are produced. The distribution of the districts or camps, about 30 in number, is shown in Fig. 4.

[2] *Mineral Resources, U. S. Geological Survey*, 1904–1914.

The deposits are contained in two distinct groups of fissure veins. The first group consists of the veins of the Cerbat Range which occur chiefly in the pre-Cambrian rocks and are genetically connected with the Mesozoic intrusives, especially granite porphyry and lamprophyric rocks. They are quartz fissure veins in which the quartz carries principally silver but also gold and ores of the other aforenamed metals. They were deposited in depth by hot waters. Their deep-seated character and close association with the major geologic structures indicate continuity in depth. They seem likely to continue productive long after the gold deposits now attracting so much attention in the volcanic rocks of the Black Mountains shall have become exhausted. Oxidation extends to depths of about 300 ft. At present the sulphide ores are principally utilized, though the rich secondary oxidized silver ores furnished most of the early-day production.

The second group comprises the veins of the Black Mountains which occur chiefly in the Tertiary volcanic rocks and whose filling besides quartz includes calcite, adularia, and fluorite. They are deeply oxidized. The valuable constituent is almost wholly free gold.

The Cerbat Mountains Group

General Description.—The deposits of the Cerbat Mountains are mostly located at from 9 to 20 miles north of Kingman. Their production for the year 1915, according to the Chloride Mining Bureau, is $3,000,000. They occur in two sets of well-defined fissure veins, with steep dip-forming conjugate systems, one striking about N. 20° W., parallel with the dominant jointing, and the other N. 60° W. perpendicular to the schistosity of the rocks. Many of the veins have a length of nearly a mile. The structure is irregularly massive. Among the primary-ore minerals, the most important are pyrite, chalcopyrite, arsenopyrite, galena, and sphalerite; more rarely, molybdenite, gold-silver telluride and stibnite. The decrease in galena and increase in pyrite noted in the lower levels, suggests a gradual change in the primary filling. Silver and lead predominate in the Chloride, Mineral Park, and Stockton Hill districts; gold, zinc, and silver in the Cerbat district. The primary ore is leaner in gold and silver than the oxidized ore, and many mines which near the surface were silver mines, with increase in depth carried more lead, and at still greater depths have become cupriferous. The so-called "copper belt" of the area extends from Mineral Park northwestward toward Chloride for a distance of several miles. It contains the Pinkham and Midnight copper mines, and in the Mineral Park end of the belt a recently discovered "copper porphyry" deposit which is attracting attention.

The water level is found at a maximum depth of about 400 ft. In general, the ores above the water level are oxidized, but in many places

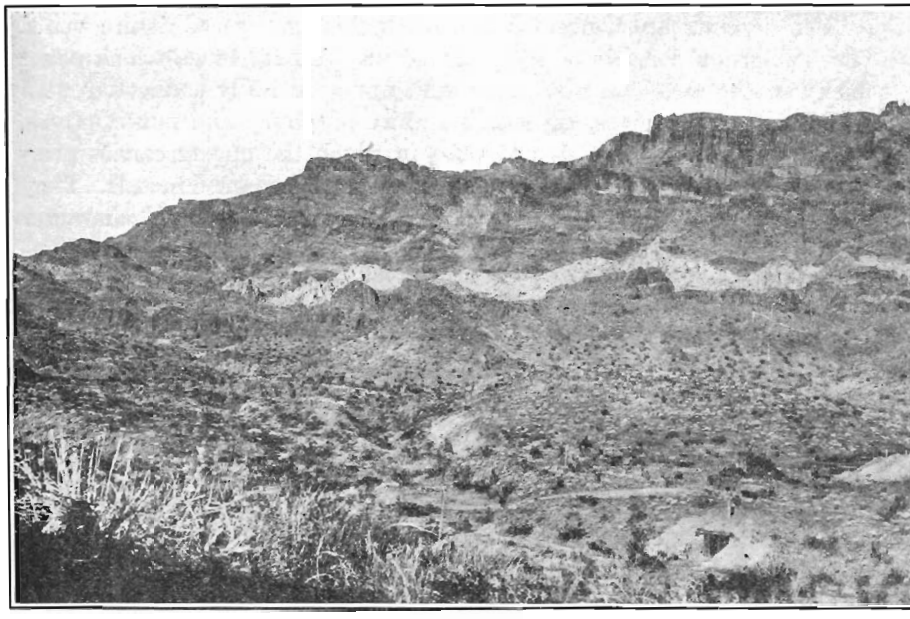

FIG. 3*A*.—TOM REED MINE AND VICINITY, LOOKING NORTHEAST (IN 1907). DARK

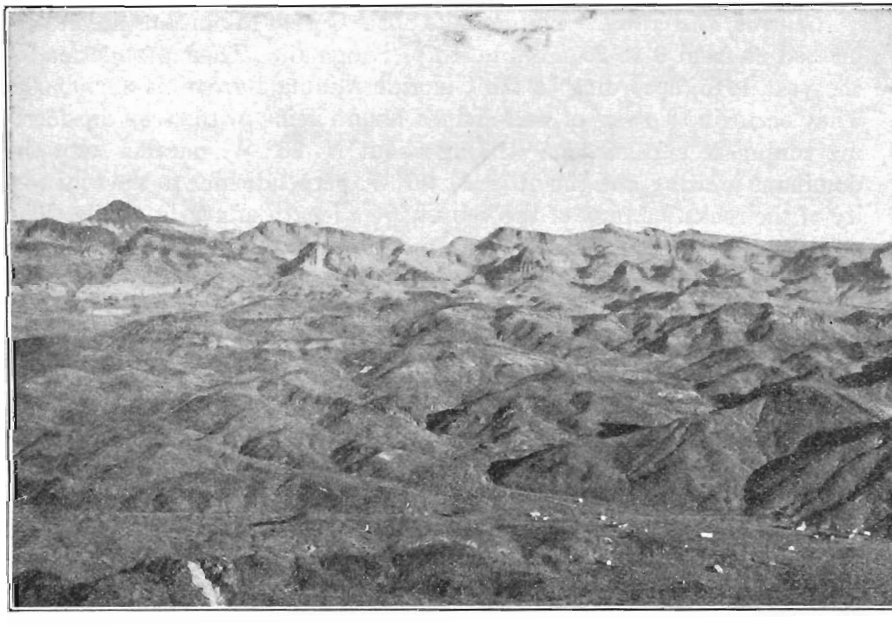

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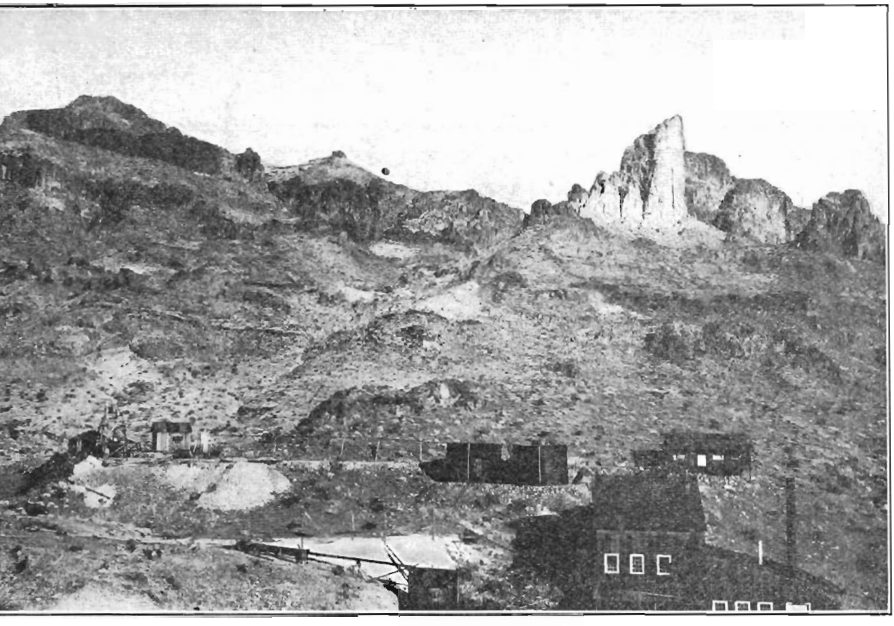
FIG. 3*B*.—FOOTHILLS OF GREEN CHLORITIC ANDESITE, LOOKING EAST FROM LELAND RANGE, 4 MILES DIS-



VOLCANIC ROCKS OF RANGE IN BACKGROUND, INTRUDED BY LIGHT-COLORED RHYOLITE.

NE. MINES NEAR VIVIAN, AND GREEN CHLORITIC ANDESITE IN FOREGROUND; MAIN NT, IN BACKGROUND.

(*e.g.*, in the Tennessee vein) galena, and also, locally, pyrite, appears near the surface in association with oxidized ores. In a few mines oxidized ores are found below water level, but not to great depth. The secondary,

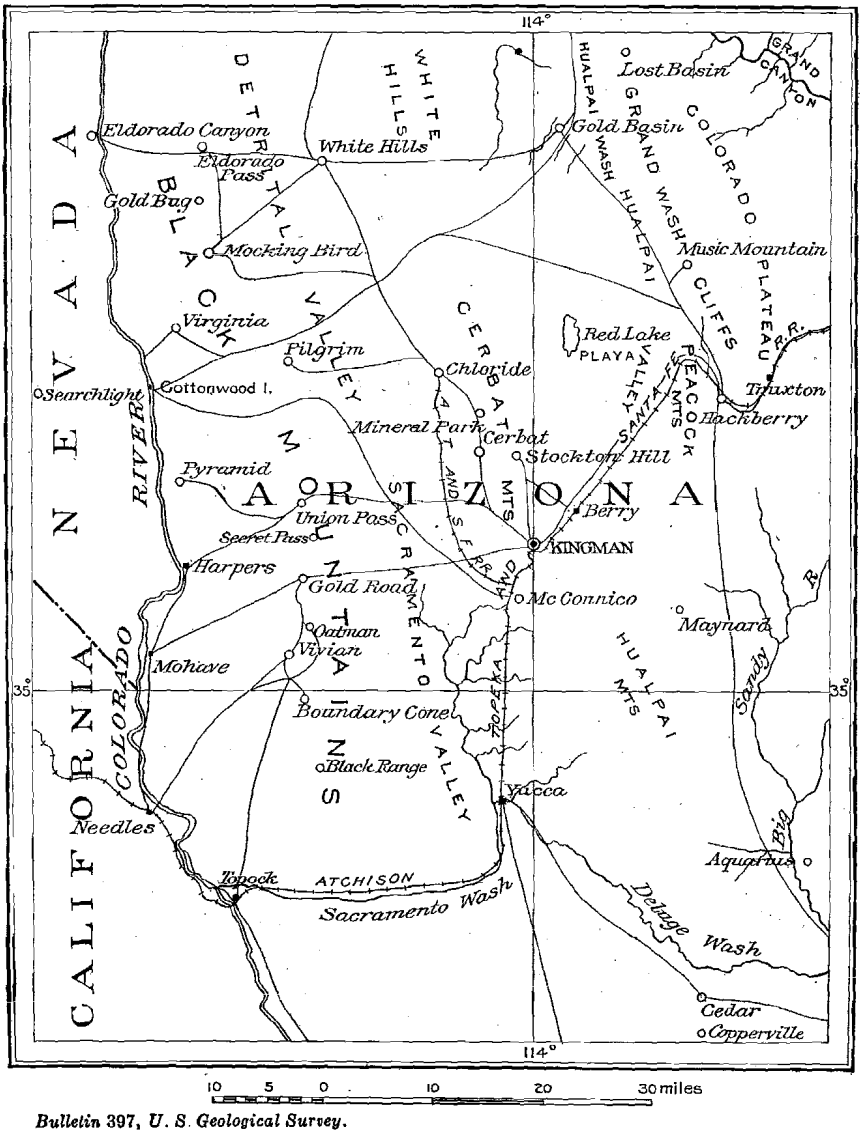


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FIG. 4.—MAP SHOWING MINING CAMPS IN THE MOHAVE COUNTY MINING REGION, ARIZONA.

or oxidized ores, consist chiefly of native silver, horn silver, and cerusite. Ruby silver and argentite are also present with oxidized ore, but do not occupy any well-defined zone between the oxidized and primary ores.

Many of the ore shoots coincide with intersections or forkings of veins. Good examples were noted in the Pinkham, Elkhart, Rainbow, Pay Roll, and Tennessee mines.

Tennessee Mine.—In the Chloride district, a dozen or more mines are opened to depths of 200 to 1,000 ft. or more, and expose large quantities of good gold-silver and other ores. Among them the Tennessee mine, situated a mile east of Chloride and owned by the United States Smelting, Refining & Mining Co., has long been one of the greatest lead-zinc producing properties of the State. It is credited with a present monthly production of $150,000. It has good orebodies on the 400, 800, 900, 1,000, 1,200, and 1,400-ft. levels, the last-named being the present limit of development. During a considerable portion of the time in recent years it has shipped about 200 tons of ore daily, mostly to Needles. The present daily output is said to be about 300 tons, mostly from the 1,170, 700 and 500-ft. levels.

The mine is on the Tennessee vein, which is regarded as a part of the great lead-bearing "lode" on which the Schuylkill and Elkhart mines to the north are situated. The vein is 12 ft. or more in width, and is locally banded. It dips about 68°E. in pre-Cambrian gneiss, with granite and schist near by and a pegmatite footwall reported in the lower levels. The orebodies which occur as lenses in the vein average about 5 ft. in width. The ore consists mainly of galena and blende, but carries a fair amount of silver and some gold and copper. At present the zinc ore is shipped to the company's smelter at Bartlesville, Okla., and the lead ore to Midvale, Utah.

The mine has been productive almost from the surface down. From between the surface and the 400-ft. level, thousands of tons of rich galena ore have been shipped. Here the main ore shoot had a horizontal extent of about 250 ft., and in places was 15 ft. in width. On the 400-ft. level, an orebody 21 ft. in width with 5 in. of pure galena was mined for the distance of about 40 ft. From the fourth to the fifth level there was a predominance of blende, but from the fifth to the sixth level galena increased to the proportion found in the upper part of the mine.

The 500-ft. level contained good ore for a distance of 800 ft., and the raise from it showed 12½ ft. of almost pure galena. On the 600-ft. level, the vein contained about 10 ft. of good ore. Besides the aforedescribed deposits, large bodies of good zinc ore, some 12 ft. in width, on the 200-ft. and 500-ft. levels, have been left standing in the mine. According to recent reports there has just been opened up on the 1170- and 1400-ft. levels fine bodies of ore averaging about 25 per cent. each in lead and zinc. The body on the 1,170-ft. level has an average width of 8 ft. and a known horizontal extent of 250 ft.

Midnight Mine.—The Midnight mine, located about 2 miles south of Chloride, and adjoining the Pinkham mine, is said to have been recently

purchased by Salt Lake parties for $250,000. It has produced considerable high-grade copper ore, which contained also important amounts of silver and gold. It is opened to the depth of 300 ft. and is said to have 25,000 tons of pay ore blocked out in the workings, including workable bodies of relatively pure zinc ore. On the 200-ft. level, where the lode is 40 ft. in width, the average zinc content is 15 per cent.

Mineral Park.—The copper porphyry deposit recently discovered near Mineral Park and owned by the Copperfield Copper Porphyry Co., occurs in "porphyry" which seems to be the intrusive granite porphyry aforedescribed, the abundant source of mineralization in this part of the field. The deposit is said to have a width of 1,000 ft. and a length of ½ mile. It contains seams and small bodies of chalcocite and native copper disseminated through the porphyry, which, throughout the greater portion of a 160-ft. crosscut tunnel, carries from 3 to 30 per cent. of copper, with a width of 6 ft., averaging 25 per cent. The deposit is reported to contain by estimate 100,000 tons of 5 per cent. ore. Ore removed in doing development work is reported being shipped to the Humboldt smelter.

Golconda Mine.—The deposits of the Golconda mine operated by the Union Basin Mining Co., in the Cerbat district, occur chiefly in the Golconda vein in the pre-Cambrian complex and seem to be associated with the Mesozoic intrusives. They have produced from essentially surface workings several hundred tons of rich ore containing chiefly gold, silver, and lead with some copper and zinc. The drift on the 300-ft. level is said to have been driven 200 ft. on a 4-ft. ore shoot that averaged about 50 per cent. of zinc, and more recently the mine is reported to be daily shipping to Bartlesville about 100 tons of high-grade zinc ore on which net returns of 9 c. per pound of zinc is realized. Some ore averaging about $12 to the ton is also treated in a 30-ton oil-flotation plant at the mine. The present monthly production is said to be about $250,000.

The mine is reported to have commercial ore on the 1,100-ft. level and a large amount of good ore in all other levels. The present production is derived mainly from the 800-ft. level. On the 900-ft. level, the ore shoot has a known extent of 850 ft. and a large tonnage of high-grade ore is being stoped. From this level a crosscut is being extended to the Tubb vein which parallels the Golconda vein 120 ft. distant on the west and has produced considerable lead-silver ore. On the 700-ft. level, the stopes are working in a 12-ft. shoot of excellent milling ore.

During the year 1915, the mine is reported to have paid two dividends of $85,000 each, which is about 20 per cent. on the issued capital, and having proved the continuity of the ore shoot in depth the company is now erecting a 200-ton oil-flotation plant for treatment of zinc ores. There is said to be $400,000 worth of zinc in the tailings on the dump and in the old stopes in the mine. The mill will be operated by electric power supplied by the Desert Power and Water Co. from its oil-burning

plant at Kingman for about $12 per horsepower per month. The power line is also being extended to Chloride and the Tennessee mine. The introduction of electric power into the Cerbat Mountain districts seems likely to result in production from many mines now dormant but which, like the Tennessee and Golconda, are known to contain workable deposits. The prospect of cheaper power in the near future is said to be good.

Other Ore-bearing Districts.—Deep development is also being done by the Middle Golconda Co. on the adjoining Big Bethel and Silver claims, which are believed to contain the north extension of the veins of the Golconda mine. Here the main vein is 50 ft. wide and contains much good-grade zinc ore.

A few miles to the east, the Arizona-Butte Mines Co. is building a very complete mill to treat zinc-lead-gold-silver ores of the Banner and other Stockton Hill mines.

South of Kingman in the Yucca, Cedar Valley, and Aquarius Cliffs districts, respectively, plants are in operation producing concentrates of tungsten, molybdenum and bismuth ores.

Lost Basin District.—In concluding remarks on the eastern part of the region, attention is here called to certain copper deposits known for a decade or more in the Lost Basin district on the northeast. The occurrence of these deposits on the trend of the great northwest-southeast mineralization belt of Arizona which contains Bisbee, Ray, Globe, Prescott, Jerome, and other important districts, and under similar geologic conditions as productive deposits in most of those districts, seems to render them worthy of mention at this time.

With a width of about 9 miles, the Lost Basin district extends from the Colorado River at the mouth of the Grand Canyon southward in the Grand Wash Cliffs for the distance of about 20 miles, with Hualpai Wash roughly forming the western boundary. The topography is mostly rugged. The country rock consists of the pre-Cambrian granitic complex, which here is considerably schistose, and the overlying Paleozoic sediments of the Grand Canyon section (Aubrey group, Redwall limestone and Tonto group).

Important gold- and silver-bearing veins occurring mostly south of the middle part of the belt in the pre-Cambrian rocks have long been worked from time to time, and some are now producing. They strike about north. Their ores are fine in texture and are excellent cyaniding ores.

The copper deposits extend from the middle of the belt eastward nearly to the summit of the Grand Wash Cliffs and edge of the Colorado Plateau. They consist of copper-bearing quartz veins and lodes which trend northwest-southeast, some being exposed by erosion through a vertical range of several hundred feet or more. They occur chiefly in the granitic rocks, but some of them, notably on the east, are in the

Paleozoic limestone and other sediments. The croppings are prominent and some are extensive. They consist principally of masses of brown and blackish iron, copper and manganese-stained quartz containing malachite and azurite. Some of the ore is reported to assay from 17 to 20 per cent. in copper and to contain also gold and silver.

The Black Mountains Group

The deposits of the Black Mountains are mostly on the western slope of the range. They occur in well-defined fissure veins, but differ in most respects very markedly from those of the Cerbat Range. They are found chiefly in the Tertiary volcanic rocks, and belong to the great group of deposits found in this class of rocks throughout the West.

Until recently the most favorable ore horizon was regarded as in the green chloritic andesite and the undifferentiated volcanics, with profitable though subordinate deposits occurring also in the upper rhyolitic series. Recent developments, however, seem to indicate that, in the Tom Reed-Gold Road district at least, the main ore zone probably extends to a deeper horizon, in the so-called older andesite or still lower rocks.

The veins in general trend northwest-southeast with steep northeast dip. They are fairly regular, but the walls are usually rough, broken and frequently full of stringers branching off from the vein. There is a general absence of fluccan or gouge. The gangue primarily was mainly calcite and dolomitic carbonates, but these minerals have largely been replaced by quartz and adularia, a variety of orthoclase free from sodium, semi-translucent and which is so intimately intercrystallized with the quartz that it is not recognizable to the eye. The gangue contains also many inclusions of brecciated altered country rock.

A striking feature of the gangue in many places, particularly in the Tom Reed-Gold Road district, is its characteristically laminated or platy, bladed and cellular structure, pseudomorphic after calcite, barite or other spar in which many contiguous or connecting plates are variously arranged. This material is aptly termed by the miner "fish-scale quartz," from the adjacent plates partly overlapping one another. The plates range from minute up to an inch in diameter and from the thickness of paper to $\frac{1}{10}$ in. in thickness. Much of the quartz intimately associated with the better-grade ore is of greenish or yellowish-green color and waxy luster, which has led to inquiry concerning the source of the color. The cause of the color is not definitely known, nor easy to determine. From preliminary tests it seems to be mainly silicates of iron, manganese, and perhaps other minerals, chlorite, actinolite, rhodonite, dioptase, etc., which may be an important source of the black iron and manganese oxides common as stain, small bodies and pockets in the croppings and more oxidized ores. It is noticeable that the greenish quartz

occurs more frequently in a crustified or banded form than does the uncolored gangue, which method of forming more readily favors the entering of various salts and minerals into its composition. In the Miller mine on the Hardy vein, 2 miles west of Gold Road, the greenish color of the quartz seems to be due largely to fluorite which is present in considerable quantity in the vein, much of it being replaced by quartz.

The deposits seem to have been formed near the surface by thermal solutions which circulated through the lavas at the close of igneous activity. They seem to belong to the late Tertiary epoch of metallization. They are oxidized to depths of 600 to 700 ft. and, as a rule, contain little or

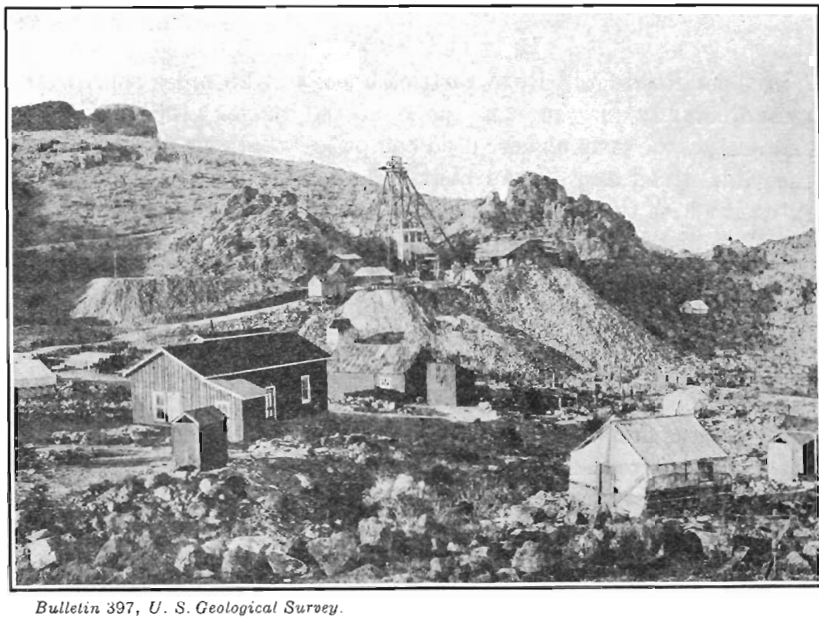

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FIG. 5.—GOLD ROAD MINE, MAIN SHAFT LOOKING SOUTH.

Silicified lode and vein wall croppings on both sides. Edges of heavy flows of volcanic rocks in left background.

no sulphides. Gold is almost exclusively the valuable constituent, usually no base metal being present. The gold as a rule is free, but occurs in very minute particles and is best recovered by the cyanide process. Gold telluride is reported from a few mines.

There is no gossan nor iron hat in the outcrops of the veins. In general, the veins weather in relief only where the filling consists chiefly of quartz or a mass of cemented silicified rock. There the croppings form prominent reefs. Likewise, the vein walls are frequently strongly silicified and hardened with the result that they too weather in forms rising to heights of 20 ft. or more above the surface and extending for considerable distances as seen at the Gold Road mine, Fig. 5. This hardened wall

rock, or so-called "ledge matter," is sometimes netted by stringers of quartz branching off from the vein. It denotes arresting or damming back of copious mineral-bearing solutions that circulated at the locality, and generally indicates workable deposits in the adjacent underlying portion of the vein as described later under the Gold Road mine. Many of the deposits, as exemplified by the Tyro, the Gold Road, and other veins, carry relatively unimportant values near the surface.

Of the ten or more districts in the range the most important is the Tom Reed-Gold Road district.

Tom Reed-Gold Road District

General Description

The Tom Reed-Gold Road district lies about 25 miles southwest of Kingman, mainly on the west slope of the range. In keeping with present usage, the term as here used comprises what was formerly known as the Gold Road and Vivian districts, and the area is approximately co-extensive with the southern part of the San Francisco district of early days. The district has a north-south length of about 10 miles and a width of 6 miles. The principal camps and centers of activity are Oatman, the settlement of the Tom Reed and neighboring mines, situated in the west slope of the range 27 miles from Kingman, and Gold Road, 2 miles north of Oatman. For more than a year Oatman continued to be the center of attraction in the Southwest.

Mineral was first discovered in the district, as aforedescribed for the Mohave County region, in the early sixties at the Moss mine 4 miles northwest of Gold Road. The mine soon produced $240,000, in gold from rich surface ore.

Production in the district has continued more or less steadily since the discovery of the Gold Road mine in 1902. Recently discoveries in the Tom Reed mine and vicinity have been attracting attention to the district, with the result that the value of the plants and machinery now installed at the various mines is said to aggregate nearly $2,000,000. Some 50 odd plants are in operation. The greater portion of them have been installed since the first of the year 1915, during which time nearly 200 companies have been organized to operate in the district, of which 150 are fully equipped and most of the others are receiving machinery. Thirty or more properties hitherto dormant have become active, and the population, which is gathered from all the mining camps in the West, has increased from 600 to more than 7,000 and is gradually increasing. Oatman, which is said to recall Goldfields' boom, is described as a well-equipped, substantial town, a cleanly, orderly, model camp, where living is such as one expects to find only in large towns. It is electrically lighted, has three news-

papers, schools, churches, a stock exchange, and well-stocked stores and business houses of all kinds. It is rapidly becoming the outfitting center for a large territory containing many new districts for a distance of nearly 100 miles north and south along the range. Wildcatting is checked by the laws of Arizona.

Owing to the demand for building space, a new camp, Old Trails, has grown up in the broad wash south of Oatman and there are a dozen other surrounding town sites and additions. Mail, passenger, and express service is by automobile chiefly from Kingman. A similar service exists between Oatman and Needles, 20 miles distant on the southwest, in which the Colorado is crossed by boat. Freight is delivered in the district at a cost of $11.50 per ton by motor truck, road locomotive, and mountain tractor from Kingman, and from Topock, formerly Mellen, located 25 miles distant at the east end of the railroad bridge crossing the Colorado. Early construction of a branch railroad from Topock to Oatman, which is quite feasible, is reported under consideration.

Good water for domestic use is pumped from neighboring springs found mostly in the porous rhyolite tuff or water rock. Seemingly, ample water for milling purposes is being found in deep mining. It also is palatable, being suitable for domestic and all other purposes. Should an additional water supply be required, it can be pumped from the Colorado River 14 miles distant, preferably from wells sunk in the gravel beds on the bank of the river. For this purpose, it is said, a company is being organized.

Development

With a capitalization of more than $53,000,000, operations are being actively prosecuted by 125 separately organized mining corporations and the activity seems to be warranted by substantial results of nearly all deep development. More than half of the companies now in the field are sinking or prepared for deep mining. Ten have good milling ore opened up and four have large producing mines of proven merit. Mining operations are steadily increasing in volume and area; more than 2,200 miners are actually employed in the district and more than $25,000 per day is being expended for wages and equipment.

The approved method of prospecting is sinking to depths of 300 to 500 ft. and then crosscutting and drifting. Practically no surface work is carried on. Gas-engine hoists, compressors, and Jackhamer drills are the usual equipment. Usually also much lateral development must be done before pay ore in large quantities is found and the mine proved. The automobile, a prominent feature in the present activity, has taken the place of the burro in prospecting.

The cost of mining and milling is about $6 per ton, of which $1.25 is for power. The power at the larger mines is electric power supplied

by the oil-burning plant at Kingman. At the Gold Road mine, treating 200 tons of ore daily, the best record obtained for mining and milling is reported to be slightly less than $3 per ton. At the Tom Reed mine, however, where 20 stamps are used, the cost is about $6. There is said to be no profit in treating $5 ore in the district on a small scale. Both the Gold Road and Tom Reed mines treat their ore by the cyanide process, and have installed the counter-current decantation system.

From what has been said of the Tyro and Gold Road veins, and from the large number of other widely distributed profitable orebodies being found at depth and the cost of mining and milling, this is not a camp for the small operator but seems rather to offer encouraging possibilities for capital to engage in deep mining. The district has received the approval of many eminent mining engineers, a number of whom have become investors there and are now directors in some of the larger companies.

Topography

The district lies mainly in the Black Mesa Mountains, which, with an average elevation of 4,000 ft., extend from Gold Road 20 miles southward to the end of the range east of Needles. Their rugged forms are due chiefly to deep dissection of a huge volcanic plateau known as Black Mesa.

The district ranges in elevation from 2,000 ft. on the west and about 3,000 ft. on the east to 4,500 ft. at the top of the range. The range portion, which is about 4 miles in width, is marked by deep canyons, steep slopes, and peaks. In a horizontal distance of about 1½ miles, the surface declines from the elevation of 4,500 ft. at the crest to 2,500 ft. on Silver Creek just below Gold Road. The edges of the harder lava beds present steplike cliffs (Fig. 3 *A*).

The principal outliers are the Hardy Mountains, a group of hills situated about 3 miles west of Gold Road. They are about 3 miles in diameter and rise about 600 ft. above the surrounding country. Two miles to the north is a smaller group, the Moss Hills, while Leland Mountain at Vivian represents similar features on the southwest.

Geology

The Tertiary volcanic rocks prevail, particularly in the eastern or range portion of the district. They practically constitute the range, dip gently eastward toward its axis and are in places covered by younger rhyolite, andesite and basalt. In the southern part the green chloritic andesite is dominant, while on the west occur also local areas of the pre-Cambrian gneiss, younger granite porphyry and micropegmatite, greenstone agglomerate, and overlying sheets of supposed Tertiary conglomerate and younger gravel and lava flows. Locally intervening between the pre-Cambrian and the overlying volcanics are occasional remnantal patches of tilted and metamorphosed Paleozoic limestone and shale be-

longing to the Grand Canyon Section. These sedimentary rocks are not as yet known to have any bearing on the deposits or mining other than to indicate to the miner where encountered the general lower limits of the volcanics.

Recent mine developments have disclosed the geology of the ore-bearing volcanics to be more complicated and seemingly of more importance to the district from a gold-producing standpoint than was at first supposed.

In the vicinity of Vivian, and extending from there toward Oatman, occurs the older or basal andesite, which is light gray, calcitic, 300 ft. in thickness, and rests mainly on the pre-Cambrian complex and Paleozoic sediments. The older andesite, however, is not known to be of wide extent in the district, a fact seemingly overlooked by Bancroft and others. It is seemingly absent from Secret Pass where the next higher rock, the green chloritic andesite, rests directly upon the pre-Cambrian granite, and from the Hardy Mountains where the green chloritic andesite similarly rests upon the Mesozoic granite porphyry or micropegmatite.[3] It is not known to be present at the Gold Road mine, and according to Sperr[4] the rock underlying the green chloritic andesite in the deep workings of the Tom Reed mine does not correspond to the older andesite described at Vivian. The older andesite is unconformably succeeded by another series of flows, the green chloritic andesite which contains an important part of the mineral deposits in the Tom Reed-Gold Road district (Figs. 1 and 3*B*). The flows aggregate a known thickness of 800 ft. The rock consists mainly of a greenish, fine-grained groundmass containing abundant whitish feldspar phenocrysts. It is very chloritic and calcitic. It is intruded by black latite and younger lavas.

The intrusive character of the green chloritic andesite or rocks grouped with it is well shown at the head of the wash, just west of the Leland mine, where dikes from 2 to 20 ft. in width, given off from the main mass, extend ⅛ mile or more westward into the older andesite. A black, fresh-looking specimen of it collected by the writer from the Leland mine proved by microscopic study and chemical analyses to be latite, and it contains chlorite in abundance throughout.[5]

The intrusive nature of the green chloritic andesite and the association of ore deposits with its intrusive phases in various parts of the district are also abundantly corroborated by later work of Sperr, Probert, Bancroft, and other engineers. Probert[6] believes it to be both intrusive and

[3] *Bulletin No.* 397, *U. S. Geological Survey*, p. 35, and Fig. 2 (1909).

[4] J. D. Sperr: The Tom Reed-Gold Road Mining District, Arizona, *Engineering and Mining Journal*, vol. 101, No. 1, pp. 1–5 (Jan. 1, 1916).

[5] *Bulletin No.* 397, *U. S. Geological Survey*, pp. 36–37 (1909).

[6] Frank H. Probert: Oatman, Arizona—A Prohibition Camp, *Mining and Scientific Press*, vol. 112, No. 1, pp. 17–20 (Jan. 1, 1916).

extrusive, that dikes and sills of it occur in the older andesite and that mineralization is dependent upon this association.

Bancroft[7] writes that in the vicinity of the mines which he examined in localities rather widely scattered in the district, he found evidence of the intrusive nature of this formation, and that the orebodies are largely formed within the intrusive.

More recently, according to Smith,[8] the bottom as well as the collar of the Tom Reed shaft at 1,075 ft. in depth was in the green chloritic andesite which in the bottom of the shaft was ore-bearing, and he suggests that the rock may here be intrusive. The supposition of the rock being here intrusive, probably as a neck, would help to account for the unusual thickness of the formation at this point, which seems to be local, since elsewhere in the Tom Reed mine and in the neighboring United Eastern, Pioneer and other properties the workings, according to Schader,[9] passed through the green chloritic andesite and into the older underlying andesite at shallower depths and have workable ore in the lower rock.

Therefore, according to the observations of six or more investigators, the green chloritic andesite (formation) contains rocks which vary considerably mineralogically from the normal andesite, rocks with which the ore deposits in general seem to be associated and which are known to be intrusive into the older andesite. The most important of these rocks seems, to the present writer, to be the dark latite occurring at the Leland mine and elsewhere. It seems to intrude not only the older andesite but also the green chloritic andesite as sheets, necks and dikes, and to be intimately connected genetically with the ore deposits. More recently, Sperr,[10] whose observations in the district have been extensive, regards all the commercial ore as occurring in the andesites intimately associated with latites. The intrusive nature of the rocks associated with the ore deposits obviously favors continuity of the deposits in depth.

The deposition of the green chloritic andesite was followed by a period of great fissuring and faulting accompanied and followed by eruption of the next higher group, the undifferentiated volcanic rocks 2,000 ft. in thickness, containing the Gold Road and other important veins, and by intrusions of younger rocks, especially latite and rhyolite in the form of dikes, necks, and rounded plug or stocklike masses, and seemingly the formation of many of the larger fissure veins. The undifferentiated volcanics are succeeded by a series of younger light-colored tuffaceous

[7] Howland Bancroft: Geology of Gold Road District, *Mining and Scientific Press*, vol. 3, No. 1, p. 21 (July, 3, 1915).

[8] Howard D. Smith: The Oatman District, Arizona, *Mining and Scientific Press*, vol. 3, No. 5, p. 172–175 (July 31, 1915).

[9] Carl F. Schader: Personal letter, Feb. 6, 1915.

[10] J. D. Sperr: "Conversational Geology" at Oatman, *Engineering and Mining Journal*, vol. 101, No. 26, p. 1119 (June 24, 1916).

rhyolites locally 1,000 ft. in thickness and known as the "water rock," which is succeeded by dark reddish andesite which in turn is followed by black olivine basalt, the youngest of the effusive rocks, which remains as a capping over a large part of the Black Mesa Mountains.

With the extensive development recently done in the district, the rocks merit detailed study with reference to their sequence and bearing on the genesis of mineralization. Such a diagnosis seems certain to prove of great economic value in preventing useless expenditure of money in some directions and leading to profitable development in others.

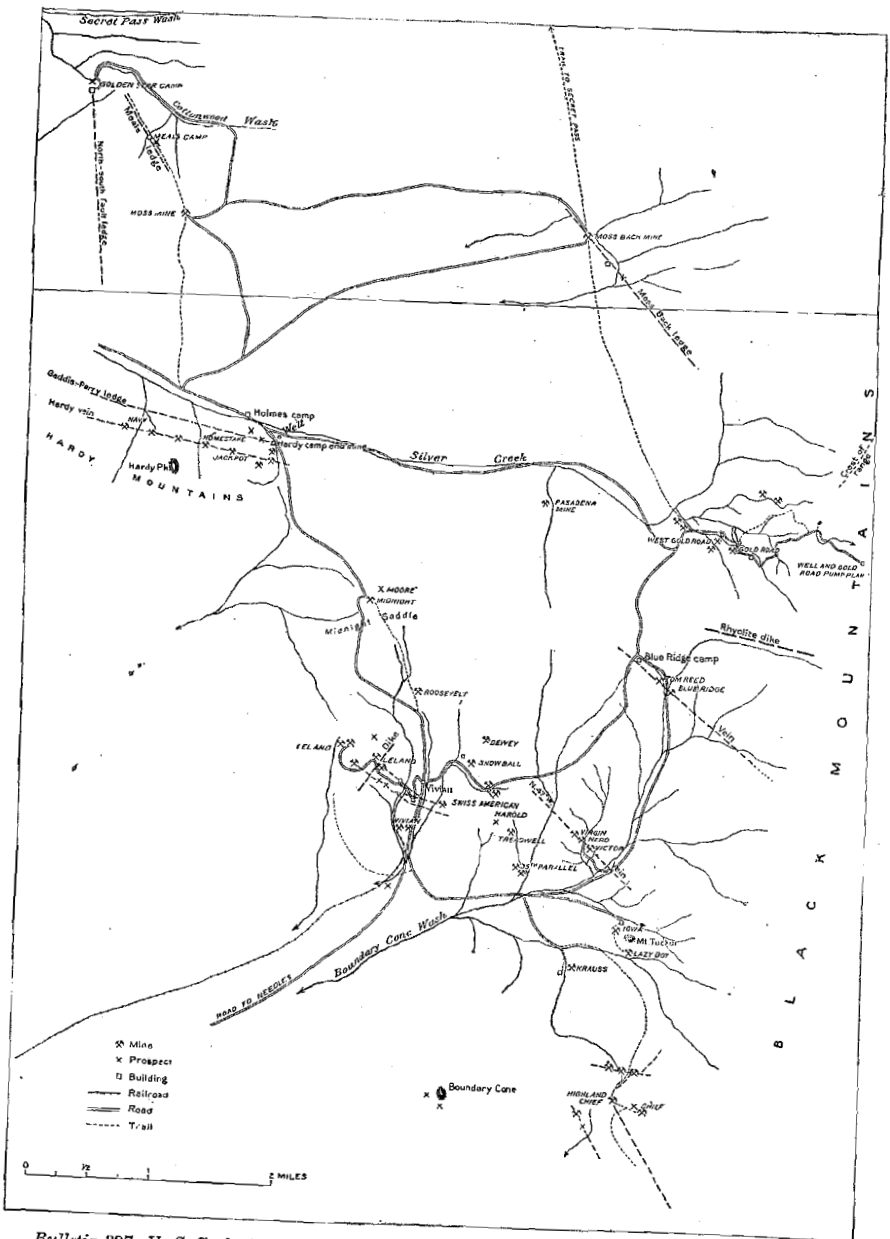
Ore Deposits

General Description.—The deposits, which are numerous, are chiefly gold-bearing fissure veins or lodes of the character already described for the Black Mountains. The veins vary from 5 to 70 ft. in width and from a few hundred feet to several miles in length. In general they are strong and persistent. They strike northwest with steep dip to the northeast. They are almost devoid of metallic sulphides, the gold being free. They occur chiefly in the lower part of the undifferentiated volcanic series, the green chloritic andesite, the granite porphyry and micropegmatite, other underlying rocks and also along certain contacts, where latite and rhyolite are generally the intrusives. Some of the deposits are very rich, but the large bodies of low-grade ore constitute the main resource. Ore having a metallic content of $10 or less is considered low-grade.

The older andesite, from the ill behavior and feathering out of certain vein deposits on entering it from the green chloritic andesite, was originally regarded by the writer as unfavorable for mineral, or essentially barren, particularly in the Vivian district. Owing to its tufaceous brecciated and fragmental nature it is almost devoid of lava-cooling shrinkage cracks and fissures, which elsewhere form favorable repositories for ore deposition. According to Palmer[11] "the occurrence of any ore shoots in the earlier (older) andesite is yet to be demonstrated."

Also, E. W. Brooks limits the area of commercial mineralization in this part of the field to the green chloritic or "younger andesite." Later developments, however, it is gratifying to note, in the Oatman and Vivian camps, report workable ore deposits in the older andesite also. It is hoped that with development similar reports may be received from several mines near Vivian which, though well-equipped for operations nearly a decade ago, have remained inactive. That the writer has never doubted that major veins probably occur in and below this formation is evidenced by the following statement: "The veins cut through the great mass of Tertiary volcanic rocks which characterize the range and un-

[11] Leroy A. Palmer: The Oatman District, Arizona, *Mining and Scientific Press*, vol. 113, No. 6, p. 195 (Aug. 5, 1916).



Bulletin 397, U. S. Geological Survey.

FIG. 6.—MINES AND VEINS IN THE TOM REED-GOLD ROAD DISTRICT.

doubtedly continue in depth into the underlying pre-Cambrian granitic rocks."[12]

According to Palmer,[13] "some ore of value has recently been found in the pre-Cambrian."

Since the deposits are confined to the vein filling and do not as a rule form metasomatic replacements in the wall rock, as at Cripple Creek and other camps, the selective preference which any bounding wall rock by reason of its more favorable physical or chemical properties for replacement may exert in favor of ore deposition seems to be practically nil. Accordingly, there is no apparent reason, other conditions being equal, why the deposits should not be equally developed in any one of several formations through which the fissure vein with like strength may extend.

The deposits consist of two types—those in which the gangue is chiefly quartz and adularia and those in which it is chiefly calcite. The source of the quartz and adularia is referred to the siliceous magmas and that of the calcite to basic or andesitic magmas with possible contributions derived from underlying limestones. The former carry the best values, occur mostly in the undifferentiated volcanic rocks and in granite porphyry and have a general northwest-southeast trend. The latter seem to occur mainly in the green chloritic andesite and trend more nearly north-south. Among the most important of the former type are the Gold Road and Tom Reed veins; among the latter, the Pasadena, Mossback and Meals veins (Fig. 6). In some cases the veins are associated with boldly cropping silicified dikes of which the deposits in certain instances may be in part replacement.

According to Platts,[14] the most productive veins, such as those in the Tom Reed, United Eastern, and Big Jim mines, are in a complicated series of fissures, part of which strike about N. 45° W., and others N. 60° W., producing with each other a conjugated system with numerous intersections near which many large orebodies are found.

Zones.—Surficially, the veins seem to mostly fall into four main zones[15] which, named in order from north to south, are the Gold Road, Tom Reed, Vivian, and Black Range zones. The Tom Reed zone is the best developed and contains the most interesting discoveries.

There seem also to be two or more horizons or vertical ore "zones." The largest and richest orebodies seem in general to lie in a "zone" of enriched oxides between the 300-ft. and 500-ft. levels. Below this zone

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[12] *Bulletin No.* 397, *U. S. Geological Survey*, p. 48 (1909).

[13] Leroy A. Palmer: *Op. cit.*, p. 195.

[14] J. B. Platts: Geology of Oatman, *Mining and Scientific Press*, vol. 112, No. 23, p. 814 (June 3, 1916).

[15] Leroy A. Palmer: The Oatman District, Arizona, *Engineering and Mining Journal*, vol. 101, No. 21, p. 895 (May 20, 1916).

the ores decrease in value, but continue to be of workable grade beyond the deepest point yet penetrated by any working. The richness of this zone as suggested by Smith[16] is probably due to secondary enrichment, by contributions leached from shallower depths, in support of which the presence of vugs and manganese oxide in the upper part of the veins is cited. This view is also seemingly corroborated by the tendency of the zone to parallel the contour of the surface. For instance, its occurrence at about the same depth in the Gold Road mine as in the Oatman camp, though at correspondingly greater elevations and higher geologic horizons. The gold was probably precipitated in large part along with the manganese oxide.

If the thickness of 600 or 800 ft. assigned to the green chloritic andesite be correct, this ore zone in the Oatman camp or, more generally speaking, in the triangular area of several square miles comprised between the Tom Reed, Pioneer, and Pasadena mines, should lie mainly in this formation.

There seems to be also present, notably in the Oatman camp and vicinity, a shallow or surface ore zone of leached oxides to which pay ores found at or near the surface are generally confined. It extends to depths of about 150 ft., between which and the zone of enriched oxides, or 300-ft. level, lies a 150-ft. intermediate zone of leached or relatively barren ground, although the valuable ore shoots, according to Sperr,[17] almost without exception come at least within 100 ft. of the surface.

These two zones have probably suffered about the same amount of leaching, the upper zone certainly not less than the intermediate or barren zone. The upper zone seemingly owes its greater ore content to the more siliceous, and consequently resistant, character of the ore which accordingly better withstands the process of leaching.

Differing from the view of enrichment by leaching and redeposition in the main zone is that of Platts[18] which holds that the ore is essentially a primary deposit formed by heat ascending solutions, that from the nature of the gangue it is evident that acid solutions could not exist, and that, except for the oxidation of the pyrite, there is no evidence of the action of surface water on the ore.

It seems quite possible, as suggested by one writer, that the groundwater table in the district may be in part dependent upon the neighboring Colorado River. If this view be correct, physiographic study will probably be able to correlate certain horizon features of the vertical section as leaching, etc., with relatively prolonged pauses in the historical downcutting of the river. It does not, however, seem safe to assume that the water table at Oatman coincides with the level of the Colorado River,

[16] *Op. cit.*, p. 173.

[17] J. D. Sperr: "Conversational Geology" at Oatman, Ariz., *Engineering and Mining Journal*, vol. 101, No. 26, p. 1119 (June 24, 1916).

[18] J. B. Platts: *Op. cit.*

which is 2,000 ft. lower than Oatman, and that therefore the ores if they persist downward will continue to be oxidized and of the same milling character to that depth as advocated by Palmer.[19] Owing to the greater elevation of the gathering zone on the east, which probably extends to the Hualpai Mountains, or longitude of Kingman, the ground-water table is not a level surface but gradually rises from the Colorado River, eastward, and at Oatman it probably stands several hundred feet or more above the level of the river.

Structure of Ore Shoots.—The ore occurs chiefly as a series of more or less tabular or lenticular ore shoots and pay streaks dipping and plunging variously within the vein, with which they exhibit a greater or less degree of parallelism. The shoots vary from 1 ft. wide to the width of the vein. They usually carry gold for their full width. They range up to nearly 1,000 ft. in length and depth, and there is a general similarity or repetition of the shoots in the same vein. They seem to have been formed by thermo-aqueous processes that followed igneous activity. In general, the quartz and values favor the hanging wall, which of the two walls is generally the best defined, and contains stringers branching off obliquely from the vein, while the spar or calcite favors the footwall. The gold is mostly associated with the quartz-adularia gangue and not rarely where sulphides have existed, it, according to Platts,[20] occurs in hematite (which is pseudomorphic after pyrite) in the quartz.

According to Palmer,[21] the first indications of the vein encountered in sinking are small stringers of quartz and calcite scattered through the andesite, usually accompanied by slight pyritization in the vein-wall andesite which yields a little free gold in the pan, while in the ore shoots the vein matter shows pronounced hematite and manganese stains. It is said that the problem in development is not so much the finding of veins as the discovery of ore shoots in the veins, that nothing sufficiently tangible has yet been found to use as the basis for a theory to guide the operator in the search for ore.

Though no rigid rule can be laid down to guide the operator in search for ore, nevertheless, from the apparently well-established facts that the metallic values have been largely imported by the replacement quartz-adularia solutions and that more gold is found where the replacement of calcite is most nearly complete, in formulating plans of exploration much benefit in most cases should be derived from a correlative study of the criteria indicating the probable courses followed by these solutions, namely, quartzose vein croppings, silicified wall rock, the quartz pseudomorphic structures, etc., which have been described. It was the quartz

[19] L. A. Palmer: The Oatman District, Arizona, *Mining and Scientific Press*, vol. 113, No. 6, p. 196 (Aug. 5, 1916).

[20] J. B. Platts: *Op. cit.*

[21] L. A. Palmer: *Idem.*, vol. 101, No. 21, p. 896.

adularia or siliceous waxy-appearing character of the deposits seen in the Tom Reed mine and the recognition of their marked similarity to the then-producing deposits of the Gold Road mine that apparently led to the resumption of operations in the Tom Reed mine following the writer's visit in 1907.

Gold Road Mine

Some of the principal mines in which the deposits have been worked are the Gold Road, Tom Reed, Leland, Pioneer, Victor-Virgin, Midnight, and United Eastern. Their general distribution is shown in Fig. 6. The most important producers are the Gold Road and Tom Reed mines.

General Description.—The Gold Road mine, owned by the United States Smelting, Refining and Mining Co., is situated at Gold Road, on the western rugged slope of the range about 1 mile below the crest, at an elevation of about 2,900 ft., mainly on the western part of the Gold Road vein. From its croppings, the Gold Road vein has long been known, but the discovery of values which resulted in the opening of the mine was made about 1902. The mine soon began to be worked systematically and paid dividends of 5 per cent. on the capitalization of $500,000. Several years ago it was acquired by the present owner for $1,500,000.

The mine is opened to a depth of 1,000 ft. or more, mainly by shafts and drifts, and ore has been mined in quantities for a distance of 4,000 ft. on the vein.

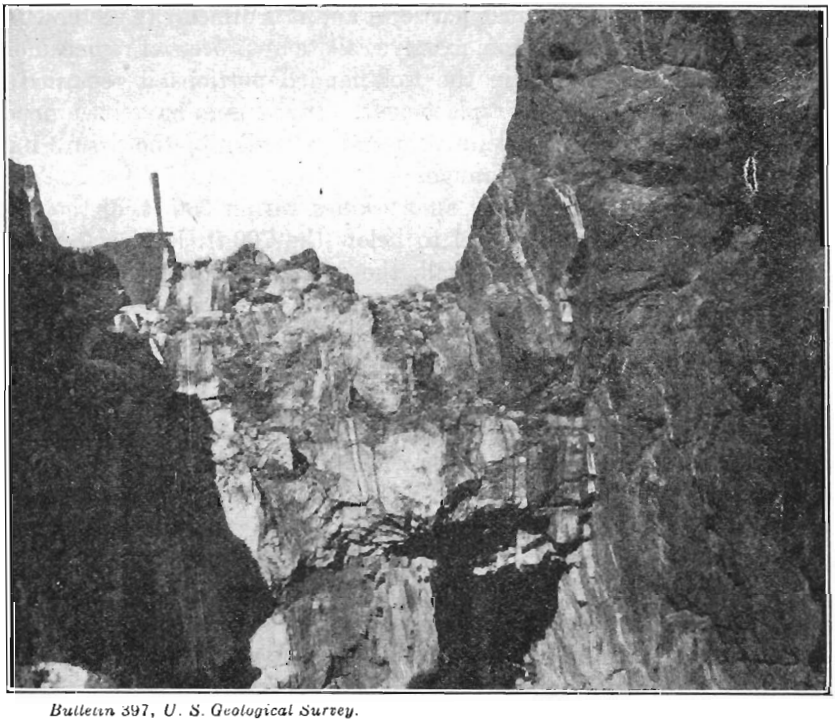
Most of the work done up to 1907 was comprised in the ground extending about 200 ft. from the main or Gold Road shaft (then known as the Gold Road mine), in either direction on the vein, and to the depth of 500 ft. Since then, however, extensive developments have been made, especially to the east on the Billy Bryan and adjoining ground.

The gross production of the property is estimated at more than $6,000,000. To the end of 1907 the production was about $2,250,000, most of which was made during 1905 and 1906. Since 1909, the output has averaged about $800,000 annually, which figure in some years was much exceeded. The present monthly production is nearly $80,000 in gold bullion.

Geology.—The country surrounding the mine is occupied by the undifferentiated volcanic rocks consisting mainly of heavy sheets of volcanic flows (Fig. 5). The series comprises andesite, trachyte, latite, rhyolite, and dacite, which aggregate nearly 2,000 ft. in thickness and are difficult to separate. The series extends from a point about 1,000 ft. west of the main shaft eastward nearly to the crest of the range. On the west it gives way to the underlying green chloritic andesite, which in the West Gold Road mine, situated near the contact, has been penetrated to a depth of 455 ft. On the east it is overlain by the upper rhyolite. The

contact on the west is probably a fault contact, as some of the green chloritic andesite occurs in the main shaft workings. The dominant dynamic structure is a pronounced close sheeting, which strikes N. 40° W., with vertical dip. The series is intruded by dikes of rhyolite and the younger dark andesite. Much of the rhyolite carries gold values. A dike of it, 40 ft. in width, located about 600 ft. south of the mine, is said to average about $5 in gold to the ton, the gold occurring chiefly in contained stringers of quartz and calcite.

Ore Deposits.—The Gold Road vein extends from a point about 700 ft. west of the main shaft southeastward through the Gold Road, Rail-



Bulletin 397, U. S. Geological Survey.

FIG. 7.—GOLD ROAD VEIN AT EAST OF LINE ROAD CLAIM, LOOKING NORTHWEST.

road, Billy Bryan and Last Chance claims to beyond the crest of the range, a distance of nearly 1¼ miles. It dips about 80° NE. approximately parallel with the close sheeting in the country rock. It varies in width from 22 ft. on the west to less than 1 ft. on the east. Between the bottom of the mine and the crest of the mountains it has a known vertical range of about 2,300 ft., and its croppings have a vertical range of about 1,300 ft. They consist essentially of iron and manganese-stained quartz, silicified rock, and calcite. In places they form conspicuous reefs or knobs rising 20 or 30 ft. above the surface, as at the main shaft or Gold

Road mine (Fig. 5). Here the associated hard silicified prominent wall-rock croppings on both sides of the vein have a lateral extent of 20 to 60 ft. The best ore usually underlies these prominent croppings, which seem to represent pool-like courses along which mineralizing solutions deposited more freely than elsewhere. Where the croppings weaken or break down, the underlying portion of the vein generally becomes lean or barren, though the fissure and its walls and filling may continue unchanged.

The vein consists essentially of quartz and adularia, with some calcite and brecciated altered rock, and is locally more or less crustified (Fig. 7). Since the more siliceous portions frequently exhibit a perfection of crustification not found in the calcic portions, and it is difficult to see how this structure could be derived from massive calcite by process of replacement, the quartz-adularia filling in the well-banded portions is regarded as largely primary rather than replacement. It seems to have been deposited in reopenings of the calcite vein and extension of the fissure itself eastward into the axis of the range.

In 1907, the vein in nearly all workings within 200 ft. of the main shaft and from the 300-ft. level to below the 700-ft. level was mostly good milling ore from wall to wall, the amount of waste in mining as shown by the dump (Fig. 5) being very small. Elsewhere, however, as seen on the Billy Bryan and other ground, portions of the vein, sometimes for a considerable extent, are relatively barren.

The vein is strongest on the west, where, as developed in the main shaft workings, it is uniformly about 10 ft. in width. It is usually in sharp contact with well-defined firm walls of the country rock, consisting of andesite, trachyte, latite, and rhyolite. It is, in general, "frozen" to the walls and is locally enriched where stringers extend from it at acute angles into the hanging wall. As a rule, hard and rough walls indicate good ore, and conversely, soft and smooth walls generally correspond with lean ore. The ore consists chiefly of fine-grained, light-greenish or waxy quartz. Much of it is platy or hackly with a peculiar chalcedonic or drusy appearance. Much of it is pseudomorphic after calcite and many of the pseudomorphic plates are thickly studded with minute quartz crystals of a still younger growth. The gold, as seen microscopically, and in places by the naked eye, is very finely disseminated, principally in the quartz-adularia portion of the gangue. On the 600-ft. level, however, the vein contained more spar or calcite than on any other level, and here the ore shoot is reported to have had an uninterrupted extent of 1,100 ft. Some sulphide ore containing pyrite, the first encountered in the mine, was found here, and it is reported to have contained higher values than the overlying oxidized ore, which is probably due to arrest in the downward progress of leached concentrates. On the 700-ft. level, the country wall rock, consisting of green chloritic andesite, was more or

less pyritic and seemed to indicate that the mine was entering the sulphide zone. The mine has not produced much ore from depths shallower than the 300-ft. level. The lowest-grade ore taken out was obtained between the surface and the 300-ft. level, where it fell to $5 a ton. The ordinary mill-run ore, it is said, rarely falls below $8 or $9 and ranges from that up to $22 a ton. It averages about $10 to the ton, but $100 ore and upward is occasionally encountered on the hanging wall, where nearly all the high-grade ore occurs.

On the Billy Bryan claim, nearly ½ mile from the main Gold Road shaft, the vein and the associated rocks show essentially the same characteristics and relations as in the Gold Road mine. The variations and phases of the rocks are well displayed in the large dump at the mouth of the drift. The principal rock corresponds to trachyte. It is in general considerably altered. The croppings of the vein are prominent and wall-like. The vein varies from 1 to 20 ft. in width and dips, in general, steeply to the southwest instead of normally to the northeast. It consists mostly of spar or calcite, which contains bands of greenish quartz. Beyond the southeast limits of the Billy Bryan claim, and, in fact, to the end of the Railroad claim, quartz prevails and carries good values. The quartz is greenish with glassy luster and locally is very brittle, closely crustified, wavy, and crinkled, its structure resembling the fine flow structure of certain lavas. Weed,[22] having access to later development, described the vein filling as "the usual mixture of calcite flakes and waxy quartz varying to a dense waxy yellow quartz in curly or crinkled bands and shreds sometimes showing a faint blackish stain."

In the eastern part of the Line Road claim, and in a considerable portion of the Billy Bryan and Railroad claims, the vein has produced very rich shipping ore from surface workings, and it is under these workings, notably on the Billy Bryan and Railroad claims, that the Gold Road Co. in 1908 encountered good ore in depth.

In its extension eastward through the Last Chance claim, and across the crest of the range, the vein contains some good-looking croppings and openings, but it is split by horses at several points and locally narrows to unworkable dimensions. In August, 1915, the mine was reported to have good-sized bodies of $20 ore on the 800-ft. level, and in November it is said to have encountered on the 900- and 1,000-ft. levels a body of higher-grade ore than any hitherto found on the lower levels.

Recently it is reported that the vein as stoped averages about 12 ft. in width. Three ore shoots are being stoped on the 500-ft. level and at greater depths. These are respectively 1,200 ft., 70 ft., and 700 ft. in length, being separated by small intervals of barren ground.

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[22] Walter Harvey Weed: The Kingman District of Arizona, *Mining World*, vol. 2, No. 23, pp. 1113–1114 (June 4, 1910).

Tom Reed Mine

General Description.—In the last year or two, owing to new discoveries, interest in the district has centered mainly in the Tom Reed mine and neighboring properties, wherefore this part of the district is known as the Tom Reed district or camp, Oatman district or camp, or simply Oatman. Here the geology and ore deposit are similar to those of the Gold Road camp, except that the deposits occur largely in lower geologic horizons in the green chloritic andesite and still older rocks (Fig. 3*A*). Some of the veins are "blind," being covered by later flows of rhyolite and younger rocks whose contact is traceable by the softened character of the contiguous weathered portion of the underlying rock.

The Tom Reed (formerly Blue Ridge) mine is situated at Oatman about 2 miles south of the Gold Road mine and about 200 ft. below it. It lies on open ground in Blue Ridge wash, near the base of the central part of the range, at an elevation of about 2,700 ft. (Fig. 3*A*). It is one of the well-known mines of the country and contains well-defined ore shoots, which for nearly a decade have been worked with great profit.

It was discovered about 1900 and was soon after owned by a party composed of Ely Hilty and others. About 1901, the Gold Road Co. sunk two shafts on the property, the Ben Harrison and the Tom Reed shafts, each to a depth of about 100 ft. with good results. About 1904, the mine was purchased by the Blue Ridge Gold Mines Co., which installed a mill and operated the mine and mill for about a year and a half, milling on an average about 30 tons of $7 ore a day. In 1906, the Blue Ridge Co. was succeeded by the present owner, the Tom Reed Gold Mines Co., which resumed operations in 1907, and in 1908 the mine was reported to be working and making gold bullion shipments regularly, since when it has been a steady producer. A little later a 12-ft. wide body of $12 ore is said to have been encountered on the 300-ft. level.

The property comprises a group of 11 or more claims, adjoining one another in part end on and extending along the vein for a distance of about 3 miles. The mine is located near the middle of the group.

Ore Deposits.—The country rock is mainly the green chloritic andesite. The vein, the Tom Reed (formerly Blue Ridge) vein, strikes about N. 50° W. and dips about 70° NE. It nearly parallels the Gold Road vein on the north and the Victor-Virgin vein on the southwest, to both of which it is geologically and mineralogically similar. On the Tom Reed property, it has an extent of about 3 miles, Fig. 6, and it is said to be continuous with the Pasadena vein on the northwest, in which event it has a length of about 4½ miles, being probably the longest vein in the district. At the Tom Reed mine it ranges up to about 40 ft. or more in width with the fissure walls usually ill defined. It outcrops boldly for the length of nearly two claims. The croppings consist principally

of the usual dark iron and manganese-stained quartz, silicified rock, and calcite.

The vein is mainly of the quartz-adularia-calcite type. Of the early-day ore, a considerable portion is reported to have run $25 in gold to the ton for the first 30 ft. in depth and about $12 from that point down.

In the Ben Harrison shaft and its workings, the vein has a width of 16 to 22 ft. On the 100-ft. level the vein consisted chiefly of 16 ft. of crushed quartz and rock with neither wall well defined; but toward the hanging-wall side there was 6 ft. of good-looking, more or less porous, clear quartz ore.

On the 150-ft. level the vein consisted mainly of crushed rock, but the footwall side of the drift was in quartz; the hanging wall contained vugs 6 in. to 1 ft. in diameter, containing blackish, porous, oxidized quartz ore.

Development.—The mine is opened to a depth of 1,400 ft. It has more than 30,000 ft. of underground work, with the longest drift extending more than 4,000 ft. out from the shaft and in ore nearly all the way. The production to June, 1916, was nearly $6,000,000. That for the year ending March 31, 1916, was $661,870.68, the average value of the ore being $22.12 to the ton and the extraction 98.6 per cent. Dividends paid during the year amounted to nearly $164,000, or 18 per cent. on the par value of the outstanding stock. By estimate 11,000 tons of ore were blocked out in the stopes at the end of the year. The mine has paid more than $2,500,000 in dividends. The net realization on the mine by June, 1913, was $3,019,569.75. By June 24, 1914, the 44th dividend had been declared. Later the mine was reported to be paying for the last several years monthly dividends of from 6 to 7 per cent. on the par value of the stock, and the ore then blocked out, by estimate $2,000,000 worth, was said to be sufficient to continue their payments for several years to come. By 1907 the production considerably exceeded $120,000, and that since 1910 is more than $5,000,000. The annual production for the last few years is reported to average about $1,200,000 in bullion, besides which a large tonnage of ore is accumulating at the mine, especially of $10 ore in the workings.

Up to June, 1913, much of the ore produced had been drawn from an orebody between the third and fifth levels, where about an equal amount remained, and this same orebody had been proven to a further depth of 200 ft. below the fifth level. The seventh-level drift, at this time 233 ft. in length, was all in ore of about the same average value as that on the fifth level. Recently, in the Black Eagle section of the mine, the crosscut on the 400-ft. level is said to have passed through 35 ft. of good ore, 30 ft. of which averages $25 to the ton, and the ore tonnage on the 600-ft. level is very large.

Later, good orebodies were reported on the 500, 600, 700, 900, 1,075,

1,200 and 1,400-ft. levels. The ore on the 1,200-ft. level is said to be similar in character and grade to that on the upper levels. Progress work on the 1,400-ft. level it is said has revealed a vein width of 12 ft. with a large orebody having a known extent of 300 ft., averaging $12 to the ton and containing some high-grade ore.

Explorations on the 1,075-ft. level for 225 ft. west of the shaft have shown the ore shoot throughout that distance to have a width of about 18 ft. and to range from $22.50 to $40 to the ton. On and below this level the vein is reported to be disturbed by a fault, but at the 1,175-ft. level it has fully recovered its former size and values.

Character of Ore.—The ore is similar to that of the Gold Road mine. It consists of a mixture of flaky calcite, waxy quartz, adularia, brecciated altered rock, and pinkish argillaceous material which is frequently of high grade. According to Weed,[23] a dense quartz whose color and luster closely resembles that of beeswax constitutes the richest ore. The ore is not hard and most of the gold is free, especially in the ore from the lower levels, but it requires fine grinding to free the finely disseminated gold and expose it to the action of the cyanide. The gold is seldom visible even in rich ore.

In milling, the total sliming system of cyanidation is employed, followed by treatment of the ore in Pachuca vats and Dorr thickeners. "Dorr thickeners," according to Smith, "appear to be particularly suited to conditions in this district where little silver is present, weak solutions are used, and the slime settles quickly." The ore amalgamates about 50 per cent. of its value on the plates and a high extraction is obtained at reasonable cost by cyanidation. In 1910, the average extraction was $42.46 to the ton. In 1912 it was $23.22. The amount of ore treated in 1911 was 39,447 tons; in 1913, 948,110 tons, with an average extraction of $24.09, and a recovery of 97.05 per cent. The average value of the ore mined in the fiscal year 1914 to 1915 is $21 to the ton. The gold is generally pure, the proportion of silver present being very small. The mill treats about 4,000 tons of ore a month.

Other Mines

Among the new properties which are attracting most attention is the United Eastern which adjoins the Tom Reed mine on the northwest and is often referred to as the "Bonanza." It is but a year and a half old, and is reported to have in sight, according to the estimates of conservative mining engineers, $11,000,000 worth of $26 ore. The mine contains more than 2,000 ft. of drift and has good orebodies on all levels between the depths of 300 and 700 ft. The vein is reported to be 43 ft. wide on the 555-ft. and 665-ft. levels, and the entire width is pay milling ore. Of this

[23] *Op. cit.*

width, 30 ft. proven for the distance of 650 ft. averages $40 to the ton and carries considerable free gold. Since August, 1915, daily shipments of $30 ore removed during development are being made to the Gold Road mill. A new 200-ton cyaniding plant, in which gyratory crushers and ball mills instead of stamps will be used, is being installed at the mine. The equipment will be adequate for sinking to the depth of 2,000 ft.

Many other new properties like the United Eastern are being opened up and in many of them good ore is being found at depths of from 200 to 500 ft. A score or more are worked by incorporated mining companies.

Extensive developments are being undertaken at the Pioneer (formerly German-American) mine by the Oatman Pioneer Mines Co. which by coöperation and use of its efficient machinery and 400-ft. level will immediately facilitate the exploration and working of adjoining properties. The Pioneer is on one of the three main lode outcrops of the district, and is said to have $1,000,000 worth of commercial ore in sight between the 400-ft. level and the surface. It is working on two veins of the 400-ft. level, of which the northeast, or Pioneer vein, has an 8-ft. oreshoot having a known extent of 600 ft. and averaging $16 to the ton, and on the southwest, or Snowball vein, the crosscut has penetrated a width of 16 ft. of good-grade ore with the outer wall not yet reached. On the 200-ft. level, a 2-ft. shoot of high-grade ore is being worked.

The Boundary Cone mine adjoining the Pioneer on the east has good ore on the 750-ft. level, and is said to contain a 5-ft. shoot of ore that averages $100 to the ton on the 200-ft. level. On the 500-ft. level, where the ore shoot has been proved for a distance of 90 ft., it has a width of 12 ft. and averages about $20 to the ton. The mine is credited with a considerable production of high-grade ore, some of which contained crystallized gold.[24]

In the Big Jim mine, a mile northwest of Oatman, the vein on the 400-ft. level is said to be 51 ft. in width, of which 46 ft. averages about $8 to the ton and 8 ft., on the hanging-wall side, $15 to the ton with some pay streaks which are very rich. On the 485-ft. level, the same ore shoot has been opened for the extent of 200 ft. and is good milling ore, most of which averages more than $12 to the ton. Here the ore is said to be more oxidized and silicified than on the upper levels. The vein parallels the projected course of the Tom Reed vein, but whether it is the northwestward extension of the Tom Reed vein which may here be faulted to the northeast, or a new vein, has not yet been determined. The mine is daily shipping about 30 tons of ore removed in development.

In the Carter mine, ½ mile south of Oatman, the main ore shoot, about 15 ft. in width descending from the 150-ft. level to the 400-ft. level, is said to contain 5 ft. of ore which averages about $30 to the ton, and 8

[24] W. P. DeWolf: The Tom Reed-Gold Road, *Salt Lake Mining Review*, vol. 17, No. 13, p. 16 (Oct., 1915).

ft. that averages $8 to the ton. This property is said to have shipped, several years ago, some very rich ore taken from between the surface and the 150-ft. level. This same vein is thought to extend through the adjoining Telluride and Lucky Boy properties, where on the 300-ft. level the entire width of 25 ft. is good milling ore.

The Gold Reed mine, a mile south of Oatman, has 4 ft. of $32 ore on the 375-ft. level.

On the Times property, the vein recently opened at 270 ft. in from the portal of the Martin tunnel, reveals 5 ft. of ore, averaging nearly $24 to the ton.

On the north, the Gold Ore mine, ½ mile northeast of Gold Road, is credited with a 9-ft. vein on the 500- and 550-ft. levels containing a 6-ft. shoot of ore which for the distance of 300 ft. averages about $12 to the ton, and a considerable portion of it nearly $100 to the ton. More than 75,000 tons of ore are said to be blocked out above the 550-ft. level. Daily shipments of ore averaging nearly $25 to the ton are made to the Gold Road mill.

The old Moss mine, where the original discovery of mineral in the Mohave County region was made, is being developed by the owners of the Gold Road mine and $60 ore is being mined from the 200-ft. level.

In the Ivanhoe mine, 2 miles northwest of Oatman, the vein, whose footwall is a partially mineralized 75-ft. "quartz porphyry dike cutting andesite and underlying sedimentaries," on the 250-ft. level, has a width of 60 ft., and on the 500-ft. level 6 ft. of milling ore has just been crosscut on the footwall side. Some high-grade ore has been shipped to the Gold Road mill.

Attention is also being attracted to the Secret Pass district, 6 miles north of Gold Road, which with a small mill is making considerable production mostly from high-grade surface ore. Here the occurrence is unusual, the ore, according to Payne,[25] being found chiefly as replacement deposits in the rock walls of a fissure occupied by a dike which the ore seems to postdate. The bullion, which is shipped to the U. S. Mint at San Francisco, is said to average about $15 to the ounce in gold. The population during the last few months of 1915 increased from 100 to 400, with prospecting extending over an area of several square miles.

At about 6 miles south of Oatman, promising deposits are reported in the Black Range zone, where a dozen companies are operating. Concerning the rocks in this part of the field, which have been roughly grouped with the undifferentiated volcanics, little is known as yet.

The deposits occur in a series of veins of which the one on which the principal mines are located is a prominent quartz outcrop known as the Nellie vein. It has been traced for the distance of several thousand feet and opened to the depth of 300 ft. on the Black Range, Nellie and Green

[25] C. Q. Payne: Oral communication.

Quartz properties. Associated with the more pronounced quartz replacement phase of the vein on the Black Range and Nellie ground, are said to be rich streaks of ore that show coarse gold when panned. The Black Range mine is said to have milling-grade ore of irregular occurrence on the 300-ft. level, of which 3 ft. averages about $30 to the ton. Here, also, the country wall rock extending along the vein, for a width of 60 ft. or more, is impregnated with replacement deposits and averages nearly $6 in gold to the ton.

In referring to the future of the Tom Reed-Gold Road district, some men favorably compare it with Goldfield, Cripple Creek or other large camps and hold that it will become one of the greatest gold-producing districts in the United States. Among the more conservative and seemingly reasonable views is that of Palmer,[26] who believes that it will become comparable with the Tintic district, Utah, that it will become a large low-grade camp with several producing mines which will yield dividends for many years to come.

Fields Similar to the Tom Reed-Gold Road District

Recent investigations[27] have shown that the southern end of the Black Mountains containing the Tom Reed-Gold Road district is the easterly one of a number of similar volcanic areas which extend interruptedly westward on either side of the railroad through the distance of nearly 100 miles to the longitude of Barstow, Cal. In these areas—which embrace the Mohave and Chemehuevis Mountains, the ranges west of Von Triger, Clipper Mountain, the Cady Mountains, the Newberry-Ord district, and the well-known Calico Mountain group and others—the geological and mineralogical conditions are very similar to what they are in the Tom Reed-Gold Road district. The areas lie from a few miles to 25 or 30 miles back from the railroad. Their volcanic rocks, which in character, recurrence, and succession, are in general identical with those in the Tom Reed-Gold Road district, range up to 2,000 ft. or more in thickness, are frequently well-mineralized, and contain strong veins. Most of the areas have been but little prospected, but some, as that of the Calico Mountain group, are productive.

[26] *Op. cit.*, p. 900.

[27] N. H. Darton and others: Guidebook of the Western United States, Part C, The Santa Fe Route, *Bulletin No.* 613, *U. S. Geological Survey*, pp. 142 to 162 and sheets 21, 22, and 23 (1915).

Discussion

J. Dana Sperr, Jerome, Ariz. (communication to the Secretary*).—Very little accurate information has been published about this district. Most of the geological data appearing in the technical press are based on "careful observations" made from an auto stage and a casual glance through the *U. S. Geological Survey Bulletins*, No. 340 of 1908 or No. 397 of 1909, both by F. C. Schrader. Mr. Schrader's report is still the best publication on the district. A really careful study of this report will uncover only a very few statements which have since proven questionable. This is a remarkable record when it is considered that only a short time was spent by Mr. Schrader in the field and that there was very little development work done at that time.

The mining world and especially Mohave County, Ariz., will feel a sense of gratitude to Mr. Schrader for revising his early report on this district and publishing it through the American Institute of Mining Engineers.

It would be absurd for me to dwell on general conditions, geological or otherwise, at this time, so I shall confine these notes to a few personal observations and opinions which may be of interest.

The "Conversational Geologists" delight in showing a proficiency in distinguishing the rocks of the district from hand specimens and proving Mr. Schrader wrong in the conclusion (erroneously laid to him) that the older andesite is non-productive.

One qualifying statement made by Mr. Schrader (p. 181 of *Bulletin* No. 397) in which he seems to have expressed one fact of greater economic importance than all the others combined, has generally been overlooked.

"So far as learned, the older andesite as a rule does not contain workable mineral deposits except along lines where the latite has erupted through it."

That statement is just as true today as it was 10 years ago. With the possible exception of the Big Jim, not a single commercial ore shoot is known to exist in the andesites which is not intimately associated with a latite. (In this district I prefer to use the name "latite" to classify any rock too acid to be an andesite and too basic to be a rhyolite. It is generally impossible to classify any of the intermediate rocks in the locality from hand specimens or even by the microscope. Mr. Schrader remarks that some of the rocks which he calls "green chloritic andesite" may be latite, so, what I refer to as a latite may, in some instances, be the equivalent of the "green chloritic andesite.")

It is impossible to classify positively the different rocks in the field, and nearly so with a microscope, owing to the extreme alteration which they have undergone. As engineer for the Tom Reed, I had some 50

* Received Jan. 17, 1917.

specimens examined by C. F. Tolman, Jr., of Stanford University and succeeded in getting three or four definite classifications. However, it is generally possible to map the different flows, at least over local areas.

There is in the district an andesite younger than the vein system, which is a little more basic than the biotite or chloritic andesite and resembles, from the descriptions, the older andesite. This later andesite is found as a capping to a depth of from 200 to 300 ft. on the Black Eagle claim of the Tom Reed. It probably belongs to the undifferentiated

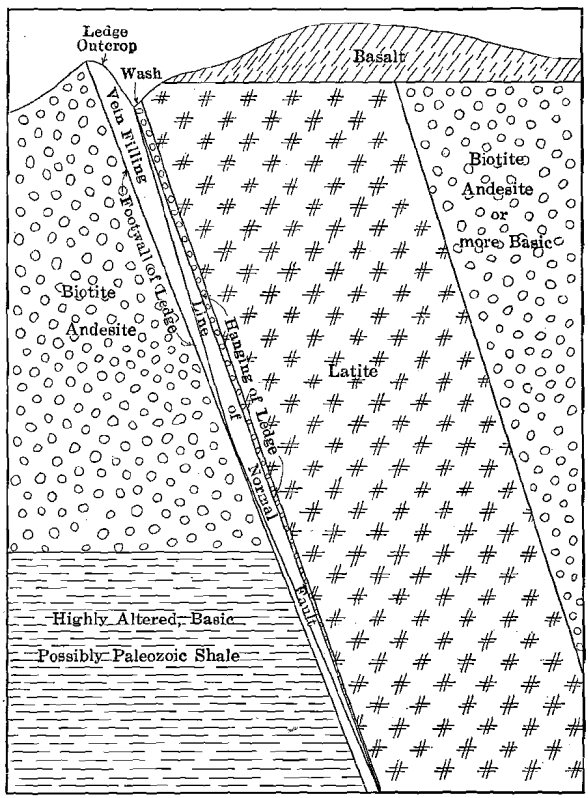

FIG. 1.—TRUE CROSS-SECTION OF TOM REED ZONE, OATMAN, ARIZ.

series mentioned by Mr. Schrader. It accounts for the impression, frequently gained, that the older andesite is sometimes younger than the green chloritic andesite. I have thought it possible that the occurrence of an andesite under the green chloritic andesite described by Mr. Schrader might possibly be due to a faulting which had placed this still later andesite in a relatively lower position over local areas. This possibility might be supported by the fault, which I am informed exists, between the two andesites described as found at the Leland.

It must be noted that the physical appearance of different parts of the same flow may vary considerably. This fact, I believe, has led to some very erroneous conclusions. My notes show that the foot wall of the United Eastern mine is a nearly normal biotite andesite from where the shaft first penetrated the ledge to at least 600 ft. in depth, although the physical appearance of the rock at 200 ft. and at 500 ft. is decidedly different. Probably the same condition has existed in other places where the ore is reported to be found within the older andesite.

I cannot admit the intrusive character of the andesite of the Tom Reed, as the bottom levels show a nearly horizontal contact between the andesite and a basic rock which may possibly be an earlier flow or a remnant of the Paleozoic sediments. But the latite on the hanging wall is almost certainly an intrusive. This latite is green and chloritic, but the microscope shows it to be a nearly normal biotite latite.

Mr. Schrader notes that the gangue was primarily mainly calcite and dolomitic carbonates, but these minerals have been largely replaced by quartz and adularia. I have observed that the greater the amount of quartz after spar, as a rule, the richer the ore. Lower levels observed show a constantly decreasing amount of quartz with uniform decrease in the gold content. At depth the vein filling seems to grade into a pure spar. Bottoms of well-developed ore shoots show very little replacement. There is no questioning the continuance of the main fissures to greater depths than will ever be opened up. The real question is whether there will be a limit to the barren calcite zone and the conditions favorable to replacement again exist.

As to the vertical horizons, the richest ore ever mined in the district was found between 200 and 300 ft. in depth.

At the bottom of p. 217, Mr. Schrader outlines a general rule to guide the operator in search of ore, with which I am heartily in accord.

If a given vein or vein system in the district shows the quartz pseudomorphic structures, etc., mentioned, its development is an excellent gamble. But so far the calcite veins have proven too uncertain to be very safe.

A condition frequently observed is the occurrence of basalt plugs, often found on the strike of the main fissures. These plugs break up the continuity of the veins, sometimes reversing the pitch and causing other freaks. Some of these plugs come to surface and may even spread as a capping over a considerable area. Others do not reach the surface. Basalts seem to be good things to stay away from.

The accompanying cross-section through the Tom Reed zone may be of interest.

It will be noted that the main fissure is the line of a strong fault. While the amount of throw of this fault is not known, it is probably about 900 ft. The physical character of the rib of andesite on the hanging wall

of the ledge at the 900-ft. level is very similar to that of the foot wall at or near the surface. No further evidence is known to the writer as to the amount of the throw.

The fault plane marked through the vein filling is a post mineral slip, very regular and distinctly traceable. I recall the first time I observed this slip. A raise had been driven carrying this slip as a foot and as I climbed through the raise I thought it had been concreted, the wall was so smooth and even. Deep vertical striations are the only irregularities.

The latite shows an intense crushing action wherever opened. In early work it generally appeared that the latite was the line of a main fault, but finding andesite on the hanging wall opposite a lower rock on the foot rather disproves this theory.

The andesite found on the hanging wall of the latite does not appear to be the same andesite within which the ledge occurs. It may be a glassy phase of the biotite andesite, but probably it is a more basic variety.

Angular inclusions of the andesite have been found within the latite 50 ft. from the actual contact. This seems to be characteristic of the latite andesite contacts in this zone.

Microscopic examination showed a resorption by remelting of the phenocrysts within the border of the andesite on the foot of the latite intrusion.

All of the rocks show an intense hydrothermal action. Practically all of the specimens collected were too highly altered for accurate determination. All but the latites show high oxidation. Pyrite in fine cubes is the strongest characteristic of this latite.

The drawback to mining is the high cost of prospecting, but when it is remembered that one United Eastern will pay 6 per cent. on 50 or more well-financed prospects and one Tom Reed will do over twice as well, the gambling chances will not seem so discouraging.

JOHN B. PLATTS, Hawthorne, Nev. (communication to the Secretary*).—I will confine my remarks to the Oatman district and to two points in which my ideas are in opposition to those of Mr. Schrader.

First, regarding the older andesite (or earlier andesite), I note that Schrader admits that this formation has greater importance in the district than he allotted to it in his former report on the district. Schrader was the first to describe the older andesite, and it is for him to say what it shall include, but in my work I have taken it to include everything between the Paleozoic and the base of the green chloritic andesite. Between these limits may be found not only the rock described by Schrader near the Vivian mine, but a number of variations from this type. The rock is always light gray in color and is nearly always in the form of consolidated tuff, or breccia and tuff, but sometimes appears as hard uniform lava flows. I was able to trace this formation on the sur-

* Received Jan. 2, 1917.

face from a point near the Ivanhoe mine to a point several miles south of the Black Range mine, a total distance of about 8 miles. In some places, notably near the Gold Range shaft, the beds of tuffaceous andesite are intercalated with thin beds of limestone. The older andesite beds may often be distinguished from the overlying formations by the difference in dip. They dip from 15° to 20° eastward and the upper lavas dip from 4° to 5° eastward. The upper surface of the older andesite forms a wavy contact with the overlying andesites, indicating a former rolling surface in an advanced stage of erosion. This indicates a long time interval between the eruption of the older andesite and the succeeding eruptions. It would seem that there was first a series of island volcanoes followed by quiet and elevation into continuous land. After a period of erosion and tilting, volcanic activity broke out afresh in the eruption of the green chloritic andesite and after a short period of quiet, the latites. After another short period of quiet the rhyolites were intruded in the form of thick dikes and stocks.

The second point has to do with the genesis of the orebodies. Schrader regards the profitable ore as the result of secondary enrichment, and says, on p. 216: "The gold was probably precipitated in large part along with the manganese dioxide." Statements similar to this have been made by a number of writers. So far the only tenable hypothesis to explain secondary enrichments in gold deposits is that proposed by W. H. Emmons. His idea is that manganese dioxide acts on chlorides, setting free chlorine which acts on any gold present, forming gold chlorides. These being soluble in cold acid water, are carried away and precipitated on the first reducing agent or alkaline substance encountered. It is evident that the gold deposits will not be found with the manganese dioxide but with the precipitating agent. Miners working in gold veins containing rich bunches in the oxidized zone are familiar with the idea that the gold will be found in the iron-stained quartz and that the black manganese stains indicate barren spots. It is evident from the chemical nature of calcite that gold chlorides cannot form in its presence, and that it can only act as a gangue for secondary gold when it is absent from the greater part of the vein that held the primary gold, both from the vein matter and from the walls.

It is unnecessary to enlarge on the application of the above principles to Oatman veins. There the wall rock is so calcitic that it will effervesce with weak acids, as limestone will. The gangue of the largest veins, including the most important so far found, such as the United Eastern, The Big Jim, and the Aztec, contains rather more calcite than quartz. It is, therefore, evident that any secondary gold deposits must be extremely localized and relatively unimportant.

The rhyolitic intrusions seem to be a more probable source of the gold-bearing quartz than the latites. Gold and silica dissolved with

alkaline sulphides could have been driven off from them through cross fissures and the more permeable andesite beds, passing outward and upward until they encountered andesite dikes in the case of the prominent siliceous outcrop veins, and calcite bodies in the case of the three large mines previously mentioned. Incidentally, the finding of these large non-outcropping orebodies does not favor Schrader's idea that the siliceous outcrops are a guide to the finding of profitable ore. Also, a number of cases might be cited where prominent outcrops have proved to be the tops of unprofitable veins.

JOHN CARTER ANDERSON, Kingman, Ariz. (communication to the Secretary*).—From an extended study of the Oatman and Secret Pass districts of Mohave County, Arizona, I believe that the genesis of the ore deposits, in most cases, is directly connected with rhyolitic intrusions later than the Tertiary flows; and that the developments of the future will prove these intrusives to be the primary source of the ore.

In support of this opinion I will instance the Wilhelm-Eclipse dike in Secret Pass and the Murdock, Nellie, Black Range dike and ledge in the southern part of the Oatman district.

The Wilhelm-Eclipse dike is a very fine-grained light-colored siliceous rhyolite dike with a strike of N.45W. traversing the full length of the Secret Pass district about midway between two major faults which mark the easterly and westerly boundaries of the district. These faults have lifted the block between so that erosion has exposed the pre-Cambrian granitic complex which underlies the range. The geological conditions present on surface are, therefore, analogous to what would probably be the 2,000-ft. level of the Tom Reed mine in Oatman, or several hundred feet deeper than the deepest opening in that mine. From the Wilhelm group of claims in the southeast end of the district, where the granitic complex is best exposed, to the Nancy Lee mine at the other end of the district, the surface rises several hundred feet. About one-third of the way from the Wilhelm to the Nancy Lee the granite is overlain by the green chloritic andesite. The dike is opened by several shafts from 40 to 200 ft. deep, the deepest being on the Eclipse claim just below the contact between the andesite and the granite. In every opening ore has been exposed. The gold is all fairly coarse as compared with the Oatman gold and some seams and streaks of high-grade have been cut which show wire gold up to ½ in. in length.

The high-grade ore is usually found in the rhyolite along the footwall contact. In the high-grade the gold occurs principally along seams and fracture planes in the rock, or in recementing quartz veinlets showing visible free gold. A cross-cut from a 50-ft. shaft on the Wilhelm cuts 45 ft. of rhyolite which is very much shattered and open, with a great deal of manganese dioxide in shrinkage cracks and fracture planes,

*Received Feb. 14, 1917.

and carries from a trace to several dollars in gold. The rock is heavily impregnated with hematite, which is clearly pseudomorphic after pyrite; and carries the best values where least altered and the poorest where the manganese is most abundant. At the Nancy Lee, where the thickness of the green chloritic andesite above the granitic complex is several hundred feet, the dike cuts a quartz and calcite cross-vein similar to those of the Oatman district, some good values resulting in the quartz vein near the intersection.

Similar conditions are being disclosed by the development of the property of the Murdock Mining & Milling Co. in the Black Range section of the Oatman district. Through the kindness of Mr. Porter, the General Manager, I have been able to learn of the results of their underground work.

The Murdock property is situated just southwest of the Boundary Cone and covers the extension of a mineralized rhyolite dike. Eastward from the end line of the Murdock the dike is largely covered by wash in its course through the property of the Oatman Syndicate. Still farther eastward its place is taken on the property of the Nellie by one of the typical quartz and calcite veins of the district.

The country rock at the Murdock is the older, or basal andesite, which directly overlies the pre-Cambrian granitic complex. An exposure of the granitic complex is to be seen just south of the dike. A cross-cut on the 300-ft. level from a shaft sunk in the hanging-wall andesite, after passing through 82 ft. of rhyolite and a 12-ft. contact ledge on the foot wall, cuts the granite. At the Nellie the country rock on the foot-wall side of the vein is the basal andesite, while the shaft sunk in the hanging wall was in the next higher flow of trachyte for 250 ft. There is a cross-fault between the Nellie and the Murdock and the block in which the Nellie is located is relatively downthrown with reference to the Murdock.

The rhyolite of the dike on the 300-ft. level of the Murdock is heavily impregnated with hematite and assays low in gold for the full width. The character of the rock, the mineralization, and the gold content are exactly similar to that in the Wilhelm-Eclipse dike coming from the same geological horizon. In both instances the gold is free, relatively coarse as compared with the gold in the producing mines, and is contained in the heart of the hematite.

At the Nellie, the vein filling on surface and where cut on the 350-ft. level is largely calcite and a pseudomorphic replacement by quartz and adularia; but one specimen from the 350-ft. level, said to be from the highest-grade streak cut, was quartz and rhyolite impregnated with hematite and identical in character with the rhyolite of the Murdock.

As the dip and strike of the dike on the Murdock and the vein on the Nellie are practically identical and the connection can be traced on

surface, I believe that a rhyolite intrusion, exposed by the deeper erosion on the Murdock, came up along a preëxisting fissure already filled with a calcite vein filling and that the solutions emanating from the dike were the agencies by which the calcite was replaced wholly or in part by quartz and adularia and the vein filling impregnated with auriferous pyrite.

This connection between the rhyolite dikes and the quartz and calcite ledges of the district cannot elsewhere be traced so conclusively, as few rhyolite dikes have been exposed by the erosion in the areas covered by the Tertiary flows. In the eroded areas, as at Secret Pass, however, the intrusive dikes are as frequent as veins in Oatman, and I believe that deeper development in Oatman will result in discovery that the ore-bearing quartz and calcite-filled fissures connect in depth with rhyolite dikes having a primary auriferous pyrite in the body of the dike; and possibly a richer contact vein between the dike and the granite.

In drifting along the contact vein exposed on the 300-ft. level of the Murdock, according to Mr. Porter, alternating small shoots of rich and lean ore have been cut; the face of the drift for several feet of advance at times averaging as much as $50. Specimens of this ore appear to be composed largely of brecciated and recemented rhyolite, similar to the high-grade ore from the Wilhelm-Eclipse dike, and show free gold in hematite and in the recementing quartz veinlets. It is probable that at points of greatest shattering, as at intersections and crossings, this recementing will be sufficient in extent to form good-sized shoots of high-grade ore.

Further evidence in favor of the rhyolite as the source of the primary ore is found in certain silicified flows which carry low values wherever sampled. The average of a number of samples recently broken by the writer at random from a silicified surface flow of rhyolite over four claims was 82c. per ton.

What the tenor of the primary ore will be, it is impossible to say, as the oxidation of the pyrite, and possibly the impoverishment of the primary ore, extends below the deepest workings in the district. There are undoubted evidences of leaching and reënrichment in the higher horizons of the veins, probably as a result of the percolation of surface waters later than the original deep-seated oxidation of the pyrite. A similar leaching of a portion of the gold in the primary ore may have accompanied the oxidation of the pyrite to depths as yet unknown. The nearest approach to an approximation of the value of the primary ore is found in the values cut in the body of the dike at the Wilhelm on the 50-ft. level and the Murdock on the 300-ft. level, and I believe that the values which will be found below the present water level of the Wilhelm will be higher than those in the cross-cut on the 50-ft. level.

With reference to the pyritic andesite cut on the 700-ft. level of the Gold Road mine indicating the near approach of the sulphide zone, it is

my observation that this pyritization of the green chloritic andesite is characteristic of the wall rock, usually on the hanging wall, in a number of instances, and the unoxidized pyrite extends practically to surface, where that formation is exposed on surface. Among the places where I have noticed this occurrence of pyrite in the wall rock is the cross-cut into the hanging wall on the 200-ft. level of the Black Eagle mine of the Tom Reed, in the hanging wall of the 300-ft. level of the main Tom Reed mine, in the cross-cuts on the 300-ft. level of the Oatman Amalgamated and in two places in Secret Pass. The oxidation that has taken place in the veins to an unknown depth seems to have had little effect on the pyrite in the wall rock. This is probably due to the fact that the water of the district is almost wholly confined within the walls of the vein itself. In only one instance that I know of does the pyritic wall rock carry gold minerals. That is at the Orphan group of claims, now the Secret Pass Gold Top Mining Co., in Secret Pass. Here the ore from a winze which enters the pyritic andesite at about 50 ft. carries $8 in gold.

This is the property spoken of by Mr. Payne. The mineralizing solutions here have come up along a major fault which marks the westerly boundary of the Secret Pass district, spreading out irregularly into the wall rock. Several thousand dollars worth of high-grade ore from a shallow glory hole were milled in a two-stamp Tetrault mill by leasers, and a considerable tonnage of surface ore running from $8 to $15 per ton in gold was opened up. This fault is later than the Tertiary flows and the rhyolite intrusions which it cuts. It is easily traceable for several miles and just east of the Orphan mine has lifted the pre-Cambrian granitic complex to a contact with an andesite later than the green chloritic andesite, which in Secret Pass immediately overlies the granite. The granite on the foot-wall side is irregularly mineralized, and in several places high-grade gold ore has been found in prospect holes.

One other ore occurrence in Secret Pass is worthy of particular notice. A rhyolitic dike of a somewhat coarser texture than the Wilhelm-Eclipse dike and having a strike of N. 35 W. which is paralleled by the major fault marking the easterly boundary of the mineralization of the district, has mineralized the granite for from 25 to 35 ft. on each side of the dike. The granite is stained a deep red by iron oxides and a sample across 23 ft. on the foot-wall side of the dike at a depth of 12 ft. assayed $4 in gold. No deeper development has yet been undertaken on this ledge.