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MINERAL DEPOSITS

OF THE

SANTA RITA AND PATAGONIA MOUNTAINS

ARIZONA

BY

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WITH CONTRIBUTIONS BY

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MINERAL DEPOSITS OF THE SANTA RITA AND PATAGONIA MOUNTAINS, ARIZONA.

By Frank C. Schrader.
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INTRODUCTION.

The field work forming the basis of this paper was a reconnaissance from March 7 to June 20, 1909, by F. C. Schrader and J. M. Hill, Mr. Schrader being in charge of the investigation. During most of the time the two geologists worked separately. Mr. Hill has supplied the substance of the material on the Greaterville, San Cayetano, and Redrock districts, and many of the mine descriptions for the Palmetto, Helvetia, and some other districts. The purpose of the paper is to furnish a general idea of the character, occurrence, distribution, and development of the mineral resources of the area covered, concerning which relatively little has hitherto been published.

The Patagonia and Nogales topographic sheets of the United States Geological Survey, on a scale of 2 miles to the inch, were used as a basis for field mapping. The general method of work employed was to make hasty sketch maps, sections, and oriented photographs of the camps and mines, a box compass and aneroid being used for determining bearing and elevations, and the work, wherever practicable, being tied to known locations in the quadrangles, Land Office section or township corners, or mining claim and United States mineral monuments. In some camps claim plats and mine maps supplied by the mining companies were helpful in the work.

To the mining companies, prospectors, and mining men throughout the field grateful acknowledgments are due for courtesies, hospitality, and other assistance generously extended. In the Helvetia camp the writer and Mr. Hill enjoyed the benefit of a conference with J. E. Spurr, who with his associates had made a detailed geologic map of the Helvetia Co.'s properties.

A field visit of several days from Waldemar Lindgren, geologist in charge of the work, shed valuable light on certain deposits in the Washington and Duquesne camps. Aid and suggestions were

also received from E. S. Larsen and other members of the Survey. The chemical analyses were made in the laboratory of the Survey by W. T. Schaller and W. F. Hunt. Prof. C. F. Tolman and Mr. Theodore Chapin, of Stanford University, have contributed geologic notes on the field adjoining this area on the north and have added to the list of publications consulted.

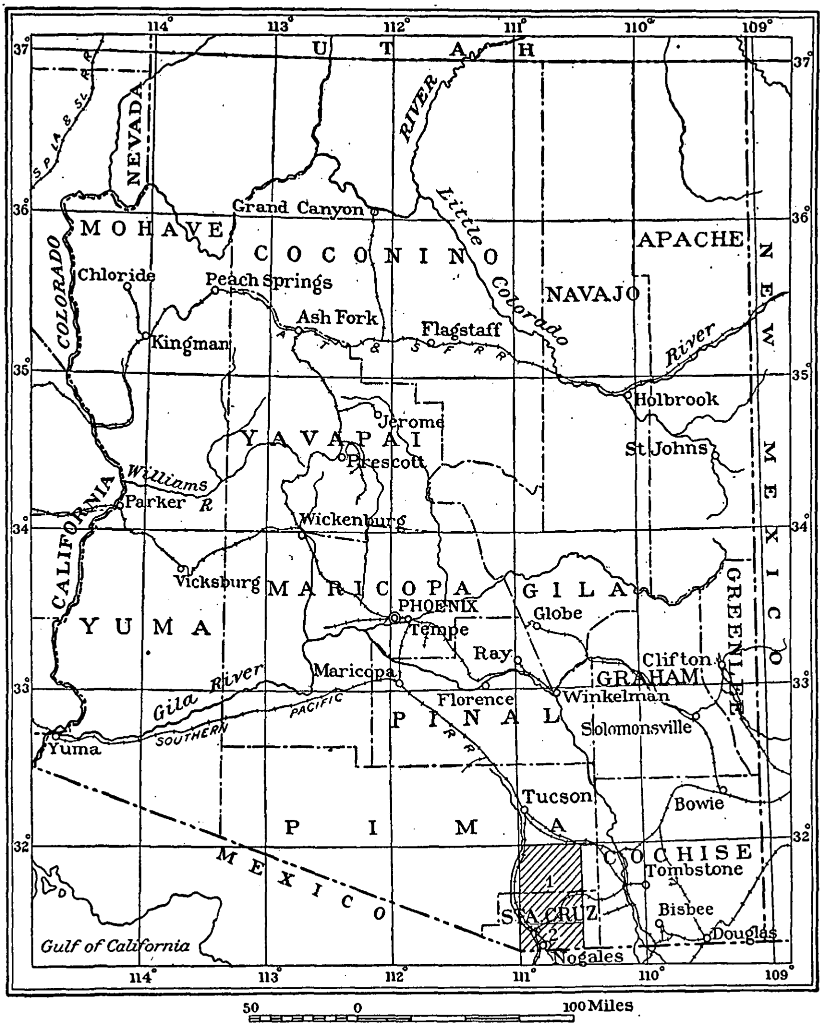

FIGURE 1.—Index map of Arizona showing location of area discussed. 1, Patagonia quadrangle; 2, Nogales quadrangle.

GEOGRAPHIC RELATIONS.

LOCATION AND MEANS OF APPROACH.

The area here described lies in the southeastern part of Arizona, in Pima and Santa Cruz counties, about 90 miles west of the Continental Divide, in the desert country of the Southwest, at a general elevation of about 4,800 feet. It is situated in the middle of the southern part of the belt of country commonly known as the Gadsden Purchase, acquired from Mexico in 1854. (See fig. 1.) It lies in the region mapped by the United States Geological Survey as the Patagonia and Nogales quadrangles, which together are bounded by parallels 31° 20′ (the international boundary) and 32° north latitude, and meridians 110° 30′ and 111° west longitude. The area extends north and south 46½ miles, is about 30 miles wide, and comprises about 1,400 square miles. (See Pl. I, in pocket.)

The area lies about 20 miles southeast of Tucson, the former capital of Arizona, the county seat of Pima County, and at present the chief town of southern Arizona. It is about 25 miles west of Tombstone and 30 miles west of Bisbee. The main transcontinental line of the Southern Pacific Railroad crosses the northeast corner of the area, in which are situated the stations Kadmon and Pantano. Vail, a shipping and supply station on this line, is 3½ miles north of the middle of the north edge of the area. The Benson-Nogales branch of the Southern Pacific Railroad, which leaves the main line at Benson, 12 miles to the east, extends southwestward across the southern half of the area to Nogales, on the Mexican border, where it connects with the Sonora Railway (Southern Pacific Railroad Co. of Mexico), which extends southward 80 miles through the State of Sonora, Mexico, to Guaymas, on the coast, and has a branch line extending to the copper camp of Cananea, 40 miles to the southeast. Over this line at least one passenger and one freight train in each direction is operated daily. Another branch of the Southern Pacific extending southward from Tucson to Nogales connects the southern part of the area more directly with the main line. The Twin Buttes line leaves this branch at Sahuarita station, 19 miles south of Tucson, and extends 7 miles southwestward to Twin Buttes. The Pioneer smelter, recently built, is 1½ miles southwest of Sahuarita, near the Twin Buttes line.

SETTLEMENTS AND MEANS OF COMMUNICATION.

The principal settlements (see Pl. I, in pocket) are Nogales, Patagonia, and the mining camps of Helvetia, Salero, Augusta, Harshaw, Mowry, Washington, Duquesne, Lochiel, and Lanoria. Most of them are connected with the railroads and with one another by stage lines, receive daily mails, and are provided with telephone and telegraphic facilities. For a long time there was a customhouse at Lanoria.

Before the building of the Benson-Nogales branch of the Southern Pacific Railroad the entire area was tributary to Tucson, 20 miles to the northwest, the chief town and central supply point for the mining regions of a very large part of southern Arizona, and this is still the point of supply for much of this area, especially the northern portion. The principal town of the area is Nogales, the county seat of Santa Cruz County, with a reported population of 3,000 people. The census of 1910 gives the population of the American side of the town as 1,761. Patagonia, a town of a few hundred Americans and Mexicans, is the supply point for a considerable part of the southern half of the area, notably the Harshaw, Tyndall, Wrightson, and Palmetto mining districts. It is situated on the railroad in the open Sonoita Valley between the Santa Rita and Patagonia mountains. From it daily stages run to Harshaw, Mowry, Washington, and Duquesne, the principal camps in the southern part of the area, respectively 6, 12, 13, and 20 miles to the south. The principal camps which it supplies on the north are Salero and its neighbors, Gringo, Mansfield, Augusta, Happy Jack, and others. A stage line is also operated between Nogales and Washington. On the north Helvetia has a daily mail and passenger service with Vail, on the railroad 18 miles to the north, and a tri-weekly stage service with Tucson, 30 miles to the northwest.

CLIMATE AND VEGETATION.

The climate of the region is arid, with hot summers, particularly in the valleys, and with mild winters. The summer heat is rendered tolerable by the dryness of the atmosphere, a more or less constant breeze, and cool nights. The climate on the whole is healthful.

According to the records of the Weather Bureau[1] kept at Tucson, which may be regarded as approximately representing the valley portion of the area, the average maximum temperature for the 13 years ending with 1911 was 108° and the minimum 17°. In the mountains, however, the temperatures are much lower.

As is characteristic of a desert climate, the amount of precipitation is small, and the ratio of evaporation to precipitation is said to be about 8:1. At Granite Reef, on Salt River, near Phoenix, about 100 miles to the north of the area, the nearest Weather Bureau station at which observations of evaporation have been made, the annual evaporation from a pan 4 feet in diameter placed on the ground is 115.18 inches and from a similar pan floating 97.74 inches.[2]

There are two annual periods of precipitation or so-called rainy seasons—one in summer, extending from about the middle of April

[1] U. S. Weather Bureau, Summary of climatological data of the United States, Section III, southwestern New Mexico and southern Arizona.

[2] U. S. Weather Bureau, Climatological division, A provisional statement regarding the total amount of evaporation by months at 23 stations in the United States, 1909–10, p. 5.

to the middle of September, and the other in winter, extending from December to March. The winter precipitation is usually the heavier and more widely distributed. In both seasons the greater part of the rainfall occurs in local showers or storms, and in hot summer weather it is often concentrated in cloud-bursts, giving rise to sudden floods. Summer showers occur almost daily and without warning but are of short duration. In winter in the mountains a considerable proportion of the precipitation falls as snow, which in the higher ranges accumulates to the depth of 4 to 5 feet but does not remain long, the highest mountains usually becoming cleared of it by April. Its gradual melting, however, and the percolation of its waters underground, keep the streams alive till the time of the heavier rains of the late summer. According to the Weather Bureau, the precipitation may in general be said to vary directly with the elevation above sea level. Over the lower portions of southwestern Arizona the average annual fall is generally less than 5 inches. Over districts with elevations between 1,000 and 2,000 feet the annual fall is nearly twice as great, rising to about 8 inches. For elevations from 2,000 to 4,000 feet the average annual precipitation is about 12 inches. From 4,000 to 6,000 feet it rises above 14 inches, and at elevations above 6,000 feet the annual precipitation probably ranges from 16 to more than 20 inches. The distribution depends somewhat on the location with relation to the prevailing direction of the winds, the first series of heights that interpose their presence to the prevailing winds receiving amounts somewhat in excess of even the higher succeeding ranges.

The distribution of rainfall by seasons is decidedly marked but fairly uniform for the different elevations. Nearly 50 per cent of the total fall occurs during July to September, inclusive, while during April to June, inclusive, the amount of fall is scarcely 10 per cent of the total. The average annual precipitation at Tucson for the 13 years ending with 1911, as recorded by the Weather Bureau, was 11.51 inches. The maximum, which occurred in 1905, was 24.17 inches, and the minimum, which occurred in 1900, was 7.79 inches.

The vegetation, especially in the valleys and foothills, is principally of the subtropical or Mexican desert type, the spinous forms and those having very little leaf surface being dominant. Descriptions and excellent illustrations of these forms appear in a report of the Desert Botanical Laboratory of the Carnegie Institution near Tucson,[1] in which the botanists refer to the great province in which this area lies as the Nevada-Sonoran Desert. The most conspicuous of these forms is the saguaro, or giant cactus, which attains a height of 20 to 40 feet.

[1] Coville, F. V., and MacDougal, D. T., Desert Botannical Laboratory of the Carnegie Institution: Carnegie Inst. Washington Pub. 6, 1903.

At an elevation of about 4,000 feet piñon, juniper pine, and other conifers appear; a little higher walnut, spruce, and many varieties of Mexican live oak are mingled with the conifers, and still higher they become the dominant timber and continue nearly to the top of the mountains, which culminate in Old Baldy, at an elevation of 9,432 feet. The best-forested part of the region is the west slope of the Santa Rita Mountains, where excellent timber of large size abounds in Josephine, Madera, and other canyons, and it is said that prior to the building of the railroad sawmills in these canyons supplied Tucson and nearly all the surrounding country south of the Gila with lumber for building and other purposes. All the timbered portion of the mountains and a considerable adjacent part of the Santa Cruz Valley on the northwest is in the Coronado National Forest, the supervising office of which is at Tucson.

From the valleys nearly to the top of the highest mountains are found many useful forage grasses, which during the rainy season, particularly in the foothills and lower mountains, attain a luxuriant growth. Cattle grazing is a considerable industry. The Federal Government is conducting experiments with the native grasses on the United States Range Preserve (see Pl. I), a tract of 50 square miles, in the Santa Cruz Valley, in the northwestern part of the area, and near by, on the McLeary ranch, experiments are also being made with spineless cactus, with reference to its use for forage.

In the main valleys of Santa Cruz River and its tributary Sonoita Creek agriculture is more or less extensively carried on, and Calabasas, at the mouth of the Sonoita, is regarded as the most productive spot in southern Arizona.

HISTORY OF MINING AND PRESENT CONDITIONS.

The first mining in the area of which any record is available was done before the Spanish conquest of Mexico in the sixteenth century, by the semicivilized ancestors of the Papago Indians, who inhabited the Santa Rita Mountains and the region adjoining on the west, once known as the Papagueria.[1] Here are the oldest mines on the Pacific slope north of Mexico.

This silver-mining region in Arizona is the northwestern continuation of the great silver-mining region of Mexico, which, notably in the States of Chihuahua, Durango, and Sonora, produced millions of dollars' worth of silver for centuries.

From central Mexico search for the precious metals was pushed northwestward, and mining operations were carried on by the Mexicans in the northern part of Mexico in the early part of the seven-

[1] Hinton, R. J., Handbook of Arizona, San Francisco and New York, 1878, p. 116.

teenth century or before.[1] In the northern part of Sonora, about 20 miles southwest of Nogales,[2] is the Planches de Plata district, one of the oldest and richest mineral regions in North America, celebrated for its great production and large nuggets or masses of native silver (bolas, or planches de plata). The largest mass, said to have weighed 2,700 pounds, was discovered in 1736 and caused great excitement and a stampede to the region.

The first civilized men to visit the Arizona region were the Spanish Jesuit missionaries, who from Sonora in 1687 explored the valley of Santa Cruz River and considerable portions of the Gila and San Pedro valleys. Their reports of the fertile valleys and mineral wealth of this new country led to the establishment on the Santa Cruz of the missions of San Xavier del Bac, Tumacacori, Santiago, and San Cayetano, the town of Tubac, and farther north that of Tucson. The first mission in Arizona was established at Guevavi, or Guebabi, about 30 miles south of Tucson, in 1687,[3] and those of San Xavier and Tumacacori soon followed.

These missions have an important bearing on the mining history of the region in that their founders and keepers, the Jesuit fathers, were in a sense the pioneer miners of the country and conducted mining operations with a considerable force of men, mostly impressed Indians, in connection with their missionary work. That they must have operated on a considerable scale is indicated by the extent of the workings and the slag dumps still seen near the mission ruins. They named the old Salero and other mines in the Santa Rita region.

The San Xavier mission, 9 miles south of Tucson, founded prior to 1694 and still standing, an object of visit to tourists, is described as a large church with imposing architecture, in which $40,000 in solid silver, taken from the mines in the Santa Rita Mountains near by, was used to adorn the altar.

Further explorations and new discoveries were made about 1810, and after that date conquest and settlement of the country were prosecuted with vigor both by the Jesuits and by the Spanish Government. The missions and settlements were repeatedly destroyed by the Apaches and the priests and settlers massacred or driven out, but they were as often reestablished, and up to 1820 the Spaniards and Mexicans continued to work many valuable mines. The best-known mine about this time, or a little later, was the Santa

[1] Ward, H. G., Mexico, 1st ed., vol. 2, pp. 136–138, London, 1828.
[2] Blake, W. P., Report of the Governor of Arizona for 1899, p. 107.
[3] Hamilton, Patrick, The resources of Arizona, 1st ed., Prescott, Ariz., 1881; 2d ed., San Francisco, 1883; 3d ed., 1884.

Rita del Cobre, which was worked probably about the middle of the thirties and produced ore yielding 75 per cent of copper.[1]

After the Gadsden purchase, made in 1853, Americans, including Poston, Mowry, and others, began to enter the region, eastern capital was enlisted, and more prominent mining settlements were made in the Santa Rita and Patagonia mountains as early as 1855, about which time the historic Mowry mine was located. In 1857 the country between the boundary and Calabasas was reported by the Emory Boundary Survey to be full of prospectors from California.

In 1856 an exploring party outfitted at San Antonio, Tex., arrived at Tubac, and proceeded to examine the silver mines in the Santa Rita and adjoining mountains, and in 1857 the Sonora Mining & Exploring Co. and the Arizona Mining Co. were formed for the purchase and development of these mines. About the same time an association[2] formed in Cincinnati, Ohio, with office also in Tubac, which by this time had a population of about 500, acquired title to valuable mining property in the Atascosa Mountains on the west and the Santa Rita Mountains on the east, including the old Salero mines of the Jesuits. Here, too, was the headquarters of the Sonora Exploring & Mining Co., of which Maj. Heintzelman, of the United States Army, was president. Its operations were conducted mostly north of Tubac, the principal property being the Heintzelman mine, which in 1857 had been opened to a depth of 50 feet and had on the dump $20,000 in silver sulphide ore that averaged about $1,400 to the ton.[3] In 1860, practically without machinery, this mine was still producing annually about $2,500 in silver, which was cast into small bars and used as a circulating medium. So rich was some of the ore from this and adjoining regions that it paid for transportation on muleback more than 1,000 miles to the City of Mexico.

In 1858 the Santa Rita Mining Co. was organized for operating both old and new properties in the Santa Rita Mountains; the Mowry (formerly the Patagonia), Trench, Compahgre, and other veins were being worked in the Patagonia Mountains; and smelters were being installed for the reduction of the ores. The ore of these mines, especially that of the Mowry, was said to be of high value, yielding, besides the large percentage of silver, about 50 per cent of lead, which was in demand by the neighboring companies to be used as flux in reducing their less favored ores. The Santa Rita and Patagonia mountains contain a score or more of the crude adobe smelters or

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[1] Hall, James, Parry, C. C., and Schott, Arthur, Paleontology and geology of the boundary: Rept. U. S. and Mexican Boundary Survey, by Maj. W. H. Emory, vol. 1, pt. 2 (H. Ex. Doc. 35, 34th Cong., 1st sess.), pp. 21–25, 1857.

[2] Blake, W. P., and others, Silver and copper mines in Arizona: Min. Mag., 2d ser., vol. 1, pp. 114, 243, 1859–1861.

[3] Blake, W. P., and others, op. cit., pp. 114–243.

their ruins, examples of which may be seen in Alum Canyon, at the Jarilla mine, southwest of Patagonia, and at Duquesne, near the Mexican border. They were mostly built by Americans after the Gadsden purchase and are an adaptation of the old Mexican fundación in efforts to extract the metals from the ore. In short, during the middle and late fifties the mining industry of this region was developed with considerable success and brilliant prospects until interrupted by the Civil War, the withdrawal of the troops, and the triumph of the Apaches.

A little later, in 1863, the ores of the Santa Rita region were described[1] as generally argentiferous gray copper and galena, with mostly quartz gangue, and the mines as but little developed. The ore of the Patagonia (now Mowry) mine was referred to as being very simple in reduction and yielding $80 in silver to the ton, reduced from adobe smelters on the ground. This mine, then owned and operated by Lieut. Mowry, seems to have been the most advanced in the region. It was developed to a depth of 200 feet and contained over a thousand feet of underground work.[2] About $200,000 had been expended in the purchase and equipment of the mine and installation of the plant. The product of the mine, said to have been $4,500 in silver a month when the plant was in full operation, was shipped to Europe and England in lead and silver bars, yielding, it is said, a clear profit of more than $100 a ton above all expenses.[3] This mine was worked extensively before the war, employing at times more than 400 men.

To protect the settlers against the Indians Old Fort Buchanan, of which Fort Crittenden is a successor, was built and garrisoned at the head of Sonoita Creek, near the center of the area, in 1855 and 1856. Later the mining industry derived material benefit from the semimonthly stage line and the Butterfield semiweekly overland mail route[4] between San Antonio, Tex., and San Diego, Cal., via Tucson, from 1857 to 1861. The breaking out of the Civil War, with the withdrawal of the garrisons and the consequent atrocities of the Apaches and the abandonment of the camps, put an almost abrupt stop to the mining industry of Arizona and for years retarded the Territory's development. After the subjugation of the Indians the industry in the Santa Rita region was successfully revived in the early or middle seventies by Col. W. J. Boyle and others, and ores from the croppings, it is reported, were found to range from $20 to several hundred dollars and from the shafts from $50 to many thou-

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[1] Pumpelly, Raphael, Mineralogical sketch of the silver mines of Arizona: California Acad. Nat. Sci. Proc., vol. 2, pp. 127–139, 1863.

[2] Mowry, Sylvester, The geography and resources of Arizona and Sonora, new ed., Am. Geog. Soc., San Francisco and New York, p. 51, 1863.

[3] Idem, p. 52.

[4] Hinton, R. J., Handbook of Arizona, San Francisco and New York, 1878.

sand dollars to the ton. This revival, besides involving the reoccupation of most of the old and the exploitation of many new properties, included the opening on the east slope of the Santa Rita Mountains of a new lead and gold region, comprising the present Wrightson and Greaterville districts, the latter of which soon produced considerable placer gold.[1]

The completion of the Southern Pacific transcontinental railroad in 1879 and that of the Atlantic & Pacific in 1883 were potent factors in opening the Territory to immigration and capital. Before the advent of the railroad ore that would not yield $100 to the ton was passed by as worthless.

After the building of the railroad the Empire district was opened, and the Total Wreck mine, which was rapidly developed to a depth of 260 feet with much lateral work, soon became the foremost bullion producer of the Territory. The average mill test of the ore, which was chiefly silver chloride carrying considerable carbonate of lead, manganese, and iron, was about $60 to the ton. A 20-stamp 70-ton mill operated on the ground extracted 84 per cent of the metal contents, and during five months had produced $450,000, the cost of mining and milling being about $8 a ton. In the Helvetia district the promising copper deposits were being successfully worked, and a smelter installed on the Omega ground had produced considerable bullion from ore reported to be of high grade and easily reduced. In the southern part of the area patents had been acquired to many properties, and by 1883 the Hermosa mine had produced $700,000. About this time also the industry in the southern part of the area received a new impetus by the opening of the Benson-Nogales branch of the Southern Pacific Railroad.

In the early and middle nineties considerable attention was paid to copper deposits. A two-stack customs smelter was in operation at Tucson, a one stack 60-ton smelter at Rosemont, and a one-stack lead smelter at Nogales, and during a part of the time 3 or 4 carloads of ore a day were shipped via Crittenden from the Washington camp. By 1903 the silver-gold-lead-copper World's Fair mine was developed to a depth of 500 feet and contained about 2 miles of work.[2]

The year 1905 [3] witnessed a marked renewal of activities in the area, notably in the Patagonia Mountains on the south and in the Helvetia district on the north, and placer work was done in the Greaterville district. A 100-ton lead smelter was completed by the Mowry Mines Co. and there was a considerable increase in the production of this company's mines and several others in the neighbor-

[1] Raymond, R. W., Mineral resources of the United States for 1875, pp. 389–390, 1876.

[2] Blake, W. P., Mining: Report of the Governor of Arizona for 1903, pp. 112–115; Geology of Arizona: Idem, pp. 126–135.

[3] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1905, pp. 138, 153, 155–156, 1906.

ing Washington and Harshaw camps. Some bullion was shipped to New York.

In 1906[1] the Helvetia Copper Co. operated a 150-ton copper matting furnace, and in its development work struck an important ore body on the 800-foot level of the Isle Royal mine, the deepest workings in the area. The neighboring Tiptop mine, containing nearly 8,000 feet of work, made almost daily shipments of copper ore. The Greaterville region produced several thousand dollars in placer gold, and some ore was shipped by the World's Fair, Four Metals, and other mines in the southern part of the area. Owing to the suspension of active operations of the Mowry mine there was a decrease in the output of silver, but there was a material increase in the lead output.

In 1907 general progress was made by a dozen producing properties.[2] The Helvetia mines produced about $40,000 in ore containing mostly copper. The Isle Royal shaft was extended to a depth of 1,000 feet, and a large body of low-grade ore was opened on the upper levels. Moderate shipments were made from the Empire district and from the southern districts generally, where also a considerable tonnage of concentrates and crude ore was shipped by the Mowry, Duquesne, and Morning Glory mines, the Mowry working 100 men. Santa Cruz County, in which these outputs prominently figure, though yielding 107 tons less than in the preceding year, showed an increase of 16 producers and was first among the counties of Arizona in the production of silver-lead ore and lead concentrates, which came principally from mines near Mowry and Harshaw.

In 1908, owing largely to the industrial depression resulting from the financial stringency in 1907, the smelters at Helvetia, Rosemont, Washington, and Duquesne were idle, and the districts dependent on these plants, some of which were leading producers in 1907, showed little activity. However, there was a known production from the northern district of nearly $16,000, mostly from Helvetia and Greaterville, besides some ore from Empire, and from the southern district of about $25,000, of which nearly one-third in gold-silver-copper ore came from Harshaw, mostly from the World's Fair mine, and the rest from Wrightson, Patagonia, and Tyndall.[3] The Santa Rita Co. installed a 14-ton mill in Caliente Canyon. The Gringo 5-stamp mill was in operation and the plant was enlarged; the 30-ton matte smelter of the Mansfield Mining Co. in the Wrightson district was nearly completed; and considerable ore was shipped from several mines to outside smelters and most of the ore that was not shipped was treated in local gold and silver mills.

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[1] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1906, pp. 147–177, 1907.
[2] Heikes, V. C., idem, 1907, pt. 1, pp. 175–178, 1908.
[3] Heikes, V. C., idem, 1908, pt. 1, pp. 305–307, 1909.

The year 1909[1] witnessed a partial revival of activities. The output of the Helvetia district, shipped to the Old Dominion Smelter and to the Globe, was 11,287 tons of ore, valued at $157,308. This came principally from the Helvetia Copper Co., which did a large amount of development work and by diamond-drill tests from the lower levels of the mines located the continuation of ore bodies and discovered a large tonnage of self-fluxing smelting ore that assayed from 2 to 5 per cent of copper. Though production elsewhere was moderate, development work was generally carried on throughout the area. Large quantities of low-grade pyritic copper ore, some assaying less than 6 per cent of copper, were shipped from the Augusta mine to Globe, and hydraulic machinery was installed on one of the Greaterville placers.

The mining industry in the area in 1910 was inactive, owing largely to the low price of copper. Outside capitalists, however, were reported to be quietly looking up good copper properties. In nearly all the districts development work was done, and some ore was shipped and more uncovered in many of the mines, as the Madera, Ivanhoe, and Flux. Prospecting was stimulated on the west by the proposed extension to Calabasas of the branch railroad from Tucson, which brings scores of good but formerly remote mines within 10 to 25 miles of railroad transportation, and by the prospect of a new, much-needed smelter to be erected at some point on the railroad, to which the west-slope districts would be directly tributary.

The decline in the price of copper caused relatively greater attention to be given to gold, silver, and lead prospects during 1911, and besides the annual assessment work considerable development work was done on an unusual number of the precious-metal claims, some of which were new. The production for this year, valued at about $30,000, was derived mostly from the gold-bearing silver-lead ores of the Tyndall and Wrightson districts. This year also witnessed the completion of the Pioneer smelter,[2] about a quarter of a mile from the Twin Buttes spur and 1½ miles west of the Tucson-Nogales branch railroad.

With the market price of copper at 15 cents a pound, the 150-ton Pioneer smelter in successful operation, and a large amount of work done on mining properties and claims, especially in the Palmetto and Harshaw districts, the outlook for the mining industry in 1913 was growing brighter. The remarkable discovery of rich chalcocite ore in the Three R group of mines and their steady production for the following 10 months attracted outside attention to that part of the

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[1] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1909, pt. 1, p. 253, 1910.
[2] Magee, J. E., official letter.

field, with the result that several surrounding properties were bonded and were being developed. Copper was the objective metal, but gold, silver, and lead were also being carefully sought for. About 100 new claims were being developed in the southern part of the area.

Late in 1914, owing to the war in Europe, work has been curtailed or suspended on many properties in this region, as in other parts of the West. Some ore, however, was being accumulated at Patagonia and other shipping points awaiting resumption of shipment with a more favorable market.

PRODUCTION.

The early production of precious metals from the districts within the area here treated must have been considerable. It is roughly estimated that by 1900 the output amounted to $1,250,000, and the accompanying tables, which cover three-fourths of the period since that date, indicate that about as much more has been produced since, making the total production for the area approximately $2,500,000.

So far as can be found, however, there are no statistics showing the early production. In the early reports of the directors of the mint estimates of county production are given, but the figures for Pima County, which originally included the present Santa Cruz County, are of little service, as they include the production of numerous districts outside of the area considered in this report.

Raymond[1] gives the production of the Trench mine, in the Harshaw district, for 1875 as 100 tons of argentiferous galena. This was smelted in adobe furnaces located near the mines and yielded $8,700 in silver.

In the mint report for 1880 Burchard[2] gives the output of mills within the area as follows:

> Harshaw mill (of Hermosa mine), four months' run, $365,654 silver.
> Holland smelter, $20,000 silver.
> Placers of Pima County, principally from the Greaterville district, $18,000 gold.

In the mint report for 1881[3] the Harshaw mine is reported to have produced $412,000 in silver bullion. In a later report[4] the same authority states that the yearly production of gold from the Greaterville placers since 1879 is estimated at $12,000.

The statistics of the production of base and precious metals in the United States have been collected by the United States Geological Survey since 1902. From the San Cayetano, Redrock, and Palmetto districts no production for the period from 1903 to 1908, inclusive,

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[1] Raymond, R. W., Production of precious metals west of the Rocky Mountains for 1875.

[2] Burchard, H. C., Report of the Director of the Mint on the production of precious metals for 1880, p. 112.

[3] Idem for 1881, p. 300.

[4] Idem for 1884, p. 80.

has been reported. The table on pages 29–30 shows the yearly production of the remaining districts in this area for the years 1903 to 1912. It will be seen that the production of the Empire and Helvetia districts was very small before 1906. During that year the Helvetia Copper Co. ran a 150-ton copper smelter for a short time and the Tiptop, Rosemont, and Omega companies shipped considerable ore. In the Greaterville district the annual placer production is usually between $2,000 and $3,000. The increase of production in 1905 is probably due to the operations of the hydraulic plant in Boston and Kentucky gulches. The Tyndall and Wrightson districts produced little before 1906, when the Rosario, Happy Jack, Gringo, Salero, and Alto mines began adding their quota to the wealth of the region. The Harshaw and Patagonia districts have always been the largest producers in the area. The output comes largely from the Mowry, World's Fair, Flux, and Duquesne mines, though the Four Metals, Golden Rose, and O'Mara mines have also produced some metal. At the Mowry a 100-ton smelter and concentrating plant were put into operation in 1905. At Washington the Pride of the West mill is capable of handling 100 tons of ore a day, and there is a 25-ton copper furnace in connection with the mill. The high production recorded in 1907 is due largely to the work of this mill and smelter.

The total amount of ore treated during these years was 178,108 tons, of which 140,782 tons came from the Patagonia district. The Helvetia district produced 30,870 tons during the same time. The Helvetia ores are largely copper ores carrying gold and silver; the Patagonia mines produce primarily lead and zinc ores with a little copper, gold, and silver. The ores of the Harshaw district are largely lead-silver ores carrying some copper and small quantities of gold. The Empire district produces more lead and silver than copper, though the latter metal is usually associated with the ores. The mines of the Tyndall district produce largely lead-silver ore, but copper accompanies the ore, which also carries some gold. In the Wrightson district the ores are mixed, carrying more copper than lead and more silver than gold.

Yearly production of gold, silver, copper, lead, and zinc in the mining districts of the Patagonia and Nogales quadrangles, 1903–1912.

[From statistics collected by the U. S. Geological Survey. The production of some districts is combined to conceal the production from single mines.]

District.	Year.	Ore treated (tons).	Gold.		Silver.		Copper.		Lead.		Zinc.		Total value.
			Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
Helvetia and Empire	1903	100			936	$500							$500
	1904	40			200	100			20,000	$600			700
	1905	600					75,000	$11,700					11,700
	1906	11,852	46.42	$960	4,444	2,977	706,625	141,325					145,262
	1907	5,711	7.35	152	6,903	4,556	478,970	95,796	28,989	1,537			102,041
	1908	944	3.68	76	2,085	1,105	93,602	12,355	16,573	696			14,232
	1909	12,250	28.88	597	20,166	10,486	1,168,878	150,711	113,670	4,888			166,682
	1910	148	3.15	65	1,372	741	10,013	1,272	10,881	479			2,557
	1911	40			838	444	13,043	1,630	5,378	242			2,316
	1912	586	2.37	49	16,873	10,377	39,792	6,565	3,759	169			17,160
		32,271	91.85	1,899	53,817	31,286	2,585,923	421,354	199,250	8,611			463,150
Harshaw and Patagonia	1903	266	4.83	100	3,996	2,099	1,562	216	66,884	1,842			4,257
	1904	461			5,265	2,865	27,000	2,510	37,855	1,513			6,888
	1905	1,500	31.93	661	73,590	44,448	9,000	1,404	338,840	15,925			62,438
	1906	122,025	17.00	352	61,895	41,470	7,934	1,507	1,454,972	82,931			126,260
	1907	14,705	37.83	782	41,493	27,386	482,006	96,402	533,358	28,268	57,038	$3,365	156,203
	1908	330	28.88	597	9,034	4,788	47,748	6,302	5,882	247			11,934
	1909	117	5.22	108	1,146	597	21,222	2,758	2,276	98			3,561
	1910	673	41.84	865	81,209	43,853	40,085	5,091	86,666	3,814	10,853	586	54,209
	1911	52	7.02	145	595	315	18,915	2,364	1,483	67			2,891
	1912	2,029	46.73	966	18,933	11,644	273,260	45,089	39,145	1,762			59,461
		142,158	221.28	4,576	297,156	179,465	928,732	163,643	2,567,361	136,467	67,891	3,951	488,102
Tyndall and Wrightson	1903	10	2.42	50	70	37	2,600	359					446
	1904												
	1905												
	1906	24	1.68	35	564	378	2,448	475	13,584	777			1,665
	1907	423	58.34	1,206	7,891	5,208	21,615	4,323	92,503	4,903			15,640
	1908	621	47.11	974	6,614	3,506	35,529	4,690	79,133	3,324			12,494
	1909	1,667	12.58	260	6,194	3,220	126,979	16,508					19,988
	1910	38	.63	13	1,706	922	2,068	252	1,913	84			1,271
	1911	594	4.98	103	11,565	6,129	54,285	6,786	183,029	8,236	16,844	960	22,214
	1912	302	75.17	1,554	4,397	2,704	30,130	4,971	48,673	2,190	25,539	1,762	13,181
		3,679	202.91	4,195	39,001	22,104	275,654	38,364	418,835	19,514	42,383	2,722	86,899

Yearly production of gold, silver, copper, lead, and zinc in the mining districts of the Patagonia and Nogales quadrangles, 1903–1912—Continued.

District.	Year.	Ore treated (tons).	Gold.		Silver.		Copper.		Lead.		Zinc.		Total value.
			Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
Greaterville placers	1903		92.91	$1,920									$1,920
	1904		120.93	2,500									2,500
	1905		241.88	5,000	62	$37							5,037
	1906		136.64	2,824	28	19							2,843
	1907		241.87	5,000	48	32							5,032
	1908		150.01	3,101	16	8							3,109
	1909		106.42	2,200	17	9							2,209
	1910		103.43	2,138	15	8							2,146
	1911		99.99	2,067	20	11							2,078
	1912		171.20	3,539	29	18							3,557
			1,465.28	30,289	235	142							30,431
Grand total		178,108	1,981.32	40,959	390,209	232,997	3,790,309	$623,361	3,185,446	$164,592	110,274	$6,673	1,068,582

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PHYSIOGRAPHY.

GENERAL FEATURES.

As shown by Ransome,[1] Arizona may be divided into three grand physiographic regions. These are a high plateau region in the northeastern part, a low-lying desert region in the southwestern part, and an intervening mountainous region. Gilbert[2] and Dutton[3] had previously made a twofold division into the plateau region and the range region. Though the three regions differ markedly from one another, as a whole the boundaries between them are not everywhere sharply defined. The plateau region is a part of the great Colorado Plateau, whose southwestern boundary, beginning at the mouth of the Grand Canyon of the Colorado, near the southeast corner of Nevada, extends in a southeasterly direction for nearly 400 miles across Arizona and passes into New Mexico a few miles northeast of Clifton, near the thirty-third parallel of north latitude.

The mountain region adjoins the Colorado Plateau on the southwest and is recognized by Gilbert and other authors as the continuation of the great basin-range province, which is typically developed in Utah and Nevada and extends in a broad belt having a maximum width of about 150 miles southeastward across Arizona into the neighboring republic of Mexico. It is composed of numerous disconnected parallel ranges which trend from southeast to northwest across the State to Colorado River. Toward the Mexican border, however, in the southeastern part of the State, the mountain belt and the ranges that compose it assume a nearly north-south trend, about parallel with the Sierra Madre system in New Mexico on the east.

The ranges are for the most part short and narrow and have axes of pre-Cambrian granitic or crystalline schist, locally naked but generally in part unconformably overlain or flanked by Paleozoic quartzites and limestones and post-Carboniferous sediments and volcanic rocks, all usually with monoclinal structure, the ranges being mostly of the tilted fault block type. Few of them exceed 50 miles in length or 8,000 feet in altitude, and they are separated by detritus-floored valleys. In the portion of the belt adjoining the plateau on the northeast the valleys are narrow and occupy a relatively subordinate area compared with the mountains. Away from the plateau, however, the valleys widen, and in the southwestern part of the belt they exceed the mountains in area and the mountain belt merges into the

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[1] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, 1904; Geol. Atlas, Bisbee folio (No. 112), 1904.

[2] Gilbert, G. K., The geology of portions of New Mexico and Arizona: U. S. Geog. Surveys W. 100th Mer., vol. 3, pt. 5, pp. 503–567, 1875; also pts. 1 and 2.

[3] Dutton, C. E., Tertiary history of the Grand Canyon district: U. S. Geol. Survey Mon. 2, 1882.

expansive low, flat-lying detrital plain, the desert region of Arizona, which, sloping very gently down to sea level at the Gulf of California, is only locally interrupted by more or less isolated rock mountains.

The boundary line between the mountainous region and the desert plains region is represented on the map as extending from Nogales, at the Mexican border, northwestward through Tucson, Florence, and Phoenix to Needles, at Colorado River, as shown by Ransome,[1] who states that there is no sharp distinction between the two provinces and that the line as drawn is provisional.

Except a few local lava flows, the deposits that floor or fill the valleys in the mountainous region and underlie the plains in the desert region consist of fluviatile and lacustrine deposits and eolian débris, wash, etc., derived from the mountains. They range from mere films, covering wide areas of planated rock surfaces, to deposits a thousand feet or more thick in the deeper parts of the valleys. These deposits are well exposed in the San Pedro Valley, about Benson, just east of the area forming the subject of this paper.

The detrital deposits produce varied topographic forms. The detrital slopes which extend down from the rock surface of the hills and mountains and which are usually long, sweeping, and gentle and form the dominant feature of this southwestern landscape are referred to as bajadas;[2] the lower and more flat-lying portions of the outwash and other subaerial deposits are called bolsons or bolson plains, and the central ponds or lake-bottom flats, most of which are but intermittently occupied by water, are generally known as playas.

The main drainage of both the mountain and the desert regions flows westward, diagonally across the trend of the ranges, through Gila, Salt, and Williams rivers into the Colorado. The tributaries of these streams occupy the longitudinal valleys between the parallel ranges.

DRAINAGE.

The Patagonia and Nogales quadrangles, comprising about 1,400 square miles, are situated in the southwestern part of the mountain region of Arizona, in the southern part of the Gila drainage basin, which has a width of 300 miles and occupies almost the whole of southern Arizona. Most of the area drains northward through Santa Cruz River, the main southern tributary of the Gila, which flows westward to Colorado River at Yuma. About 80 square miles of upland on the east, extending from the Canelo Hills north-

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[1] Ransome, F. L., U. S. Geol. Survey Prof. Paper 12, fig. 1, p. 10, 1903.

[2] Tolman, C. F., Erosion and deposition in southern Arizona bolson region: Jour. Geology, vol. 17, pp. 136–163, 1909.

eastward beyond Elgin, drains eastward through the headwaters of the Babocomari into Rio San Pedro, and thence northward into the Gila.

RELIEF.

The altitude of the area ranges from 2,650 feet in the Santa Cruz Valley, on the northwest, to 9,432 feet on Old Baldy,[1] the highest peak of the Santa Rita Mountains,[2] near the center of the area, the vertical range being thus about 6,800 feet. The mountains collectively average about 5,500 feet in elevation, the valleys or nonmountainous portion 4,300 feet, and the area as a whole about 4,800 feet.

MOUNTAINS.

SANTA RITA AND PATAGONIA RANGES.

The conspicuous topographic features of the area are the Santa Rita and Patagonia mountains, which begin near the north edge and extend in a southerly direction through the middle of the area to the Mexican border, having a length of about 45 miles. Though the northern range is known as the Santa Rita Mountains and the southern as the Patagonia Mountains, the two are so closely connected as to form a nearly continuous range, being separated only by the narrow transverse valley of Sonoita Creek, in the southern part of the area. The topography of the mountains is for the most part well expressed on the accompanying contour map (Pl. I, in pocket).

In areal outline the mountains are irregular and form a sort of crude crescent, open to the east. They range from about 4 miles in width near the middle part to 12 miles in the northern part, including the Empire Mountains, an outlying group on the east, and 30 miles in the southern part, including the San Cayetano Mountains on the west and the Canelo Hills on the east. They culminate near the center of the range in Old Baldy, at the altitude of 9,432 feet. From this point, roughly speaking, they decline to the north and south ends of the range into the foothills about 5,000 feet in elevation, which rise about 1,000 feet above the adjacent bajada of the valley plains. The crest of the northern third of the range, however, stands rather uniformly at about 6,000 feet. A considerable portion of the crest of the range is serrate.

Although the mountains in general have a north-south trend, they include topographic forms which trend diagonally across their main

[1] This peak was formerly called Mount Wrightson, after Col. John W. Wrightson, of the Cincinnati Enquirer, manager of the Salero Mining Co., of Cincinnati, who was killed on the adjoining west slope of the range by the Indians.

[2] The Santa Rita Mountains were described by Pumpelly, in Hinton's "Handbook of Arizona," as the highest mountains of Arizona south of the Gila.

axis, in a northwest-southeast direction, as expressed by the Mount Fagan mass on the north, the Canelo Hills and their continuation beyond the Sonoita on the southeast, and the Grosvenor Hills on the west. On the west also the northward course of Santa Cruz River across the southwest corner of the area belongs genetically with this group of forms. This northwest trend of the features is also to a considerable extent followed by the geology and mineral deposits, as is expressed by the mapping of the formational belts on Plates II and III (in pocket) and described more fully under "Geology."

In general the topography is rough, especially through the axial portion of the range. The forms are of various types, including, besides precipitous fault scarps, the forms produced by deep dissection and weathering of plutonic, volcanic, and sedimentary rocks in an arid mountainous region. Examples of these forms are shown in Plates IV, V, and VI, *A*.

The mountains are largely due to faulting. The structure is broadly monoclinal, with a gentle dip to the east. The fault scarps in general face westward and give to the west side of the range a general slope of about a thousand feet to the mile. This is considerably steeper than the slope on the east side, which in part follows the monoclinal dip. The sedimentary rocks are prevalent on the eastern slope and in the northern part of the range, where the topographic forms, as shown in Plates IV, *B*, V, and VI, *A*, range from prominent buttes, steep cliffs, and scarps of hard Paleozoic quartzite and limestone to the gentler forms carved in soft Mesozoic shales and sheets of Quaternary unconsolidated detritus. In the Old Baldy district[1] the topography is peculiarly rugged and the forms include scarps, cliffs, and canyons produced by the faulting and deep dissection of tilted volcanic flows, which here are more than 2,000 feet thick, overlie the plutonic rocks, and form the summits of the mountains. In a measure forms of this same class prevail in the Patagonia Mountains and their southern continuation in Mexico.

There are low passes through the range at several points. The principal ones are at Box Canyon and at Melendreth Pass, opposite Greaterville, in the northern part, and in Sonoita Canyon below Patagonia and on the Washington-Nogales road west of Washington, in the southern part.

EMPIRE MOUNTAINS.

The Empire Mountains form an outlying northeast-southwest group about 7 miles long and 3 miles wide 5 miles east of the north end of the main range. They rise to a maximum elevation of 5,360

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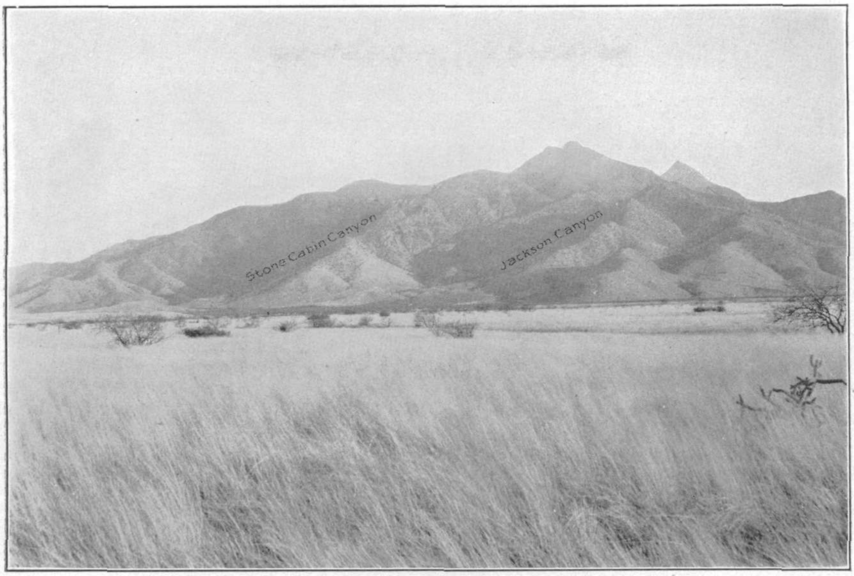
[1] The term "district" in this report refers to some one or other of the mining districts. They are shown on Plate I (in pocket) and are described later.



A. VIEW OF NORTHWEST BASE OF SANTA RITA MOUNTAINS IN OLD BALDY DISTRICT.

Showing mostly volcanic-rock topography. Looking southeast from southern part of United States Range Reserve, near road forks and Sawmill Canyon, at an elevation of 3,500 feet.

B. OLD DICK MINE (1), MOHAWK MINE (2), AND QUARTZITE BUTTE (HART BUTTE) IN CREST OF SANTA RITA RANGE.

Looking southeast from aplite ridge at an elevation of 4,400 feet.

feet and are characterized largely by the same topographic and structural features as the main range, from which they are separated by Davidson Canyon.

The fault scarp exposing the edges of the eastward-dipping monoclinal beds that form the west front of the range extends from Andrade's ranch southward to Barrel Spring, or nearly to Scholefield's ranch, a distance of about 7 miles.

SAN CAYETANO MOUNTAINS.

The San Cayetano Mountains, an outlying group southwest of the Santa Rita Mountains, form a single-crested north-south mass about 5 miles long and 2 miles in breadth at the middle and highest point, where they rise to nearly 6,000 feet, or 2,000 feet above Josephine Canyon. The topography is rough, as they are composed of eroded volcanic rocks. The structure, like that of the Santa Rita Mountains, is monoclinal, with the dip to the east.

CANELO HILLS.

The Canelo Hills consist of a broad hilly ridge on the southeast of the main range. They extend from Old Fort Crittenden southeastward for about 20 miles and are 2 or 3 miles wide. For the most part the elevation of the crest is about 6,000 feet, or 2,000 feet above the valleys on the east. They are 8 or 10 miles from the main range, from which they are separated on the north by the valleys of Sonoita and Harshaw creeks and Redrock Canyon and on the south by the broad head of the Santa Cruz River valley. The slopes, especially on the southwest, are generally steep and rough. The structure for the most part is monoclinal, with dip to the southwest, an exception to the general eastward-dipping structure of the other ranges in the area.

VALLEYS.

The valleys, or nonmountainous portion, constitute the larger part of the area, as shown on Plate I (in pocket), and almost surround the mountains.

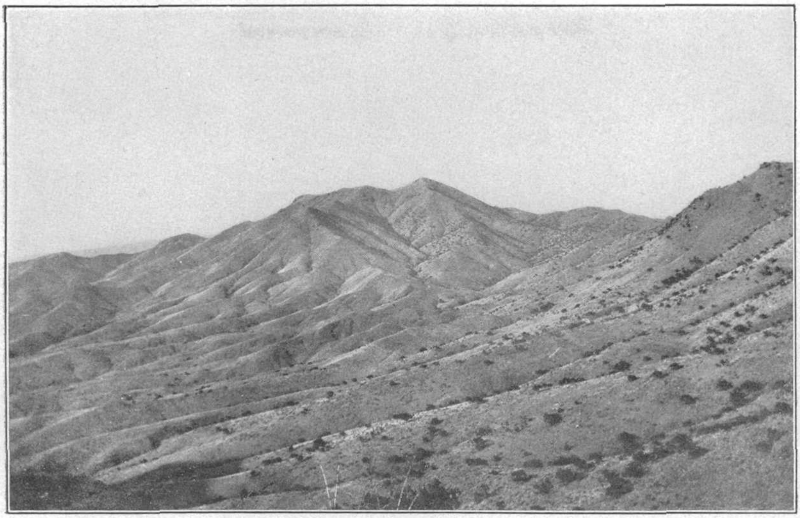
SANTA CRUZ VALLEY.

The valley of Santa Cruz River in its upper part is hook-shaped. The river rises in the southeastern part of the area, on the southwest slope of the Canelo Hills, about 12 miles north of the Mexican border and the same distance east of Patagonia. For the first 26 miles of its course it flows southward, parallel with the neighboring streams that continue in this direction and enter the Gulf of California. About 14 miles beyond the Mexican boundary, however, after encircling the south end of the Patagonia Mountains in a curve about 12 miles in width and almost doubling back upon its former course, the Santa Cruz flows north-northwestward past Tucson and joins the Gila at the old town of Maricopa, 160 miles distant from the point where it recrosses the international boundary. From a point a few miles above Calabasas to the Gila, except in the regions of Tubac and Tucson, it flows as a sunken stream.

In the first 26 miles of its course the river occupies an open depression known as the San Rafael Valley,[1] bounded by the Canelo Hills and the Santa Cruz Mountains on the east and the Patagonia Mountains on the west. The portion of this valley north of the boundary line is somewhat basin-shaped, opening southward, and is about 12 miles in width, 1,000 feet in depth, and fairly uniform. The floor lies at a mean elevation of about 4,800 feet and declines gently southward at the rate of about 30 feet to the mile. The important mining camps of Washington and Duquesne lie on the western margin of this valley. The river in its course through the middle of the basin is joined nearly at right angles by numerous small tributaries from both the east and the west. These tributaries are dry during most of the year, but in the upper parts of their courses they occupy shallow canyons and deep gulches cut into the Quaternary detrital deposits and locally into the underlying rocks.

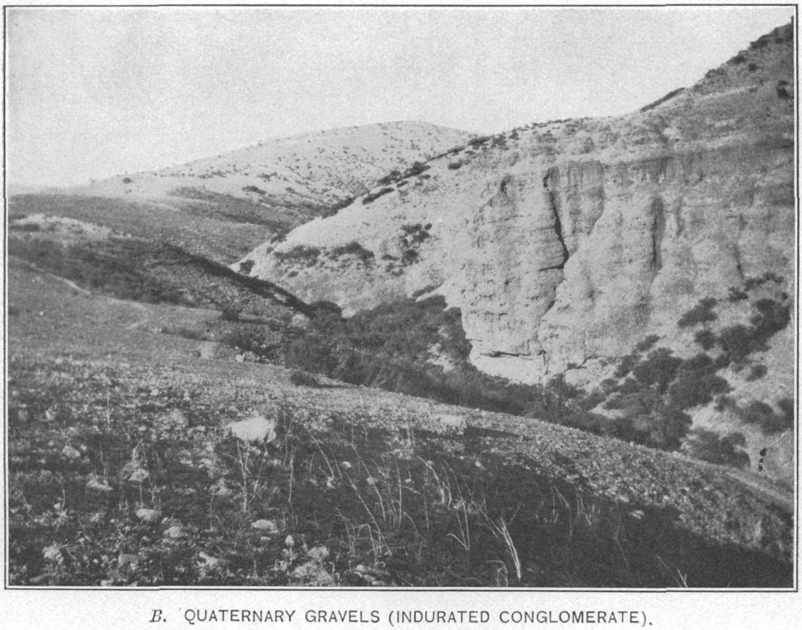
After returning from Mexico, about 5 miles east of Nogales, the river flows for 14 miles in a northwesterly course by way of Calabasas across the southwest corner of the area mapped. Here it has an average elevation of 3,560 feet and a gradient of about 40 feet to the mile, and the width of its valley, measured from the base of the Patagonia Mountains at an elevation of about 5,000 feet to the Atascosa Range of the Pajarito Mountains, 6 miles southwest of Nogales, is about 17 miles. The topography of the valley is for the most part rough and is characterized by low hills, long ridges, and shallow canyons, gulches, and washes carved into the Quaternary detrital deposits and the volcanic and other rocks. Most of the tributary drainage lines join the river at about right angles. West of the river the hilly country becomes more pronounced. It contains Mount Benedict, with its mines, and to the south, beyond the border, it is known as the Sierra de Nogales. Except near the outlying San Cayetano Mountains on the north the river occupies approximately the middle of the valley. Owing apparently to lateral migration in connection with down cutting, the stream along much of its course is bordered on the southwest by a more or less abrupt scarp, but on the northeast it is bordered by a gently sloping lowland from

[1] U. S. and Mexican Boundary Comm. West of Rio Grande Rept., S. Doc. 247, pt. 2, pp. 19–20, 1898.



A. MOUNT FAGAN AND SLOPES.

Showing erosion topography in ridges and gulches in Mesozoic rocks, mostly shale. Looking north-northeast from head of Sycamore Canyon.



B. QUATERNARY GRAVELS (INDURATED CONGLOMERATE).

At west base of Red Mountain on Gar Canyon, an eastern tributary of Alum Canyon, near Patagonia. Looking east-northeast.

1 to 2 miles in width, and toward Calabasas the flat increases in width and occurs on both sides of the channel. Here the river sinks, but it rises again at Sahuarito Butte and at Tucson, to the northwest, outside of the area shown on the map. The principal tributaries in this part of the valley are Sonoita Creek and Nogales Wash, or Potrero Creek.

Sonoita Creek heads east of the center of the area, on the east side of the Santa Rita and Patagonia mountains, flows in a generally southwest course across the range and joins the Santa Cruz at Calabasas, 25 miles from its source and 10 miles north of Nogales. From Old Fort Crittenden to its mouth it has a fall of about 1,300 feet, or about 50 feet to the mile. It seems undoubtedly to be an antecedent stream. It furnishes the only graded natural pass through the range, and this pass is utilized for a highway and a railroad throughout its length. The source of the stream is commonly referred to Monkey Spring, on the Pennsylvania ranch, in the Canelo Hills 7 miles north of Patagonia, which constantly furnishes it with a copious supply of water. Its head drainage, however, has a much wider scope and includes the plains country as far as the Sonoita railroad station, 5 miles northeast of the Canelo Hills, and the rugged, canyon-scored southeast slope of the Santa Rita Mountains, extending to Old Baldy at the summit of the range and containing the Mansfield, Augusta, Gringo, and other camps of the Wrightson district. It is in close proximity to the Cienega Creek drainage basin on the northeast, from which it is separated by a narrow, very low, and inconspicuous divide. From Old Fort Crittenden to Patagonia it takes a southerly course, diagonally across the axis of the Canelo Hills, and from Patagonia it flows in a more westerly direction across the axis of the main range. Except for 5 or 6 miles of its course below Patagonia, which lies in a box canyon bounded by walls of igneous rock from 200 to 700 feet high, the creek flows through a strip of flood plain or lowland about a mile in width, which materially widens near the Santa Cruz. At Patagonia the Sonoita is joined by Harshaw Creek, which drains the Canelo Hills and a considerable area of rugged "red rock" country to the east and the important mining camp of Harshaw on the south. In the western part of its course the Sonoita drains the south end of the Santa Rita Mountains, including the Grosvenor Hills and the San Cayetano Mountains, all made up for the most part of volcanic rocks and having a rough topography.

Providencia Canyon, Wild Hog Canyon, and other tributaries heading in the rugged heart of the Patagonia Mountains, drain the western part of the Patagonia district, containing the Golden Rose and other mines.

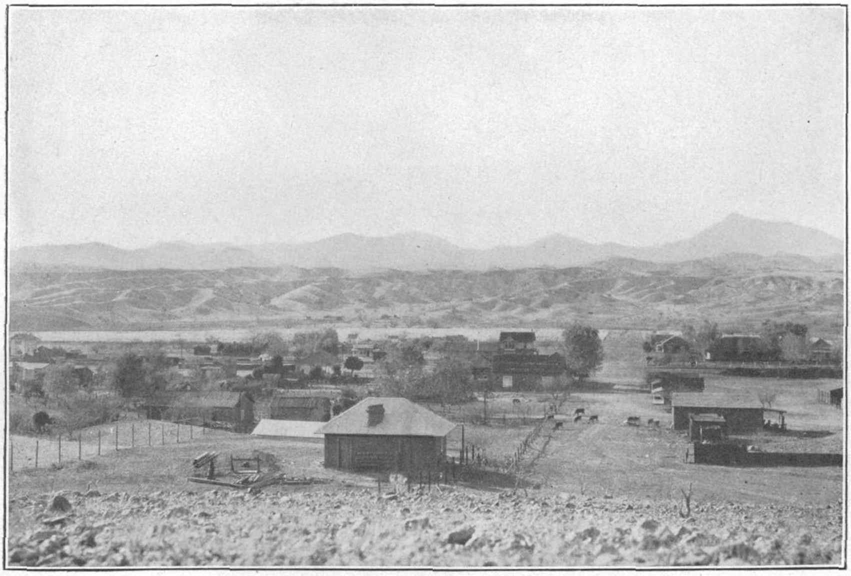
Nogales Wash, also called Potrero Creek, heads 5 miles or more south of the Mexican border, flows northward through the town of Nogales, and joins the Santa Cruz at Calabasas. In the lower part of its course it flows through a narrow flood plain of agricultural land bounded by low bluffs marking the edge of hilly country, which on the west is drained by numerous tributaries of considerable length, heading in the Atascosa Mountains.

In the latitude of the San Cayetano Mountains the Santa Cruz Valley becomes a detrital plain and expands northward into a wide, open basin. At the north edge of the area it has a width of 40 miles or more, and Tucson, 20 miles farther northwest, stands upon it. Of this great valley plain feature only a relatively small portion is contained in the area treated. This portion, however, extends from the San Cayetano Mountains on the southwest nearly to Pantano, some 40 miles distant on the northeast, and from the base of the Santa Rita Mountains to the northwestern limits of the area. From the rugged foot of the mountains at an elevation of about 4,200 feet the surface declines gently to 2,650 feet at Santa Cruz River, 12 miles distant, at the average rate of 130 feet to the mile, but the slope is steeper in the bajada portion, which occupies a belt from 3 to 4 miles in width along the mountains and descends to about the 3,200-foot contour, giving a slope of nearly 300 feet to the mile for the bajada and about 50 feet to the mile for the lower bolson plain.

Locally the bajada, in the form of huge alluvial fans or cones, occupies embayments reaching far back into the mountains, as at Helvetia, near Proctor's ranch, and in Madera Canyon. (See Pl. II, in pocket.) Both bajada and bolson plain are scored by transverse dry washes, arroyos, gulches, and canyons, which are sunk more or less abruptly to depths of 10 to 100 feet in the Quaternary detrital deposits and obstruct transportation. They trend mostly northwestward toward Santa Cruz River. In places the valley plain is bordered by areas of beveled rock floor produced by sheet-flood and wind erosion, an example of which may be seen in the lower part of the Helvetia embayment carved in the granite.

The most important tributaries received by the Santa Cruz in this portion of the area are those in Josephine Canyon and Madera Canyon, both perennial streams in the mountainous parts of their courses.

Josephine Canyon heads on the southwest slope of Old Baldy, takes a southwesterly course, drains the larger part of the Tyndall mining district, and joins the Santa Cruz at Tumacacori, about 18 miles distant. Madera Canyon heads on the northwest slope of Old Baldy, takes a northwesterly course, and drains a considerable portion of the Old Baldy district.



A. QUATERNARY DEPOSITS ON SONOITA CREEK.

Shows mostly eroded topography. Patagonia in foreground, Santa Rita Mountains in background, and Old Baldy at right.

B. INCLINED BEDDING STRUCTURE IN RHYOLITE TUFF.

One mile northeast of Nogales, looking southwest.

CIENEGA VALLEY.

The Cienega Creek basin lies in the eastern and northeastern parts of the area. The head branches of Cienega Creek extend to Old Baldy on the west and the Canelo Hills on the south. The creek flows in a northerly course to Pantano Wash, at the north edge of the area, about 30 miles from the Canelo Hills. Pantano Wash drains northwestward into Rillito Creek, which joins the Santa Cruz 7 miles west of Tucson.

In the upper half of its course the Cienega Valley is an open, nearly equidimensional basin contained in the crescent of the range. Measured from the base of the Santa Rita Mountains on the west to the base of the Whetstone Mountains on the east it is 15 miles across. When seen as a whole from its north edge, the basin presents a nearly level sky line and has much the appearance of an extensive park. Toward the foothills it is adorned with scattered clusters of live oak. When viewed more closely, however, the surface is found to be a gently rolling plain dissected by numerous drainage lines into long sloping, nearly flat-topped ridges. The longer slopes are on the west side of the basin, toward the higher of the two bordering ranges, the Santa Rita Mountains, which supply most of the Quaternary detrital deposits that underlie the plain, and, in consequence, the creek is crowded to the opposite or east side of the basin.

In the latitude of Greaterville, near the middle of the basin, from the base of the mountains on the west, at an elevation of 5,000 feet, to Cienega Creek, at 4,500 feet, the surface declines at the rate of about 50 feet to the mile. The fall of the creek from south to north is also about 50 feet to the mile.

At the outlet of the basin the valley plain contracts into a narrow neck several miles in length, bounded by the foothills of the Empire Mountains on the west and the Whetstone Mountains on the east. Through this neck, which is much dissected by lateral tributaries, the creek flows at an elevation of about 4,000 feet in a narrow valley or canyon sunk 200 feet or more below the surface.

BABOCOMARI VALLEY.

The east-central part of the area, a high plainlike tract, is the only portion which does not drain into Santa Cruz River. It is drained by the headwaters of Babocomari River, a small stream which flows into the San Pedro on the east.

GEOLOGY.

PRINCIPAL ROCK GROUPS.

The area here treated contains a large variety of both igneous and sedimentary rocks. The rocks range in age from pre-Cambrian to Recent. For the most part they have been considerably uplifted, faulted, intruded, and deformed. Deformation has given to the several outcrop belts a general northwesterly trend. Areally, excepting for the Quaternary gravels, the igneous rocks are dominant.

The principal sedimentary groups, beginning with the oldest, are of Paleozoic, Mesozoic, Tertiary, and Quaternary age, and the igneous groups are the pre-Cambrian or basal granite, the Mesozoic intrusive rocks, and the Tertiary volcanic rocks.

The general distribution of the rocks is approximately outlined on Plate II (in pocket), and their vertical relationship is shown in the accompanying geologic sections (Pl. III).

A general description of the rocks is given here, and fuller local details appear in the sections on the several districts and mines. The rocks with which most of the ore deposits are connected in origin are the Paleozoic limestones and the Mesozoic intrusive rocks.

SEDIMENTARY ROCKS.

PALEOZOIC ROCKS.

CAMBRIAN (?) ROCKS.

Character, structure, and distribution.—The Paleozoic era is represented in the area by sediments belonging to the Cambrian (?), Devonian, and Carboniferous periods. The rocks here tentatively referred to the Cambrian consist of pink to red massive quartzites, dark-greenish siliceous shale, schist, and conglomerate. These rocks are not extensively exposed. They are cut by the Mesozoic intrusive rocks and in most places rest on granite. They occur principally in the north-central part of the area, in the Helvetia and Greaterville districts; farther north, near the Cuprite and California mines; in the western part of the area, in Madera Canyon and Montosa Basin; and farther south, in the San Cayetano Mountains.

In the Helvetia-Greaterville exposure, which is the largest, the rocks occur in a narrow interrupted north-south belt along or near the axis of the range, extending from a point north of Helvetia to a point south of Greaterville, a distance of about 12 miles. In the northern part of the belt they are principally heavy-bedded or massive quartzites having a thickness of about 700 feet and occurring in two series of isolated outcrops most of which represent monoclinal fault blocks. They form much of the crest and produce the most rugged topography of this part of the range.

In the environs of Helvetia (see Pls. VIII and IX and fig. 2), where the structure is very complicated, a thrust fault of low angle and great displacement which dips gently to the southwest has brought the Cambrian (?) quartzite and other sediments into unconformable contact with the underlying granite. The contact, starting near the southeast corner of the area shown on the map of the Helvetia district (Pl. VIII), follows an irregular line to the middle part of its north edge.

In the outcrop about half a mile northwest of Helvetia, which is more than a mile in length and half a mile in maximum width, the quartzites are dark red and massive and, as shown in section *A–A′* of Plate IX, seem to dip very steeply to the east, though they are so altered and deformed by faulting and folding that the bedding was not definitely determined. The rocks rest upon or against the granite on the west and are succeeded by the younger Paleozoic limestones on the east.

In a similar outcrop 1¾ miles southeast of Helvetia, extending for 3 miles along the crest of the range (Pl. II, in pocket), the rocks are very red and massive, dip steeply to the east, and show but little bedding. They form the so-called buttes or high-domed bald knobs that stud the crest of the range, of which Hart Butte and others (Pl. IV, *B*) are examples.

Near Greaterville, in the upper part of Box Canyon, the Cambrian (?) quartzite is thin to heavy bedded and brown or pale pink. It dips 40°–50° ENE. and is conglomeratic, especially at the base, where it rests upon the coarse porphyritic granite. Higher in the section, above a considerable interval presumably occupied by unexposed Paleozoic limestone, appears a bed of reddish-brown mottled conglomerate about 100 feet in thickness, dipping 60° NE., which is thought to belong to the basal part of the Mesozoic.

The outcrop of the Cambrian (?) rocks near the Cuprite mine occupies a north-south belt of about half a square mile just east of the mine. It consists principally of quartzite and is bounded by granite and Paleozoic limestones on the west and overlying Mesozoic sediments on the east.

The Cambrian (?) rocks outcrop also about 4 miles east of the Cuprite mine in Davidson Canyon, about a third of a mile south of the California mine and Andrade's ranch. This area occupies about 1 square mile and except on the north, where it is in contact with the Paleozoic limestones, it is surrounded by Mesozoic sediments, the granite of the Empire Mountains lying near by on the southeast. The rocks here consist essentially of dark-greenish quartzite, or siliceous shale, greatly crushed, mostly into small cuboidal blocks. They are overlain in a few places by remnants of the light Paleozoic limestone.

About half a mile south of the California exposures the quartzite appears in a small area covering about half a square mile, and here it contains a few prospects.

In the west-central part of the area the Cambrian (?) rocks outcrop in the east or main fork of Madera Canyon, in the Old Baldy district, on the west slope of the Santa Rita Range, at an elevation of about 6,500 feet. This outcrop forms a narrow north-south belt about 2 miles in length and scarcely a quarter of a mile in maximum width. The Cambrian (?) rocks rest on the granite to the west and are delimited for the most part by intrusive quartz monzonite on the east, while on the northeast they pass beneath the younger Paleozoic limestone. The rocks of this belt are essentially quartz-mica schists, locally garnetiferous and epidotized. They are intruded by dikes of quartz monzonite porphyry and lamprophyre.

Another exposure of the supposed Cambrian rocks occurs in the middle of the western part of the area, in Montosa Basin, a depression about a mile in diameter in the foothills of the range, in the Tyndall district. The belt is about half a mile wide and extends about 5 miles northwestward to a point beyond Agua Caliente Canyon. Here the rocks, as seen principally in Montosa Basin, consist essentially of greenish and reddish shales. They are in part mineralized and cut by the Mesozoic intrusives. They dip steeply to the southwest beneath the younger Paleozoic limestones, with which they seem to be conformable. On the northeast they give way to the granite and quartz monzonite and on the south to andesite. If the dip that is well shown toward the southwest side is maintained across the belt, which, as the rocks are concealed, is by no means certain, the beds here, as in the Greaterville district, have a thickness of about 5,000 feet.

The Cambrian (?) rocks are also exposed 12 miles north of Nogales in the south end of the San Cayetano Mountains. Here they occupy a north-south strip about three-fourths of a mile long and one-fourth mile broad, tapering to the north. They form a small but prominent knob and occupy the col adjoining it on the north. They consist of thin-bedded red and green quartzites and hornfels, dipping to the east conformably with the monoclinal structure of the range. These rocks are underlain by diorite on the west and pass beneath the rhyolite flows on the east.

From the exposures described it is inferred that beneath the overlying younger rocks the Cambrian is probably present in a considerable portion of the area. As seen at a distance, it appears to be well represented by quartzite in the middle west slope of the

Empire Mountains, a locality which seems likely to prove one of the best in the area for studying the sequence and stratigraphy of the Paleozoic rocks.

Age and correlation.—No fossils were found in the rocks described, but from their lithologic resemblance, especially that of the quartzite, to similar rocks in other regions and their similar relations to the overlying Devonian and Carboniferous, whose age has been determined on fossil evidence in this area, they are here tentatively referred to the Cambrian. The quartzites are thought probably to contain the equivalent of the Bolsa quartzite of the Bisbee quadrangle,[1] and of the two quartzite formations above the Barnes conglomerate and below the Devonian beds of the Globe and Ray quadrangles.[2] The probable presence of at least two quartzite formations in the area, as at Ray, is suggested by the twofold or beltlike series of outcrops, best shown in their extension northward from Helvetia. The intervening cherty limestones of Ray or the Abrigo limestone of the Bisbee quadrangle are represented by the crudely banded limestone overlying the basal quartzite in Tiptop Mountain, as shown in section *A–A′*, Plate IX.

DEVONIAN AND CARBONIFEROUS ROCKS.

Character, structure, and distribution.—Conformably overlying the Cambrian (?) rocks is a series of Paleozoic limestones and associated sediments aggregating 4,000 feet or more in thickness. These rocks as shown on the map (Pl. II, in pocket) are widely distributed, but they are not extensively exposed, though more so than the Cambrian (?) rocks. They belong to the group of Paleozoic formations characteristic of the mining districts throughout the Rocky Mountain region. They consist, in ascending order, of thin-bedded gray fossiliferous limestone, thick-bedded light gray-white limestone, and thin-bedded dark-gray fossiliferous limestone. The division first named is principally Devonian, and the two others are referred to the Pennsylvanian. Only in a few localities, as shown on the map, has any attempt been made in this work to differentiate the divisions.

Like the Cambrian (?) rocks, these limestones have been extensively folded, upturned, faulted, and fissured and subsequently invaded by the Mesozoic intrusives and highly altered, locally to crystalline marble, limestone silicate, and jasperoid rocks or garnetiferous masses, and mineralized, thus becoming one of the most important ore-bearing reservoirs in the area. Not rarely, as in the Helvetia and Rosemont camps, the rocks in belts of considerable extent are

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[1] Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, Pl. XII, 1904.

[2] Ransome, F. L., Geology of the Globe district, Arizona: Min. and Sci. Press, vol. 102, p. 747, 1911.

so silicated and changed that they can not be differentiated macroscopically from quartzite or from the aplite dikes by which they are intruded.

The contact of the limestone with the intrusive rock is generally broken down or indefinite. In some places, however, clear evidence as to the intrusive character of the contact can be seen. In Washington camp, for instance, in the north prong of Bonanza Gulch, just above the forks, quartz monzonite occurs in sharply welded contact with greenish silicated limestone or quartzite dipping 60° W. Endomorphic hornblende is well developed in the quartz monzonite, and the sedimentary rock is locally altered to a kind of hornfels. At the Copper Point mine, in Copper Canyon, in the Empire district, is seen a similar relatively sharp contact between the dark-greenish silicated Carboniferous limestone and the light hornblendic quartz monzonite of medium grain, and along the contact the limestone is completely metamorphosed and contains a great deal of diopside and less secondary silica, and the quartz monzonite is fine grained or aphanitic.

The principal occurrences of these rocks, beginning on the north, are in the Empire, Helvetia, Greaterville, Tyndall, Redrock, and Patagonia districts. In most places they rest upon the Cambrian (?) beds or upon the granite. They are also intruded by the granite and are commonly in later fault contact with it, thrust-fault contacts being especially noteworthy in the Helvetia camp. In the Greaterville district the junction of the limestone with the granite is a sharp vertical fault contact which extends northwestward entirely across the Santa Rita Range, a distance of 7 miles.

Age.—The limestones are here assigned to the Devonian and Carboniferous on the evidence of fossils found in place in them in the Empire, Helvetia, Patagonia, Greaterville, and Redrock districts.

On the collections made in the Greaterville district in the long limestone ridge just south of the Pima and Santa Cruz county line, E. M. Kindle, paleontologist, reports as follows:

> The fossils present are the following:
>
> Acervularia inequalis H. and W. vel davidsoni E. and H.
> Cladopora prolifica H. and W.
> Amplexus sp.
> Atrypa reticularis Linn.
> Spirifer hungerfordi Hall.
>
> This fauna is identical with that which characterizes the Martin limestone in the vicinity of Bisbee, Ariz. It is of Middle or Upper Devonian age. Prof. H. S. Williams has considered the Martin limestone fauna to be Middle Devonian in age.

The exact locality from which this collection was made is 2½ miles S. 20° W. from Greaterville, in the upper part of the ridge between Fish and Sawmill canyons. The limestones in which the fossils occur are generally thin bedded and dark grayish black to brown. They dip about 50° SW. and are separated from the sharp fault plane between granite and limestone, already described, by limestone conglomerate.

Blake[1] reports having collected, seemingly from this same locality, *Spirifer hungerfordi*, *Atrypa reticularis*, Bellerophon, and *Acervularia davidsoni*.

From the variation in the character of the rocks to the northwest it is probable that Carboniferous beds are also present in the same belt in which the Devonian occurs, but it is likewise probable that the Devonian occurs more or less coextensively with the Carboniferous throughout the northern part of the area.

Collections made at well-distributed points in the Empire, Helvetia, Patagonia, and Redrock districts establish the identity of the Carboniferous among the limestone beds. A list of these collections, with comments of G. H. Girty, the paleontologist who determined them, follows:

Lot 5, 2 miles east of Helvetia:
Echinocrinus sp.
Productus occidentalis.
Composita subtilita.
Schizodus n. sp.
Bellerophon sp.
Indeterminata.

Lot 135, Total Wreck mine:
Bryozoan, probably Tabulipora.

Lot 247, near Mowry:
Composita subtilita.
Bellerophon sp.
Pleurotomaria sp.
Schizostoma aff. catilloides.
Orthonema sp.
Trochus? sp.

Lot 248, near Mowry:
Bellerophon aff. crassus.

Lot 249, near Mowry:
Productus semireticulatus?
Spirifer rockymontanus?

Lot 250, near Mowry:
Productus semireticulatus.
Spirifer rockymontanus.
Composita subtilita.

Lot 251, near Mowry:
Productus aff. mexicanus.
Pugnax aff. osagensis.
Pleurotomaria sp.

Lot VIII–55, near Mowry:
Productus cora.
Spirifer rockymontanus.
Spirifer cameratus.
Spiriferina sp.

Lot VIII–56, near Mowry:
Echinocrinus cratis.
Echinocrinus cratis var.
Echinocrinus trudifer.
Echinocrinus trudifer var.
Echinocrinus gracilis?
Echinocrinus aff. aculeatus.
Euomphalus n. sp.
Tabulipora? sp.
Productus semireticulatus.
Composita subtilita.
Myalina sp.
Bellerophon crassus?
Murchisonia aff. copei?

Lot VIII–62, near Mowry:
Crinoidal fragments.
Fistulipora sp.
Productus ivesi.
Productus occidentalis?
Pugnax osagensis.
Composita mexicana.
Astartella? sp.
Undetermined pelecypods.

Lot VII–37, Canelo Hills:
Stromatoporoid corals?
Bryozoa (ramose) indet.
Fistulipora? sp.
Spirorbis sp.

[1] Blake, W. P., Some salient features in the geology of Arizona, with evidences of shallow seas in Paleozoic time: Am. Geologist, vol. 27, pp. 160–167, 1901.

All the collections except lots 135 and VII–37 are clearly Carboniferous, and although several types found in lot 250 occur with little change in both the Mississippian and Pennsylvanian, all things considered, I feel very little doubt that the horizon is Pennsylvanian. It seems highly probable, also, that the rocks which furnish these collections represent the Naco limestone of the Bisbee quadrangle. Lot 250 (and 249?) probably represent the lower part of the Naco and lot 247 (and 248?) the upper part of the Naco. The upper part of the Naco is probably to be correlated with the Manzano group of central New Mexico and the lower part of the Naco with the Magdalena limestone of that region, and both may be represented in the Hueco limestone of western Texas. Lots 5, VIII–56, and VIII–62 without much doubt belong to the Hueco fauna. Lot VIII–55 suggests an older stage of the Pennsylvanian, either basal Hueco or pre-Hueco. Lot VII–37 is clearly Paleozoic and probably Carboniferous. The evidence is not conclusive and the age may be older. Lot 135 probably belongs in the Pennsylvanian.

Lots 247 to 250, inclusive, were collected on the northeast slope of the small hill just northwest of the Mowry mine,[1] in the southern part of the area, from various points between the North Mowry mine and the top of the hill, about a quarter of a mile to the southwest. The limestone here is medium to heavy bedded, dips about 45° NE., and exposes a thickness of 800 feet or more. The lots are numbered in ascending geologic order. Lots 251[2] and VIII–62 were obtained at the top of the hill, from thin-bedded dark-blue limestone which lies nearly flat. The stratigraphic sequence of this locality with that of lot 250, adjoining, is not shown on the ground, owing to an intervening north-south fault. Lots VIII–55 and VIII–56 came from the same limestone area, at a point about a mile northwest of the Mowry mine, on the easterly one of the twin peaks. Lot VIII–55 was obtained from thin-bedded light-gray semicrystalline limestone on the south slope of the peak, and lot VIII–56 from thin-bedded dark-gray or blackish limestone at the top of the peak, apparently at a higher horizon. The limestones in the Mowry area contain many traces of fossils, most of them too poorly preserved for identification.

Lots 5 and 135 were obtained in the northern part of the area. Lot 5 came from the top of Sycamore Ridge, shown at the right in figure 2 (p. 93), 2 miles east of Helvetia, from nearly flat-lying dark-bluish massive compact semicrystalline limestone. Here also the limestone contains numerous small indistinct forms or fragments of organic remains, not well preserved. Lot 135 came from the gray semicrystalline limestone of the Total Wreck mine, in the Empire Mountains.

Lot VII–37 came from the upper east slope of the Canelo Hills, in the southeastern part of the area, 10 miles east of Patagonia, 2½ miles northwest of Canelo Pass, and about a mile east of the La

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[1] The limestone area extending from Mowry and the Mowry mine 2½ miles northwestward and erroneously shown on the geologic map (Pl. II, in pocket) as Devonian has since the map was printed been found on fossil evidence to be Carboniferous (Pennsylvanian).

[2] The specimens in this lot were collected and kindly furnished by Mr. John W. Prout, jr.

Plata mine. Here the fossils occur in thin-bedded brownish-gray compact, nearly flat-lying limestone.

In and adjoining the Redrock district the Carboniferous was identified in the crest of the Canelo Hills at the head of O'Donnell Canyon, 9 miles east of Patagonia and 1 mile northeast of the New York mine.

Fossils are reported to occur also in the limestone in Montosa Basin, in the western part of the area, but the short time available afforded no opportunity to search for them during this work.

MESOZOIC ROCKS.

Character, structure, and distribution.—Unconformably overlying the Paleozoic rocks already described, usually with gentle dips, is a series of relatively soft interbedded shales, sandstones, and calcareous layers having a maximum thickness of about 6,000 feet. These beds crop out at several places in the area and are generally overlain by Tertiary or Quaternary gravels or younger Quaternary wash and débris. They are most extensively exposed in the northern part of the area, in the Helvetia and Empire districts, where they extend in a belt about 8 miles in width from a point near the axis of the Santa Rita Range eastward beyond the Empire Mountains, a distance of 15 miles. They occupy the region of Mount Fagan, where they produce a characteristic erosional topography of long-crested ridges and gulches, as shown in Plate V, *A*.

In the lower part of the section the rocks are mostly of a dull red color and in places conglomeratic, but in the upper part the red rocks largely give way to green and gray or earthy-colored shales and sandstones, some of which are but slightly consolidated.

The basal member of the series as exposed near Helvetia and in the east slope of the Empire Mountains is a bed of conglomerate about 300 feet thick, which rests apparently with depositional contact unconformably upon the Paleozoic limestone and other rocks. In the bottom of Sycamore Canyon near Helvetia the contact and adjoining lower part of the section dip about 75° NNE. Here the conglomerate is red and variable, grading into sandstone both longitudinally and vertically.

Likewise on the east slope of the Empire Mountains the contact and adjoining overlying beds dip steeply to the southeast. In this locality the conglomerate is medium to coarse and is mottled with green, reddish, and white pebbles and cobbles of limestone, quartzite, quartz, and other materials. On the south slope the contact trends diagonally across the Paleozoic limestones. At the contact the dip of the Mesozoic strata is steep, but, as shown in section *A–A′*, Plate III (in pocket), it flattens rapidly with increasing distance from the mountains, and the beds, in places covered with Quaternary gravels and wash, seem to underlie almost the whole of the Cienega Creek basin and apparently reach well into the flanks of the Whetstone Mountains, at the eastern border of the area, beyond which, according to Dumble,[1] these mountains are composed chiefly of Carboniferous sandstones and limestones. Between the Empire Mountains and the Helena mine, 4 miles to the west, the beds seem to have in general a gentle dip to the southeast, and in places they are cut by a vertical north-south sheeting and interbedded with Tertiary lavas.

In the Greaterville district the Mesozoic rocks occupy for the most part an irregular north-south belt about 2 miles wide, extending for 9 miles along the east base of the Santa Rita Mountains. Toward the south, at the county line, the continuity of the belt is locally interrupted by the upfaulted Devonian limestone and farther south by the Quaternary deposits.

In the northern portion of this belt the rocks consist principally of thin-bedded arkose sandstone, dolomites, and mudstones, some of which are silicified and altered to pale-green hornfels. The more indurated and heavier beds occur next to the mountains, in the basal part of the section. On the west the rocks rest upon the granite; on the east they pass beneath the Quaternary gravels. The dip in general is easterly, but the structure is that of a broad unsymmetrical syncline with easterly plunge, so that while in the north limb the rocks dip gently south-southeast, in the south limb they dip steeply to the northeast, the angle of dip along the granite being as high as 80°.

In the middle of the western part of the belt the rocks are steeply domed by an intrusive mass of granite porphyry, shown on Plate II (in pocket) and locally known as Granite Mountain. Elsewhere they are also cut by small dikes and sills of a dense white porcelain-like rhyolite. South of the mountain, where the rocks stand nearly on edge and are incised by gulches, many good exposures occur.

In the southern part of the belt, particularly on the east, in the upper part of the section, the series is represented mainly by almost typical brilliant-hued "red beds," which are lithologically similar to beds of determined age farther south. They consist principally of red shale with deep-red to pale-pink sandstone, conglomerate, and grit. The shale is heavy bedded and more or less massive. The rocks dip steeply to the northeast and locally stand about vertical. Along the road just west of Young's ranch they are in unconformable contact with the Paleozoic (Devonian?) limestone and a mile north

[1] Dumble, E. T., Notes on the geology of southeastern Arizona: Am. Inst. Min. Eng. Trans., vol. 31, pp. 706, 710, 1902.

of this point, in Sawmill Canyon, the contact between the two formations is that of a very sharp fault, well shown in the low hills on each side of the stream.

A mile and a half south of this area, at a point 5 miles northwest of Pennsylvania ranch, Adobe Canyon affords the following partial section:

Section of Mesozoic rocks in Adobe Canyon.

	Feet.
Thin interbedded, partly metamorphosed red shales, quartzites, sandstones, and conglomerates	400
White quartzite	40
Interbedded red fossiliferous shales and white sandstones (in beds 2 to 8 feet thick)	200

These beds dip 85° NE. and are unconformably overlain by less indurated Tertiary beds, described later.

In the middle of the eastern part of the area croppings thought to belong to this group of rocks or to the Triassic extend interruptedly along the railroad to and beyond Elgin.

On the south, in the Patagonia district, the series is exposed in the vicinity of Mowry in several small areas aggregating a few square miles. The beds of the largest area rest upon Paleozoic limestones on the northeast and upon granite on the southwest. Here the series contains a fossiliferous thin-bedded arenaceous limestone which is probably several hundred feet thick.

Age and correlation.—The fossiliferous limestone just mentioned is well exposed about half a mile northwest of Mowry, in a low ridge which the trail to the Morning Glory mine crosses just southwest of the county stage road. It dips about 25° NNW. The fossils are abundant, especially near the crest of the ridge, where some beds are composed almost wholly of shells, but most of the forms owing to attrition before burial are not well preserved. In the collections made at this locality, mostly by J. W. Prout, jr., T. W. Stanton identified Ostrea sp., several specimens; fragments of other bivalves, some of which seem to belong to Chamidæ; and a fragment of an ammonite, probably belonging to the genus Acanthoceras.

Mr. Stanton reports that "these forms are sufficient to place the horizon in the Mesozoic, and all the species are apparently identical with unpublished forms known elsewhere in the Comanche series of the Cretaceous."

From this faunal evidence and from the lithologic resemblance of the rocks to those of the Comanche series in the Bisbee district, the rocks here described as Mesozoic are correlated with the Comanche series ("Bisbee group") of the Bisbee quadrangle.[1] Although

[1] Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, Pl. XII, 1904.

no detailed study has been made of the series, it seems very probable that the fossiliferous beds may represent similar beds composing the lower part of the Mural limestone in the Bisbee district. The fossiliferous beds, however, so far as observed, form but a relatively small part of the Mesozoic section as here mapped and shown in the sections, especially on the north, and, taken as a whole, it very probably includes in its little-indurated upper part beds which differentiation in later work may prove to be post-Cretaceous, as appears more fully in the description of the Tertiary rocks.

It is likewise possible that the basal part of the Mesozoic section as herein recognized may contain beds which are pre-Cretaceous, especially because a considerable thickness of lower Mesozoic beds, including some of Triassic age, occurs at the east border of the area, adjacent to the Whetstone Mountains.[1] Some beds also seem to be similar to beds in the Tucson quadrangle, to the north, which C. F. Tolman[2] has "tentatively considered as the equivalent of the Manzano group (Carboniferous) but without fossil evidence," and which may therefore be of pre-Mesozoic age.

CENOZOIC ROCKS.

TERTIARY ROCKS.

Character and occurrence.—The deposits here referred to the Tertiary are of several different kinds and probably differ considerably in age.

Overlying with apparent unconformity the Mesozoic exposure in Adobe Canyon, above described, is the following partial section of Tertiary rocks:

Section of Tertiary rocks in Adobe Canyon.

	Feet.
Coarse conglomerate composed principally of pebbles of volcanic rock and the underlying sediments	200
Red and green argillaceous shales with a few thin layers of sandstone and soft fossiliferous limestone	150
Red grits and sandstone with some thin beds of shale	100
Greenish concretionary shales in fossiliferous calcareous beds or limestone	100?
Beds concealed	50?
Purplish conglomerate composed principally of volcanic pebbles with some of sandstone and shale	50

These rocks, like the underlying Mesozoic beds, with which they were uplifted, dip steeply to the northeast, the angle of dip decreas-

[1] Dumble, E. T., Notes on the geology of southeastern Arizona: Am. Inst. Min. Eng. Trans., vol. 31, p. 706, 1902.
[2] Letter, June 10, 1912.

ing slightly in the upper part of the section, and are unconformably overlain by Quaternary gravels.

Age and correlation.—Among the fossils collected from these beds T. W. Stanton identified the following forms, from which he pronounced the beds as evidently of fresh-water formation and probably of Eocene age:

Unio sp., several specimens.[1]
Unio sp., related to U. rectoides White.
Viviparus sp.
Viviparus sp., related to V. wyomingensis Meek.
Physa sp.
Physa sp., related to P. pleromatis White.

The section here given seems to represent beds in the Tucson quadrangle to the north described by Tolman[2] as "extensive red conglomerates (containing rhyolitic tuffs, andesites, and basalts) and sandstone, which are of late Cretaceous or early Tertiary age and which grade into less indurated beds that postdate the uplift of the Catalina Mountains."

Owing to the small area of the exposure these rocks in Adobe Canyon are not shown on the map. There can be little doubt, however, that between the Mesozoic or older formations and the younger overlying formations they probably have a wide distribution in the area; at some localities they may have been erroneously included in the Mesozoic. Beds which seem to be even younger than the Tertiary of Adobe Canyon apparently underlie the Quaternary gravels at the northern border of the area. These beds were seen from the passing railway train only but appear to extend interruptedly from Vail eastward to and beyond Pantano. They are mostly thin bedded. Some of them are earthy-gray, apparently unconsolidated lake-bed silts and argillaceous material and contrast strongly with the more indurated red sandstones on which they rest in places, and here and there they probably extend southward into the area mapped as Mesozoic.

Deposits which seem to correspond to these younger beds occur also in the southwestern part of the area, along Santa Cruz River and Sonoita Creek and east of Calabasas. They are composed mostly of fairly well rounded material, are thinly and evenly bedded, and have gentle dips. Dumble[3] describes them as lake-basin deposits and refers them to his Baucari division of the Tertiary (which is probably Pliocene) of the Sonora province, Mexico. At one point in the canyon to the east he noted an exposure of 100 feet or more

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[1] One lot containing this species was collected and donated by Mr. and Mrs. Stockton and Messrs. Johnson, Morgan, and Barnett, of Patagonia.

[2] Letter, June 12, 1912.

[3] Dumble, E. T., Notes on the geology of southeastern Arizona: Am. Inst. Min. Eng. Trans., vol. 31, p. 697, 1902.

of even-bedded lake deposits. The beds in general are overlain by brown massive Quaternary gravels or conglomerates and rest unconformably upon the volcanic tuffs described later.

QUATERNARY DEPOSITS.

Detrital deposits.—As shown on the map (Pl. II, in pocket), about half of the area is underlain by a more or less continuous sheet of detrital Quaternary deposits, probably including a representative of the Gila conglomerate of Gilbert.[1] These deposits nearly everywhere occupy the valleys between the mountains, from which their plainlike constructional surface recedes with increasing gentleness of slope. The character of this slope is best seen when viewed at right angles, for at present the deposits in many places are being extensively eroded and dissected into a mass of ridges, mesa-like hills, and hummocks (Pl. VI, *A*), only a part of whose summits still accord in level with the constructional surface. The deposits, especially where consolidated, are locally called "cement rock."

These deposits consist of rock material derived by processes of subaerial erosion from all the formations exposed in the surrounding mountains. They are local in character and become finer away from the mountains. They range from coarse angular blocks in the steeper piedmont portion of the bajada to relatively well rounded gravel, sands, and silts underlying the bolson plain and playa in the middle of the valley. In places they attain a thickness of more than 150 feet. They seem to have been in process of accumulation from the early Quaternary down to the present time. Fossil evidence of lacustrine or fluviatile character has been found elsewhere in the Southwest, as in the beds of the dry lake north of Benson, and the gravels around Greaterville, at the east base of the Santa Rita Mountains, have yielded, according to Blake,[2] fossil remains of a species of Bos of gigantic size which he likens to the *Bos primigenius* of Europe and the more closely related forms of America.

The deposits are mostly unstratified or poorly stratified, but in some localities where they were laid down in alluvial fans or cones by sheet-flood waters flowing from the mountain canyons and gorges into the more open embayments they are fairly well stratified and show cross-bedding. They are for the most part unconsolidated, but locally they are thoroughly indurated, as in the exposure shown in Plate V, *B*, where the material is changed into a hard conglomerate that is firmly cemented by a reddish and brownish ferruginous matrix derived by oxidation from the pyritic content of the rhyolite

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[1] Gilbert, G. K., The geology of portions of New Mexico and Arizona: U. S. Geog. Surveys W. 100th Mer., vol. 3, pt. 5, pp. 540–541, 1875.

[2] Blake, W. P., Remains of a species of Bos in the Quaternary of Arizona: Am. Geologist, vol. 22, pp. 65–72, 1898.

of the adjoining Red Mountain. Here the deposit is fairly well stratified. Elsewhere the cementing matrix is calcareous or siliceous, its composition depending on the source of supply.

Alluvium.—Deposits of fluviatile alluvium consisting of relatively recent stream-laid silts, sands, and gravels have been laid down by the streams along their present channels. They occur in narrow belts, principally along Santa Cruz River and Sonoita Creek, as shown on the map (Pl. II, in pocket), and locally they constitute the most arable land of the area.

IGNEOUS ROCKS.

The igneous rocks of the area comprise two main divisions, the Mesozoic intrusives and the Tertiary volcanic rocks.

MESOZOIC INTRUSIVE ROCKS.

The Paleozoic sedimentary rocks are intruded by igneous masses and dikes of granular rocks which are much older than the Tertiary volcanic rocks described later. These granular rocks are of Mesozoic age, and as they do not intrude the known Cretaceous of the quadrangle they are pre-Cretaceous or at latest very early Cretaceous. They probably belong for the most part to the same general period of intrusion as the batholiths of the Pacific coast.

The most abundant of these intrusive rocks are granite and quartz monzonite, granite porphyry, and aplite. The larger masses or batholiths are accompanied by dikes of similar material and by characteristic complementary lamprophyric dike rocks and intermediate forms, rendering the field of more than ordinary interest petrographically. These intrusive rocks occur in most of the mining districts. Fissure veins are associated with many of them and seem to be related to them in origin.

GRANITE.

The oldest of the intrusive rocks is granite. It intrudes the Paleozoic limestones in several districts, where it has played an important part in the origin of the ore deposits. It is itself in turn intruded by other Mesozoic rocks. As shown on the map it is also the most abundant and widely distributed of these rocks, but the areas represented as granite almost certainly contain some granite which is not intrusive into the Paleozoic strata but is pre-Cambrian, as such rocks are known to be generally present in the desert ranges of the Southwest. Owing to its similarity in composition and appearance this older rock could not be differentiated from the younger granites in this work.

The granite in general is a reddish coarse to medium grained, coarsely porphyritic rock. It is composed principally of orthoclase (or microcline), quartz, and biotite, but it generally contains as essentials also oligoclase and hornblende. Locally a little augite is also present. Apatite, zircon, and magnetite occur sparingly as accessories. The granite, however, varies considerably in character from place to place. In some localities it appears to be a hornblende granite, and in others it apparently stands close to granodiorite. Exceptions to this general description are noted in the discussions of the different districts or camps.

The rock in places is much crushed. The minerals are pressed and bent, and the fractures are seamed with quartz and calcite. The alteration products are chiefly muscovite and kaolin, derived mainly from the feldspar, and chlorite, derived from biotite. Pyrite and hematite are present in some places. Much of the rock is entirely disintegrated and fresh specimens are not available. It weathers rapidly into dull yellowish-brown granite sands, covering rounded topographic forms. The sand is composed mainly of quartz and pink feldspars as much as half an inch in length.

The granite in general lies on or near the axes of the ranges, the sedimentary formations on either side overlapping or adjoining it, in some places apparently in normal depositional contact, or in thrust-fault contact, as at Helvetia, or in vertical-fault contact, as in the Greaterville district, where it is brought sharply up against the Devonian. As shown on the map (Pl. II, in pocket) the granite is widely distributed. It seems to underlie much of the northern part of the area, constituting the uneven floor upon which the other rocks rest unconformably.

It outcrops principally in two belts. One belt, in the Helvetia and Greaterville districts, is about 2½ miles wide and extends from a point north of Helvetia to a point south of Greaterville, a distance of 10 miles. For most of this distance it forms the crest of the range and is in intrusive and fault contact with the principal overlying Carboniferous and other Paleozoic sediments on the east and south.

The other belt is near the middle of the western part of the area in the Old Baldy and Tyndall districts. It has a width of about 3 miles and extends from Stone Cabin Canyon southwestward across the county line nearly to Agua Caliente, a distance of 7 miles. In this belt the granite forms most of the rugged western slope of the range and rises to an elevation of 7,000 feet near the axis. On the south it is in contact principally with the intrusive quartz diorite and quartz monzonite and the faulted Paleozoic sediments. On the east it is overlain by the Tertiary volcanic rocks, with quartz diorite intervening toward the south.

There are also on the north two outlying areas of the granite, containing 5 or 6 square miles each, one in the Empire district and one in the vicinity of the Cuprite mine, in the northern part of the Helvetia district. In both of these areas the granite is in contact principally with the Paleozoic and Mesozoic sediments.

The granite is considerably faulted and is generally cut by two or more sets of joints (Pl. IV) and by a sheeting which is nearly horizontal or only gently inclined. In places fissures were formed and are occupied by Mesozoic and later dikes and by quartz veins, which were affected by still later movement. Along the faults, fissures, and joint planes the granite is much shattered and stained with manganese and iron. In places it is epidotized and here and there it is mineralized. Some of the fissures are marked by gouge and slickensided surfaces.

In the Helvetia-Greaterville belt the granite is cut by two prominent sets of joints and a pronounced sheeting. The joint systems trend about north-northwest and east. The sheeting is nearly horizontal. On the Helvetia side it inclines gently to the west, about parallel with the thrust fault described. On the Greaterville side it slopes gently to the east, indicating probable postsheeting axial elevation. There are also numerous minor displacements or faults of which one system strikes approximately east, parallel with the jointing. Some of these fault fissures are filled with quartz and some are occupied by rhyolite dikes, while others have but little to show their location. The fault contact between the granite and the steeply upturned Cambrian (?) quartzites and other sediments on the east and its sharp vertical contact with the Devonian on the south indicate that the vertical displacement of the granite belt as a whole is probably considerable.

In the rugged Stone Cabin Canyon belt, where movement has been more extensive and varied, the structure is less regular and is locally complicated, but it is roughly expressed by a dominant joint system dipping to the north-northwest at angles of 45° or greater and by a close sheeting dipping to the south-southeast. In places the joint system is paralleled by closely spaced aphanitic dikes with associated quartz veins. There is also a system of slips or faults dipping steeply to the south-southwest.

In the Empire district the dominant sheeting in the granite dips steeply to the west, and the scarp of the monocline is composed largely of uplifted granite.

In the exposures near the Cuprite mine the principal jointing dips steeply to the west and the granite is cut by both siliceous and basic intrusives.

As the granite in some places intrudes the Carboniferous limestone but has nowhere been found to intrude the known Cretaceous or the next older sediments, which are apparently pre-Cretaceous, and as it in turn is invaded by most of the other Mesozoic intrusives, it is regarded as probably pre-Cretaceous. It may in part be pre-Cambrian.

OLDER QUARTZ MONZONITE.

Quartz monzonite of two ages occurs in this area. The older facies is almost as abundant as the granite and is the next younger Mesozoic intrusive rock. (See Pl. II, in pocket.) It occurs in the southern part of the area, mainly in the Patagonia Mountains, and in an outlying mass near Mount Benedict, between Santa Cruz River and Nogales Wash, southeast of Calabasas. In both of these localities the rock is commonly known as "granite."

In the Patagonia Mountains the older quartz monzonite forms a belt 6 miles wide, which crosses the Mexican boundary near the middle of the southern edge of the area and extends north-northwestward from the boundary for a distance of 10 miles through the Patagonia and Palmetto districts. On the east the older quartz monzonite intrudes the Paleozoic limestones at the Washington and Duquesne camps and apparently also at Mowry. Between Duquesne and the Mexican boundary and between Guajolote Flat and the north end of the belt it is in contact principally with younger intrusive granite porphyry, a tongue of younger quartz diorite partly intervening at the north. In the middle portion of the belt it is in contact for several miles on the east with the Mesozoic sediments, though disconnected patches of Tertiary rhyolite occur here and there between the two formations. On the west for about 5 miles along the middle part of the belt it is in contact with the intrusive granite porphyry, and elsewhere it is overlain by Quaternary deposits.

In the Mount Benedict belt the older quartz monzonite is surrounded by Quaternary gravels and wash, and is intruded by granite porphyry, diorite, and lamprophyric dikes, described in the section on the Nogales district (pp. 348–355).

The older quartz monzonite also crops out between the two areas above described by the roadside on Santa Cruz River at or just below the mouth of Yerba Buena Cányon, 5 miles northeast of Nogales. The croppings are worn down to the level of the wash surface but are distributed at intervals in such a manner as to suggest that the older quartz monzonite is probably the bedrock immediately underlying a considerable portion of the wash-covered area in this region.

The older quartz monzonite is in general a black-speckled gray granitoid rock. It is medium to coarse grained and locally porphyritic. It varies but little from camp to camp or place to place. Local descriptions are given in the sections on the Duquesne mines, in the Patagonia district, where it played an important part in connection with the origin of the ore deposits, and the Mount Benedict mines in the Nogales district. At Mowry, where it occurs in the Mowry mine in association with the deposits, it is a dark speckled reddish-gray coarse-grained porphyritic granitoid rock containing prismatic feldspar phenocrysts an inch or more in maximum dimension. Here the rock is considerably altered, but the microscope shows it to be coarse grained, eugranitic, and composed principally of orthoclase and oligoclase-andesine or more calcic feldspar in about equal amount, considerable quartz and hornblende, a small amount of biotite and augite, accessory magnetite and apatite, and secondary pyrite, marcasite, and chalcopyrite. The dark minerals are nearly all altered to heavy dark-green masses of chlorite and metallic iron. The rock is a quartz monzonite approaching granodiorite in composition. The microscopic determination of the rock as quartz monzonite is confirmed by its chemical composition given in column 2 of the subjoined table:

Analyses of quartz monzonite.

	1	2	3
SiO_2	67.17	65.60	65.70
Al_2O_3	....	18.30	15.31
Fe_2O_3	....	3.22	2.54
FeO	....	2.28	1.62
MgO	....	.58	1.62
CaO	2.61	2.86	2.56
Na_2O	3.62	3.02	3.62
K_2O	3.99	3.09	4.62
Loss, etc	....	1.05	1.94
	77.39	100.08	99.53

1. Specimen 169, country rock (younger quartz monzonite) at Carrie Nation mine, in Old Baldy district. Partial analysis by W. F. Hunt, United States Geological Survey. (See p. 64.)
2. Specimen of older quartz monzonite from intrusive mass on 400-foot level in Mowry mine, Patagonia district. Analysis by chemist of Consolidated Mines, Smelter & Transportation Co., kindly contributed by John W. Prout, jr., manager.
3. Specimen from stock near lake northwest of San Miguel Peak, south of Telluride, Colo. Analysis by H. N. Stokes, United States Geological Survey. Cross, Whitman, U. S. Geol. Survey Geol. Atlas, Telluride folio (No. 57), p. 6, 1899.

Comparison of these analyses with published data further corroborates the microscopic determination that the rocks are both quartz monzonite.

In the quantitative system of classification the rock represented by analysis 2 is a toscanose (I.4.2.3). The calculated mode is as follows:

Mode of older quartz monzonite from Patagonia district.

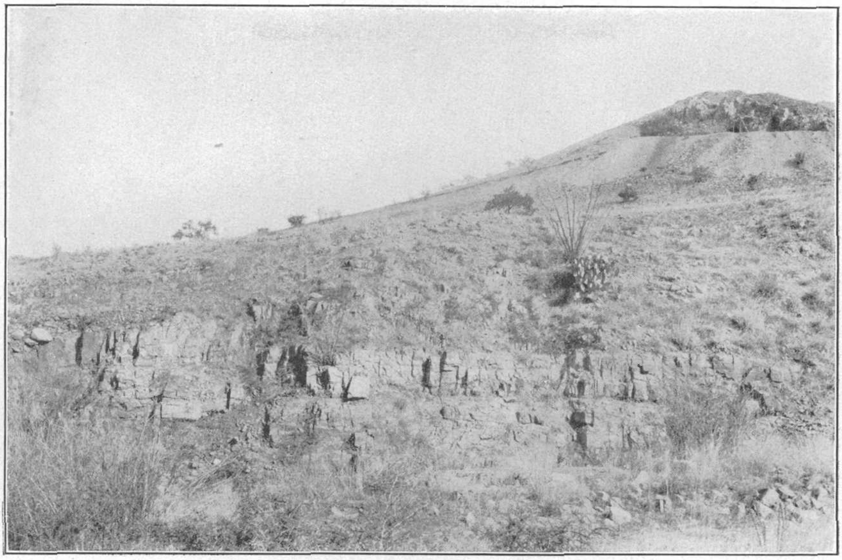
Quartz	26.10
Orthoclase	18.25
Albite	25.15
Anorthite	19.46
Corundum	2.86
Hypersthene	2.98
Magnetite	4.64

With the exception that the rock is slightly low in magnesia, an unimportant constituent, the analysis agrees closely with that of the rock in a large stock near San Miguel Peak, south of Telluride, Colo., described by Cross as quartz monzonite. The analysis of this rock is given in column 3 for comparison.

QUARTZ DIORITE.

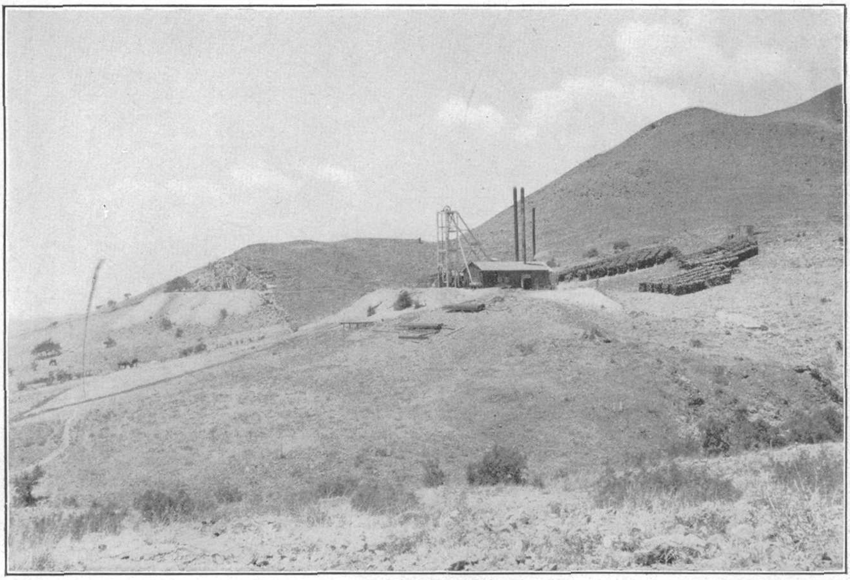
The rock here described as quartz diorite is regarded as next younger than the older quartz monzonite and is next to the granite in abundance and economic importance. It occurs principally in an irregular belt in the middle western part of the area (see Pl. II, in pocket), mainly in the eastern part of the Tyndall district. In a belt about 3 miles wide it extends from Agua Caliente Canyon southward for 20 miles to Sonoita Creek. It is important economically in that it contains nearly all the mineral deposits of the Tyndall and Wrightson districts and the southwestern part of the Old Baldy district. It intrudes the granite, quartz monzonite, and Paleozoic sediments on the north, where it is also cut by a system of mineral-bearing faults trending northwest, and it is intruded by the granite porphyry on the southeast and is very generally overlapped by and more or less interbedded with the Tertiary lavas about the border of the belt. Elsewhere it occurs in smaller batholithic masses, stocks, and dikes, cutting the older rocks, and is widely distributed, being, however, more plentiful in the southern than in the northern part of the area. On the south it forms the prominent hill extending a mile and a half east of Nogales along the international boundary. In the Patagonia district it occurs in several small areas and contains the Golden Rose, O'Mara, and other mines. In the Harshaw district it occupies several square miles in a northwest-southeast belt and contains the Hardshell, World's Fair, and other important mines. In the Palmetto district it occupies a narrow wedgelike area, about 2 miles long, between the quartz monzonite and the granite porphyry and intrudes the quartz monzonite as dikes, sills, and irregular bodies. In the San Cayetano district it occupies a north-south belt about half a mile wide and 4 miles long, which contains some prospects. In the Old Baldy district it occupies a similar belt about a third of a mile wide and 3 miles long, which also contains important prospects. In the northern part of the area it occurs chiefly as dikes, with which mineral prospects are generally associated. In the Helvetia district it is sparingly present in the Helvetia and Tiptop camps.

Much of the rock is close-jointed or sheeted, and in places it is stratiform, with the layers horizontal. This structure, an example of which is shown in Plate VII, *A*, is probably due to flow within the magma. North of the Darwin mine, at Salero, the rock is cut



A. FLOW (?) STRUCTURE BEDDING IN QUARTZ DIORITE AT SALERO, IN GULCH NORTHWEST OF PLAZA.

Croppings of vein and west shaft of Salero mine at the right. Looking northwest.



B. SALERO OR DARWIN MINE AND QUARTZ DIORITE PORPHYRY.

Just north of Salero, at an elevation of 4,150 feet. Looking northwest.

into slices from 3 to 6 inches thick by a sheeting that dips steeply to the south. In Josephine Canyon, below the Tia Juana mine, a prominent sheeting system dips steeply to the south and another a little north of west.

The rock weathers into gray to reddish-brown rounded forms, as shown in Plate VII, *B*, and by reason of its iron content the soil resulting from its disintegration is reddish brown.

Typically, as seen in general throughout the Caliente-Sonoita belt, and as represented by a fresh specimen from the reservoir hill at Nogales, the diorite is a dark iron-gray massive fine to medium-grained granitoid rock, with usually a pinkish or reddish hue. It is composed principally of oligoclase-andesine in small prisms and short prismatic laths. It contains considerable brown biotite in relatively large foils, mostly altered to pale-green chlorite, a nearly equal amount of hornblende, a moderate amount of orthoclase and quartz, nearly all interstitial, a little augite, considerable magnetite, and accessory apatite. Magnetite is undoubtedly a primary constituent, but in the altered forms of the rock much secondary magnetite is also present. The rock in general is low in dark minerals, especially in the forms most nearly approaching a true diorite, which in general are the finer grained. It is commonly rather siliceous. The feldspars are locally more or less muscovitized or altered to sericite and kaolin-like material, and the ferromagnesian minerals to chlorite and epidote. Here and there the rock contains considerable orthoclase, epidote, and some titanite.

From this typical form of the rock, however, wide variations occur. In the more basic forms, which stand near gabbro but which are not common, the plagioclase ranges to labradorite, augite is the principal mafic mineral, and the orthoclase and quartz become relatively inconspicuous or absent. A silver-bearing augite diorite from the south slope of the Santa Rita Mountains, described by Bond,[1] seems to belong to this facies. Bond regards not only the magnetite but also the native silver as primary and states:

> Native silver in hypidiomorphic crystals varying from 0.05 to 0.2 millimeter in size, included in all cases in magnetite, are of constant occurrence through the rock; their sharp crystalline faces and angles lead to the supposition that they are an original constituent; a few partially corroded forms and irregular grains are seen.

In the Tiptop camp, about a quarter of a mile north of Bulldozer Hill, the granite is cut by a fine-grained dike rock in which hornblende and biotite are plentiful, and here the rock approaches a true diorite.

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[1] Bond, Josiah, A silver-bearing diorite in southern Arizona: Eng. and Min. Jour., vol. 39, p. 1268, 1910.

In some localities the rock contains much tourmaline and magnetite, as at the McCleary mines, in the Old Baldy district. More commonly, however, the variations lie on the siliceous side of the type form, to the extent that the rock becomes a more or less typical quartz monzonite (see below), being composed of oligoclase or oligoclase-andesine and orthoclase in about equal amount, with a subordinate amount of quartz, biotite, a little hornblende, magnetite, and apatite, and the rock as a whole throughout the area shows a very pronounced leaning toward monzonite.

It is not unlikely that some forms of the rock contained in the belt may be intrusive into other forms, but as no contacts, dikes, or other indications to this effect were observed in this work, the phases ranging from basic diorite standing near gabbro on the one hand to siliceous quartz monzonite on the other are here provisionally regarded as contemporaneous and as variations of the same general magma, and their further separation, if such separation is possible, is left to await more detailed field and petrographic examination.

YOUNGER QUARTZ MONZONITE.

Microscopic examination of specimens collected at points well distributed throughout the diorite belt shows that much of the rock which can not well be differentiated from the diorite in the field is a quartz monzonite of the type above described. However, it differs macroscopically from the quartz monzonite of the Patagonia Mountains in being finer grained and less granitoid, and to differentiate it from that rock it will be referred to as the younger quartz monzonite.

In column 1 of the table on page 61 is given a partial analysis of a specimen of the younger quartz monzonite collected at the Carrie Nation mine, in the southwestern part of the Old Baldy district. Here the rock is medium grained and reddish gray, has a crude or indistinct banded structure, and macroscopically shows considerable biotite. The microscope shows it to be composed principally of oligoclase-andesine and orthoclase in about equal amount, biotite, mostly in large foils, and a subordinate amount of quartz, with a little hornblende and magnetite. A few larger crystals or phenocrysts are oligoclase-andesine.

GRANITE PORPHYRY.

Granite porphyry and aplite or their allied forms occur in a very extensive series of variations in this area. They are probably differentiations from the same general granitic magma, and some have undergone alteration by silicification or other processes.

They range from typical granite porphyry and aplite to rocks composed almost wholly of quartz with only very minor amounts of feldspar. They are widely distributed in small stocks and dikes intruded into the pre-Mesozoic and rarely in the Mesozoic sediments; also into the granite, and to a less extent into the quartz monzonite and diorite.

The granite porphyry, which approaches the granite in plutonic habit, is a light-colored coarsely porphyritic granitoid rock composed chiefly of phenocrysts of feldspar, mainly orthoclase, quartz, and locally biotite or muscovite, embedded in a finer granitic or microcrystalline groundmass likewise composed mostly of orthoclase and quartz. Apatite, zircon, and titanite occur as accessories. The rock is locally pegmatitic and has an agglomerate-like structure, and some specimens are graphic.

Though not abundant the rock is widely distributed and occurs in nearly all the districts. It comprises many types and is generally associated with ore deposits. One of the most prominent exposures of the rock occurs 2 miles east of Helvetia. Here a stock forms a prominent butte in the crest of the Santa Rita Range, occupying a circular area with a diameter of one-third of a mile. The rock is much sheared and altered and contains numerous prospects showing deposits of malachite, azurite, and limonite, apparently occupying shear zones. Underground it is probably connected with the larger deposits in the mines on the west.

In the northern part of the Helvetia area of limestone, north and northeast of the town, there is a coarsely porphyritic, very siliceous facies of this rock which weathers yellowish-red and usually has a slightly glassy surface and is pitted. This rock is composed largely of quartz, but it contains some phenocrysts of orthoclase feldspar and a very few of dark minerals, and is accordingly designated alaskite porphyry. In the Greaterville district it intrudes the Paleozoic and Mesozoic sediments in the form of a small stock and forms Granite Mountain, a conspicuous knob about half a mile in diameter and 500 feet high. Here the rock contains disseminated pyrite and chalcopyrite.

In the western part of the Harshaw district and adjoining portions of the Palmetto district the granite porphyry occupies about 9 square miles in a northwest-southeast belt and contains the principal mineral deposits in this part of the area, including those of the Three R, Thunderer, Standard, Sunnyside, and other mines. On the west it intrudes the granite and the diorite, and on the east it is overlain by rhyolite. The rock contains widely disseminated pyrite and chalcopyrite, mostly in silicified shear zones or allied bands, some of which are 200 feet or more in width. In this area the rock is speckled gray and coarsely porphyritic. The phenocrysts greatly preponderate in volume over the microcrystalline groundmass and the feldspars, some of which are nearly half an inch in diameter, considerably exceed those of quartz in size and number. The feldspars are of a dull whitish color and in general highly altered to muscovite, but in some of the rock, as at the Three R mine, in the Palmetto district, they are almost completely replaced by a secondary pink uniaxial positive mineral which was determined to be alunite. (See p. 361.) Considerable apatite and some zircon are present as accessories. Pyrite and chalcopyrite are disseminated through the rock and are locally inclosed in both the feldspar and the quartz. Some of the pyrite crystals are coated with dark bluish secondary chalcocite and covellite. The rock is less siliceous than the granite porphyry of the Helvetia district. It is greatly crushed and formerly was probably a pegmatite.

APLITE AND APLITIC ROCKS.

The granite and granitoid rocks and the surrounding Paleozoic sediments in various parts of the area are cut by many dikes and some small stocklike masses of flesh-colored or reddish fine to medium granular rocks composed almost wholly of orthoclase and quartz, a little sodic plagioclase, and a negligible amount of muscovite, biotite, or other mafic minerals, with zircon and apatite usually present as accessories. The alkali feldspar in some of these rocks is represented in part by microcline or microperthite or both, as at the Ridley mine, southwest of Helvetia, and in a few places, as in the upper part of Box Canyon, it consists chiefly of microperthite. The plagioclase is mostly oligoclase but ranges from albite-oligoclase, seen in a typical form in the rock from Madera Canyon, to oligoclase-andesine, at the Pride of the West mine, and andesine, near Calabasas and at the Old Frijole mine. In places the rocks are slightly porphyritic and contain glassy-faced phenocrysts of the feldspar.

From the rather typical aplite thus described these rocks, according to their mineral composition, range on the one hand through granitic aplite to aplitic granite or even to granite, and on the other through alaskite aplite, alaskite, and alaskite porphyry to almost pure quartz, so that many of the dikes are very difficult to distinguish from quartz veins or quartzite, the determinative feature being as a rule a few small widely scattered feldspars embedded in the quartz and scarcely noticeable to the untrained eye. Some of the rocks seem to correspond closely with the alaskite and alaskite porphyry, in the Silver Bell district, described by Tolman[1] and Stewart.[2]

[1] Tolman, C. F., jr., Copper deposits of Silver Bell, Arizona: Min. and Sci. Press, vol. 99, pp. 710–712, 1909.

[2] Stewart, C. A., The geology and ore deposits of the Silver Bell mining district, Arizona: Am. Inst. Min. Eng. Bull. 65, New York meeting, pp. 455–505, Feb., 1912.

Alaskite, according to definition, is a granular hypidiomorphic or allotriomorphic rock and consists essentially of quartz and alkali feldspars, generally containing very little zircon, mica, and plagioclase. Alaskite aplite is mineralogically similar to alaskite but is panidiomorphic in texture and generally fine grained. As shown on the map (Pl. II, in pocket) alaskite aplite occurs at various points in the northern part of the area, principally at Helvetia and near the Cuprite mine. In or associated with the alaskite aplite in the Helvetia camp are dikes of extremely siliceous rock which cut the granite and limestone at numerous places and most of which seem to be connected with ore deposits. The largest dike trends northward through the Copper World shaft; similar dikes occur on Monument Hill and in the Omega mine. The croppings of these dikes are very similar and resemble iron-stained quartz veins. Microscopic thin sections from the dikes show the rock to consist in some places, as in the south wall of the upper tunnel of the Omega mine, of more than 90 per cent of quartz in which are embedded a few widely scattered idiomorphic kaolinized and sericitized crystals of orthoclase. The general and intimate association of the muscovite marginally with the orthoclase apparently indicates that much of the muscovite may be secondary, derived from the orthoclase. A magmatic origin of the rock and its deposition as a dike, as opposed to an origin from aqueous solutions and its deposition as a vein, are indicated by the granular texture of the quartz, the interlocking arrangement of its grains, and the general absence of any resemblance to vein quartz.

In the western part of the Old Baldy district dikes of fine granular, nearly typical aplite intrude the granite parallel with the jointing. They are in places closely spaced. Along some of them are quartz veins, and as a rule the granite next to them is altered and silicified and locally it is mineralized. Near the middle of the western part of the area, in the Tyndall district, the granite is intruded by an aplitic mass and in a zone about 300 feet in width along the contact is much iron stained and contains widely disseminated pyrite, kaolin, and chalcopyrite, and locally silicified lenses with more concentrated mineralization.

Except in the very siliceous forms of these aplitic dikes the plagioclase, though in small amount, tends to be characteristically present, as in nearly all the other igneous rocks of the area, and its persistence is regarded as an expression in these rocks of the monzonitic character of this petrographic province in general. These rocks as a group, as may be seen even by a close megascopic comparison, are obviously related mineralogically to the quartz monzonites already described, though not so closely as to the granites.

LAMPROPHYRIC DIKE ROCKS.

Narrow dikes of a basic character and peculiar structure accompany some of the intrusive masses as ferromagnesian complementary rocks and are usually associated with ore deposits. They were noted at the Blue Jay mine, in the Helvetia district; at the Old Baldy property, in the Old Baldy district; just south of the Madera-Caliente pass leading to the Treasure Vault mine; in the Tyndall district; at the Allen mine, in Cottonwood Canyon; in Squaw Gulch, 4 miles west-northwest of Patagonia; and south of Calabasas, in the Nogales district.

At the Old Baldy property in Madera Canyon the rock is an iron-gray porphyry. It is distinctly lamprophyric and consists principally of a microcrystalline to cryptocrystalline groundmass of orthoclase, biotite, and albite-oligoclase, with some magnetite, in which are embedded abundant phenocrysts of orthoclase.

South of Calabasas, in the area containing deposits of tungsten described on page 355, the granite is cut by narrow dikes of a purplish-green, dark iron-gray, or nearly black fine-grained rock showing in some specimens macroscopic needles or slender laths of hornblende. This rock in thin section is seen to be holocrystalline and to consist principally of sodic plagioclase, mostly oligoclase-andesine, and hornblende, mostly in long, slender laths and rodlike forms, all having a crudely trachytic or parallel flowlike structure. Orthoclase and magnetite are present in moderate amount, and much chlorite, calcite, and some epidote occur as secondary minerals. This rock stands close to the spessartite of Rosenbusch. Some of it contains considerable orthoclase and epidote.

SYENITIC ROCKS.

At several places in the area, chiefly in the southern part, there are dikes of syenitic character, or intermediate between the siliceous and basic rocks already described. In the Harshaw district in Alum Canyon, at the Invincible tunnel and other points, occurs a purplish-gray medium-grained rock which corresponds to syenite and is probably intrusive into the older rocks. It is composed principally of orthoclase in hypidiomorphic development, biotite in small foils, and other micas and contains a very little quartz and accessory zircon, apatite, and iron.

Farther north, in the southern part of the Wrightson district, west of Temporal Gulch in the ridge a quarter of a mile northeast of the Castle Butte mine, occurs a reddish-brown coarsely porphyritic rock containing some feldspar phenocrysts nearly half an inch in maximum diameter. This rock is composed principally of phenocrysts of orthoclase-microcline with some of albite, biotite, hornblende, and quartz, of various sizes, embedded in a fine granular groundmass of feldspar, quartz, and biotite about equal to the phenocrysts in aggregate volume. Magnetite and apatite are present as accessories and chlorite, epidote, and hematite as secondary alteration products. The rock is a quartz syenite porphyry. A finer-grained phase of the same rock occurs in the hill southeast of this locality, half a mile east of the Castle Butte mine. Here the groundmass is greater in volume than the phenocrysts, which are of medium and about equal size.

GABBRO.

In some places the older rocks are intruded by a dark iron-gray basaltic or diabasic and submetallic-looking rock which ranges from fine to medium or rarely coarse grained and weathers reddish brown and dark red. At Mowry, in the Patagonia district, it intrudes the quartz monzonite and the adjoining Paleozoic limestones. It outcrops plainly in the northwestern part of the camp, where it trends northward, crossing the main road between the Phelps place and the post office, and it occurs in the Mowry mine, where from its calcareous nature it is known as the 500-foot "lime dike."

In thin section the rock, though highly altered, is seen to be holocrystalline and medium grained and to be composed principally of andesine or more calcic plagioclase and augite or other pyroxene with magnetite, apatite, and perhaps olivine. It now contains much secondary hornblende, chlorite, calcite, sericite, kaolin-like material, and hematite.

Microscopic examination of this rock shows it to be a gabbro, and this determination is corroborated by the accompanying analysis of a specimen (No. 378) of the rock collected from the Mowry mine, made by the chemist of the Consolidated Mines, Smelter & Transportation Co., and kindly furnished by Mr. J. W. Prout, jr., manager.

Analysis of gabbro from Mowry mine.

SiO_2	48.00
Al_2O_3	17.40
Fe_2O_3	6.95
FeO	5.00
MgO	1.29
CaO	8.28
Na_2O	4.19
K_2O	3.06
Loss	4.20
	99.02

Except that the analysis is low in magnesia and high in potassium, it corresponds closely with the analysis of a rock from Wilmurst Lake, Hamilton County, N. Y., described by C. H. Smyth[1] as

[1] Smyth, C. H., jr., On gabbros in the southwestern Adirondack region: Am. Jour. Sci., 3d ser., vol. 48, p. 61, 1894.

gabbro. In most respects also it compares well with the analyses of the gabbros at Preston, Conn.,[1] but the rock, to judge from the specimens collected and examined, is too greatly altered to be placed in the quantitative system.

DIABASE.

A black porphyritic rock corresponding closely to olivine diabase occurs in two systems of dikes in the southwestern part of the Redrock district, but as the rock in places cuts the Tertiary andesite as well as the older rocks it is regarded as probably a holocrystalline facies of the Tertiary basalt and is described later under that heading.

TERTIARY IGNEOUS ROCKS.

GENERAL FEATURES.

After the deformation, intrusion, uplift, and erosion of the Paleozoic rocks, the formation of most of the mineral deposits, and the deposition of the Mesozoic sediments great quantities of Tertiary lavas were poured out, as is shown at various places by many superimposed flows of these rocks aggregating sections of considerable thickness, which indicate that at one time they had a much wider extent than now and probably covered much or all of the area. These lavas rest unconformably upon the pre-Tertiary rocks, which are also cut by dikes of similar composition. Most of the present exposures of these rocks occupy a northwest-southeast belt about 12 miles wide and 25 miles long extending diagonally across the middle part of the area, Patagonia being situated near the middle of the southeastern half of the belt and Old Baldy near the middle of the northwestern half. These rocks, named in probable chronologic order, consist of rhyolite, quartz latite porphyry, older andesite, tuffs and agglomerates, younger andesite, and basalt.

Though these rocks are considerably younger than the principal mineral deposits of the quadrangle and are therefore seemingly of little economic importance, nevertheless they are associated with some deposits that seem to be promising, as at the Helena camp, in the Helvetia district; the Aztec properties and the Hardshell mine, in the Harshaw district; and the Gringo, in the Wrightson district.

RHYOLITE (MIOCENE?).

The Tertiary period of igneous activity was ushered in with great outpourings of rhyolite, whose original extent can no longer be determined. The rhyolite is in general a light-gray siliceous rock

[1] Loughlin, G. F., The gabbros and associated rocks at Preston, Conn.: U. S. Geol. Survey Bull. 492, p. 114, 1912.

having about the same chemical composition as granite. It is usually stained reddish brown by iron oxide. It is composed principally of a dense glassy pale-brownish groundmass, in which are embedded numerous phenocrysts of orthoclase, quartz, a little sodic plagioclase, and small amounts of biotite, augite, and hornblende. The rock is mostly disposed in a series of conformable superimposed flows with a few intercalated beds of coarser volcanic ejecta, ash, tuff, and agglomerates, and on the southwest these ejecta occupy two areas of considerable size.

The rhyolite, as indicated on the map, is widely distributed and occurs in six main areas containing from 3 to 25 or 30 square miles. In the Old Baldy area, a north-south belt about 2 miles wide and 9 miles long, in which Old Baldy is situated south of the center, the rhyolite has a known thickness of 2,100 feet between an elevation of 7,700 feet and the top of Old Baldy at 9,432 feet. Elsewhere it descends to lower elevations. The flows dip about 30° E., and on the west, from the vicinity of Old Baldy to the north, down Madera Canyon, they are sharply delimited by the Old Baldy fault, of whose scarp the edges of the tilted beds form the upper part. The fault approximately follows the north-south contact between the rhyolite on the east and the older granite and diorite on the west. On the west the rhyolite rests principally upon quartz monzonite and granite; on the north it lies upon the Paleozoic limestone; on the east it passes beneath the andesite.

In the irregular area south of Patagonia, Red Mountain, occupying about 7 square miles, is composed of coarsely porphyritic tridymite-bearing rhyolite profusely impregnated with crystals and grains of pyrite, chalcopyrite, and chalcocite. The oxidation of the iron content of these minerals colors the entire mountain a brilliant red. At a number of places in this area, as described later, there are promising copper prospects. Where the rhyolite is scored by Alum Canyon on the southwest, the weathered surfaces of the rock and the neighboring alluvial gravels are coated with efflorescences and incrustations of alum, whose sulphate constituents seem to be derived from the oxidation of the pyritic content of the rock.

At the Helena mine, in the Helvetia district, a reddish-brown medium to fine grained rhyolite is intruded into the Mesozoic(?) shale and sandstone and is connected with the ore deposits.

From the fact that rhyolite intrudes the Mesozoic(?) sediments and from the known age of similar rocks in the Southwest, the rhyolite is regarded as probably of late Miocene age. In the San Cayetano district the rhyolite is intruded by dikes of a gray rock which corresponds to quartz monzonite porphyry and with which the ore deposits are associated.

QUARTZ LATITE PORPHYRY.

In the middle of the western part of the area, in the Tyndall district, occurs an intermediate form of the Tertiary igneous rocks that may represent an effusive facies of the more plutonic quartz monzonite which underlies it and to which it corresponds closely in composition. It is here mapped as quartz latite porphyry. It occurs principally in an irregular belt about 1½ miles in width extending from a point a little west of Salero northward to Josephine Canyon, 5 miles distant. The topography of this belt is rough, as shown in Plate I (in pocket). The rock is mostly of a dull pale-reddish or greenish-gray color and is porphyritic, with medium to thick crystals of orthoclase and oligoclase-andesine and smaller dark crystals of hornblende, biotite, augite, and a little quartz, all embedded in a felsitic or cryptocrystalline groundmass which may be holocrystalline. In places the rock resembles a dacite or quartz-bearing andesite, but orthoclase is always present.

On the east the quartz latite porphyry rests upon the quartz monzonite, which it also locally intrudes, and on the northwest it extends unconformably beneath the andesite. It also seemingly intrudes and contains bowlder-like inclusions of granite porphyry, a considerable amount of which occurs in the mines. The rock is probably intermediate between the rhyolite and andesite in age, but as its relations to the rhyolite are not known it may be older.

OLDER ANDESITE.

At several places in the area, mostly in the central or southern part, as at the Gringo mine and the Anaconda group, in the Wrightson district, occurs a medium-grained gray, generally porphyritic andesite which weathers brown, is generally much altered, and contains considerable calcite. It is locally epidotized and propylitically altered, as at the Gringo mine, or sericitized, as at the Sonoita prospect west of Patagonia. At the Gringo mine it is composed principally of long and short laths of oligoclase-andesine, hornblende, and biotite, resting in a glassy isotropic base in parallel fluidal structure, with a few larger feldspar phenocrysts, some nearly 0.2 inch long, considerable magnetite, and a little augite and calcite.

Owing to the occurrence of this rock in small areas only and the lack of exposures showing its relation to other formations, it is not differentiated on the geologic map. From its resemblance to andesites containing similar mineral deposits widely distributed in the Southwest, the andesite is regarded as probably lower or middle Miocene.[1] On the west fork of Squaw Gulch, a quarter of a mile

[1] Ball, S. H., A geological reconnaissance in southwestern Nevada and eastern California: U. S. Geol. Survey Bull. 308, p. 49, Pl. I, 1907. Schrader, F. C., The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: U. S. Geol. Survey Bull. 340, pp. 53–83, 1907.

above the mouth, it is cut by rhyolite dikes, suggesting that it may be older than the rhyolite.

TUFFS AND AGGLOMERATES.

In the southwestern part of the area occur a class of Tertiary deposits very different from those of Adobe Canyon, on the east (p. 54). They consist essentially of explosive volcanic products, tuffs and agglomerates, but they seem to be largely water-laid and to contain some interbedded conglomerate or coarse sandstone, and Dumble[1] reports also beds of limestone. They seem to have been deposited in low places or lake basins, and according to Dumble[2] they represent and are continuous with his Nogales division of the Tertiary in the Sonoran province of Mexico on the south.

These rocks occupy two principal areas, as shown on the map, one of several square miles at Nogales and in the immediate vicinity, extending to the north, and a somewhat larger area 14 miles north of Nogales, on the east slope of the San Cayetano mountains and the adjoining part of the Tyndall district, on the east. An additional exposure not differentiated on the map occurs near Salero.

The topography of the Nogales area may be likened to that of a gently tilted plateau scored by canyons and arroyos or dry washes to depths of 50 to 150 feet. The tuffs are exposed chiefly in these drainage ways. On the ridges, especially on the west, they are generally covered by Quaternary gravels and other partly consolidated detrital material; on the east, as seen in Proto Canyon, they pass beneath the coarse agglomerates with which the upper members are interbedded; and on the south, near Nogales, they rest unconformably on diorite.

The tuffs occur in beds from 6 inches to 8 feet or more thick, the average thickness being about 2 feet. (See Pl. VI, *B*.) Their general dip is gently to the northwest, but owing to local folding and doming of the beds wide variations in angle and direction of dip occur. A mile and a half east of Nogales the dip is about 70° E. The structure in general suggests the northerly side of a large dome or an anticline with northward-plunging axis. The rocks seem to have a total thickness of several hundred feet. A joint system traversing them dips 60° E.

The tuffs range in color from flesh-pink to cream-yellow. They are mostly medium or fine grained and are composed of heterogeneous material. Some beds consist chiefly of small semirounded pebbles of red and purple rhyolite, granite porphyry, and quartzite. Others, especially the finer beds, are conglomeratic at the base only. From

[1] Dumble, E. T., Notes on the geology of Sonora, Mexico: Am. Inst. Min. Eng. Trans., vol. 29, p. 129, 1899.

[2] Dumble, E. T., Am. Inst. Min. Eng. Trans., vol. 31, p. 698, 1901.

their general character the tuffs seem to be mainly rhyolitic, though they are known to contain considerable andesitic material and a specimen of a fine-grained variety examined under the microscope is composed chiefly of angular fragments of indeterminable plagioclase with but little orthoclase, a few particles of quartz, and some dark mineral, biotite or hornblende, embedded in a glassy groundmass. Some of the fine-grained porous beds containing few or no pebbles make a fairly handsome building stone and are quarried for this purpose. At Salero the rock varies from light gray or whitish to cream-pink and reddish.

The agglomerate conformably overlying the tuffs on the east, extending through the lower 1½ miles of Proto Canyon and along Santa Cruz River between the mouth of the canyon and Yerington, is a heterogeneous varicolored mixture of angular blocks and subangular bowlders, pebbles, cobbles, and finer material, ranging from bowlders several feet in diameter down to grit or coarse sand, consisting of granite porphyry, granite, diorite, and andesitic and rhyolitic materials, all well cemented and disposed in crude heavy beds or tabular sheets dipping about 40° E. and in the upper part of Proto Canyon resting unconformably on granite. According to Dumble essentially the same or similar rocks occur on the Santa Cruz 6 miles to the northwest, near Calabasas.

In the San Cayetano area the tuffs are more distinctly rhyolitic. The beds have a dished dip as if they had been deposited in a lake basin. On the west they rest unconformably on the foothill rhyolites of the San Cayetano Mountains; on the east they are capped by a blackish scoriaceous, vitreous porphyritic andesite.

The Salero exposure, not differentiated on the map, occurs about a mile southwest of Salero, on the north slope of Mount Allen. It lies mainly between the 4,500 and 5,000-foot contours, is about 500 feet thick, and consists principally of medium to fine grained rhyolite tuff. On the east the tuff with gentle dip rests on diorite, and on the west it is capped by several hundred feet of reddish-brown columnar porphyritic andesite forming the cap and peaks of Mount Allen and the adjoining hills. The beds are thin to medium in the lower part of the section and seem to be water-laid, but become heavy and massive in the middle part and continue so to the top. At one place toward the west the beds dip 80° SW., indicating that considerable disturbance has taken place since their deposition. Much of the rock is finer grained and of a purer grade than any seen about Nogales. The microscope shows a specimen of it to consist principally of pale-brownish or clouded volcanic glass with some spherulitic or other glassy structure, but little cryptocrystalline material and a few small incomplete crystals of orthoclase or sanidine, quartz, and oligoclase.

Though data fixing definitely the age of the tuffs are not available, from their stratigraphic relations to the rhyolite, andesite, and Pliocene (?) lake beds they seem to be intermediate between the rhyolite and andesite and are here provisionally referred to the late Miocene.

YOUNGER ANDESITE.

After a period of disturbance, uplift, and erosion that followed the eruption of the rhyolite and probably that of the quartz latite porphyry, extensive outpourings of andesite took place. The andesite of this period is a dark-gray to reddish-brown rock with a brownish felsitic to glassy groundmass and is usually porphyritic, with medium-sized phenocrysts of oligoclase-andesine to andesine-labradorite and smaller forms of hornblende, biotite, augite, and hypersthene in parallel fluxion structural arrangement. It occurs in typical form capping Mount Allen, southwest of Salero, where it is an augite-hypersthene andesite with phenocrysts of andesine-labradorite feldspar.

The rock in general is widely distributed, especially in the south-central part of the area, where it occurs mainly in three irregular belts. One belt in the western foothills of the Santa Rita Range has an average width of about 3 miles and extends from Sonoita Creek east of Calabasas interruptedly 11 miles northward to Montosa. The second belt, principally occupying the eastern foothills of the Santa Rita Range and having an average width of about 2½ miles, extends from Sonoita Creek below Patagonia 16 miles northward across the county line to the head of Sawmill Canyon and contains most of the mineral deposits in the Wrightson district.

The third belt or triangular area, covering about 20 square miles, lies between the Patagonia Mountains on the southwest and the crest of the Canelo Hills on the northeast, and extends from Harshaw 13 miles northward to Old Fort Crittenden.

The topography in these belts, owing to erosion of the andesite, is generally rough. (See Pls. I and II, in pocket.) The andesite usually occurs in heavy flows with which, as with the rhyolite, are intercalated beds of tuffaceous material. In some places, as at the summit of Mount Allen, it exhibits columnar structure similar to that commonly found in basalt.

The rock in general rests unconformably upon the rhyolite and the older rocks, and in places these rocks are intruded by andesite, mostly in dikes. From its character and relations to the rhyolite, which are similar to those of other postrhyolite rocks of known age in the Southwest, the andesite is regarded as of late Miocene age.

BASALT.

The eruption and partial erosion of the younger andesite were followed by outpourings and intrusions of basalt, which, however, were local in character. In the Redrock district the valley of Redrock Canyon is largely underlain by andesite flows which overlap the Paleozoic sediments of the Canelo hills on the east and the younger rhyolite on the west. In places 2½ to 3 miles east-northeast of Patagonia the andesite is cut by numerous dikes of a dark-greenish, iron-gray, or blackish, locally porphyritic fine-grained rock which corresponds very closely to normal olivine basalt. The dikes occur mainly in an east-west system, but some trend north and south. In thin sections the rock is seen to be holocrystalline and composed mainly of andesine-labradorite, augite, and olivine, with accessory magnetite and apatite and secondary hematite, chlorite, calcite, and epidote. One section contains also a little quartz. The structure is ophitic and in places trachytic and porphyritic, with phenocrysts mostly of feldspar. The rock in all respects corresponds to a diabase, but as it cuts the younger andesite it is regarded as probably a holocrystalline facies of basalt.

Basalt occurs also in the southern part of the Helvetia district, at the head of Box Canyon, in an area about a quarter of a mile long a mile north of Young's ranch.

UNDIFFERENTIATED IGNEOUS ROCKS.

At the south end of the Santa Rita Mountains and the Tyndall district, lying mostly to the north of Sonoita Creek, as shown on Plate II, is an irregular barren area of about 10 square miles, composed of igneous rocks not differentiated in this work. These rocks, however, are known to belong for the most part to the surrounding Tertiary younger andesite and rhyolite, and the area probably includes also some diorite.

QUATERNARY BASALT.

That eruptions have also occurred in post-Tertiary time is shown in the southwestern part of the area about 3 miles east of Nogales and half a mile north of the Mexican boundary (Pl. II, in pocket). Here a north-south belt about half a mile long and a fifth of a mile wide is occupied by dark iron-gray or blackish basalt, which is interbedded with and in part overlies the Quaternary gravels, well toward the top of the formation.

SUMMARY OF GEOLOGIC HISTORY.

The geologic history of the principal events recorded in the area begins with the deposition of the Cambrian (?) sandstones, shales, and conglomerates unconformably upon a sea floor of eroded granite, probably of Archean age. Then followed a very long period of marine conditions, during which the later Paleozoic limestones were deposited conformably upon the Cambrian (?) beds. At some time after the deposition of the Paleozoic rocks the region was uplifted and the mountain ranges were in part formed, the process being attended by faulting and the invasion of the rocks by granite and other Mesozoic intrusives. Most of the mineral deposits are associated with these intrusive rocks.

Later, after the Mesozoic erosion, marine conditions again prevailed throughout at least a greater part of the area, and upon the eroded and submerged surface of the Paleozoic and older rocks was deposited a great thickness of Mesozoic shales, sandstones, limestones, and conglomerates regarded as of Lower Cretaceous (Comanche) age.

At or near the close of the deposition of the Mesozoic beds came a period of uplift and erosion, with the beginning of volcanism, which in turn was followed by a period of fresh-water lacustrine conditions, during which the early Tertiary conglomerates, shales, and sandstones, as shown in the Adobe Canyon section, were deposited unconformably upon the eroded Mesozoic beds. After this, in the lower portions of the area, the deposition of similar sediments continued to approximately the close of the Tertiary, being accompanied or interrupted in places by great outpourings and some intrusions of rhyolite, quartz latite, andesite, and basalt. This period of volcanism alone records several interesting events:

1. Extensive eruption of the rhyolites, followed by great faulting and uplift, as shown by the Old Baldy fault, whose nearly vertical scarp exposes a section of the lavas more than 2,100 feet thick in which the flows are tilted to angles of 30°.
2. Subaerial erosion and deposition.
3. Extensive formation of tuffs and agglomerates on the southwest, resting unconformably on the eroded rhyolites and other rocks, and perhaps contemporaneous eruption of the quartz latite.
4. Extensive eruption of the andesite and its deposition unconformably on the eroded rhyolite and other rocks, followed by faulting, formation of the Tertiary veins and deposition of gold in them, and erosion.
5. Eruption of the basalt.

From early Quaternary time to the present there have prevailed extensive subaerial erosion and deposition of detrital material unconformably upon the older formations, giving rise to the constructional bajada and bolson plain, features which, though still in process of upbuilding by the addition of new material near the higher mountains, are elsewhere in general deeply incised, and in many places are already reduced by erosion to destructional forms, as shown in Plate VI, *A*. During the later part of this period of erosion the more recent alluvial silts and gravels have been deposited along the present streams.

The general accordance of the geology and of the broader structural features, such as the Greaterville fault, and consequently to a certain extent also of the mineral deposits, with the northwest-southeast trend of the topographic features was suggested in the discussion of topography. An example of this accordance is indicated on Plate II (in pocket) by the alignment of the limestone belts of the Canèlo Hills and of Washington and Mowry on the southeast with those of Greaterville and of Montosa Basin, respectively, on the northwest. The same is also largely true of the andesite, rhyolite, granite porphyry, and quartz monzonite belts, including the Mount Benedict outlier of the monzonite on the southwest.

MINERAL DEPOSITS.

GENERAL CHARACTER AND AGE.

The metallic deposits of the area here described are principally fissure veins and replacement or contact-metamorphic deposits containing gold, silver, copper, lead, zinc, tungsten, and molybdenum.

Sulphides generally begin to appear rather near the surface, but the lower limit of the oxidized zone is irregular and ranges from less than 100 to 300 feet below the surface. Water occurs in most of the mines, and the ground-water level in general stands at depths of about 250 feet.

The deposits represent at least two distinct periods of mineralization and occur in two sharply contrasted groups that differ considerably in age. The earlier and more valuable group occurs in association with the Paleozoic sedimentary rocks and the Mesozoic granular intrusives and is of Mesozoic (probably early Cretaceous) age. The later group of deposits occurs in or associated with the Tertiary igneous rocks and is of Tertiary age, probably Miocene.

MESOZOIC (EARLY CRETACEOUS?) DEPOSITS.

GENERAL CHARACTER.

The older deposits occur in or associated with the Paleozoic sedimentary rocks (principally limestones, quartzites, schists, and shale) and the Mesozoic granular intrusives (granite, granite porphyry, aplite, diorite, quartz monzonite, and syenite) and the lamprophyric dikes with which the intrusives are genetically connected. They contain the ore minerals of gold, silver, copper, lead, zinc, tungsten, antimony, and molybdenum and are widely distributed and plentiful throughout most of the area. They are apparently Mesozoic, and in the age classification of metalliferous deposits given by Lindgren[1] for the western part of the continent they seem to belong to the late Mesozoic epoch of metallization. As they nowhere occur in the Cretaceous rocks of the area they are here referred to the early Cretaceous, though in the variety of their mineral content they correspond closely with the deposits that characterize the early Tertiary metallogenetic epoch, except those of Colorado. They were apparently deposited chiefly by ascending thermal solutions that circulated as a close after-effect of the intrusion of Mesozoic magmas. On the west slope of the Santa Rita Mountains, in the east-central part of the Tyndall district, native silver is found in the intrusive diorite, and Bond[2] regards it as primary in that rock.

These older deposits first attracted attention to the mineral wealth of the area and have furnished almost the whole of its production. They embrace nearly all the ore deposits of the area. On the whole they have suffered considerable erosion, and their general nature, together with the profound character of the metamorphism of the intruded sedimentary rocks, which in places extended far from the contact, and the relative coarseness of grain maintained by the granite at or near the contact, leads to the inference that as a whole the deposits were probably formed originally at considerable depth.

The deposits occur in three chief forms—fissure veins, contact-metamorphic deposits, and replacement deposits.

FISSURE VEINS.

The fissure veins are numerous and widely distributed. They are particularly plentiful on the west slope of the Santa Rita Mountains and in the Patagonia Mountains. The veins range from 1 foot to 20 feet or more in width, 6 feet being perhaps an average, and they are commonly separated from the wall rock by a few inches to a foot or more of gouge. They occur in both the igneous and sedimentary rocks. In places they parallel the dominant jointing or fault system, with steep or vertical dips, but more commonly they occupy independent cross or diagonal fissures and in a general way lie approximately parallel with the axis of the range. Many are persistent, some have a length of a mile or more and a known vertical

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[1] Lindgren, Waldemar, Metallogenetic epochs: Canadian Min. Inst. Jour., vol. 12, pp. 106–111, 1909; Econ. Geology, vol. 4, pp. 415, 419, 1909.

[2] Bond, Josiah, A, silver-bearing diorite in southern Arizona: Eng. and Min. Jour., vol. 89, pp. 1268–1269, 1910.

range of nearly 1,000 feet, and some have been opened to a depth of 500 feet.

The gangue or filling of the veins is chiefly quartz, with fluorite and barite or heavy spar. It is locally banded and usually contains, besides the ore minerals, pyrite, arsenopyrite, sphalerite, psilomelane, rhodochrosite, pyrolusite, specularite, hematite, limonite, siderite, and utahite. The ore minerals are chiefly argentite, cerargyrite, native silver, gold, pyromorphite, pyrargyrite, galena, cerusite, anglesite, chalcopyrite, cupriferous pyrite, chalcocite, bornite, malachite, azurite, chrysocolla, octahedrite, molybdenite, wolframite, and scheelite. In the vein deposits, which, to judge from their banding structure, were formed by circulating thermal solutions, concentration, particularly of the silver and lead ores, has taken place in the oxidized zone, and these rich oxidized portions of the deposits supplied most of the production of the early days, especially in silver.

In some places the ore is not restricted to the fissure but extends in irregular bodies laterally several feet into the wall rock, which has locally been metasomatically replaced and silicified by the ore-bearing solutions.

CONTACT-METAMORPHIC DEPOSITS.

The contact-metamorphic deposits occur principally in or near the contact zone of the Mesozoic intrusive rocks. Along this zone contact metamorphism, accompanied by the development of garnet and mineralization, has generally taken place. The width of the metamorphic zone varies from a few feet to 200 feet or more. In this zone the invaded sedimentary rocks are in places highly altered, the normally dark-blue limestone being crystallized and changed to white marble and the shales and sandstones being altered to indurated hornstone and quartzite.

The intrusive rocks which are the most abundant in connection with these deposits are the granite, quartz monzonite, granite porphyry, and aplite. They occur in the form of batholiths, stocks, small irregular masses and dikes. Of the sedimentary rocks the most common are the limestones.

The deposits occur in irregular bodies in a zone from 1 foot to 40 feet or more in width, principally in the Carboniferous limestone, which is well known to be a most favorable rock for the formation of ore deposits of this class. They are usually massive, and the gangue is composed chiefly of garnet, together with iron-bearing pyroxene and molybdenite, calcite, secondary quartz, epidote, pyrite, pyrrhotite, magnetite, and other contact-metamorphic minerals. The amphibole minerals are chiefly tremolite, actinolite, and gedrite. The pyroxenes are diopside, wollastonite, and hedenbergite. The quartz locally replaces chert and earlier contact-metamorphic minerals, such as calcite and actinolite. The garnet, at least in the Washington-Duquesne camp, is andradite, the calcium-iron variety.

These contact-metamorphic deposits are mainly copper-bearing, but they generally carry a little silver and gold and some of them also sphalerite. The chief ore minerals are chalcopyrite and cupriferous pyrite. These sulphides generally appear at or near the surface, but the oxidized zone, which in general extends to depths of 200 to 300 feet, now contains the common carbonates and oxides of copper and iron, silver chloride, and chrysocolla, and at greater depth their sulphides together with galena, molybdenite, and ore minerals of silver, zinc, and some gold. To this class belong most of the productive copper deposits in the Helvetia and Washington-Duquesne camps. The present workable copper deposits are chiefly the result of concentration or enrichment, consisting of malachite, azurite, chalcocite, etc., derived by processes of oxidation from the chalcopyrite and cupriferous pyrite which occur as contact-metamorphic minerals and as accessory constituents in the intrusive granitic rocks.

The contact-metamorphic deposits are extensively worked and have contributed nearly all the production in the Helvetia and Washington-Duquesne camps. Just how much they have produced is not known, as it is difficult to differentiate some of them from adjoining replacement deposits.

The ores occur in general as irregular masses in the limestone at its contact with the intrusive masses or dikes. Where conditions for mineralization were favorable the deposits extend for considerable distances from the contact out into the limestone.

At the Pride of the West mine, in the Duquesne camp, the deposits are on the contact of a quartz monzonite dike intruded into relatively pure crystalline limestone and occupy a zone 30 feet or more in width. The zone consists of an irregular mixture of coarse calcite, garnet, sphalerite, chalcopyrite, pyrite, pyrrhotite, and magnetite. Locally coarse crystalline limestone adjoins the dike and next to the limestone are 2 feet of sphalerite, garnet, quartz, pyrite, and other minerals. Elsewhere in the mine 2 feet of magnetite next to the dike is succeeded by 3 feet of sphalerite, mixed with chalcopyrite, which in turn is followed by chalcopyrite in crystalline limestone, which near by becomes very coarse.

The contact-metamorphic deposits were the first of the deposits to be formed, as they and the Paleozoic sedimentary and Mesozoic intrusive rocks with which they are connected are cut by later veins and associated dikes. They are earlier than the replacement deposits, which generally adjoin them. They were formed in part directly by magmatic influence of the molten batholith or stock in its peripheral contact with the limestone and other sedimentary rocks, and in part by the resulting hydrothermal solutions and pneumatolytic activities that accompanied or followed the intrusion, dissolving out the limestone and replacing it metasomatically or otherwise by depositing the ores and their associated minerals. Some of the minerals, as chalcopyrite, are probably in part at least of pneumatolytic origin.

The limestone largely supplied the calcareous and allied constituents of the garnetiferous pyroxene, wollastonite, and tremolite bearing gangue, while the quartz, the ore minerals, especially the cupriferous pyrite and chalcopyrite, and presumably most of the iron in the andradite, are foreign and apparently were supplied by the intrusive magma and the thermal solutions which accompanied and especially followed the intrusion. That the intrusive rocks and the attending solutions were the principal contributors to the mineral constituents of the contact zone, as well as bearers of the ore minerals, and that the materials were not derived from the surrounding limestone for any great extent beyond the contact-metamorphic zone are indicated by the purity of the bordering limestone and by its wholly unaltered condition at many places very near the contact, as, for example, to the north of the Bonanza mine and at the Kansas and Belmont mines, where the limestones within 50 feet of the metamorphic zone are little changed.

The same is also indicated in various places and ways by the decrease and final vanishing of the contact-metamorphic phenomena with recession from the contact on the sedimentary side. For instance, in the Washington camp about a quarter of a mile north-northwest of the hotel the limestone, which is normally a relatively pure rock with vertical dip, is altered for 60 to 75 feet back from the contact and in general contains scattered garnetiferous and ferruginous material, especially along the fractures, bedding planes, and seams, as follows:

Section of limestone at contact in Washington camp.

	Feet.
Garnetiferous and ferruginous limestone	1
Mineralized brown and greenish silicated limestone, some garnetiferous	3
Covered but presumably similar to foregoing	18
Crystalline limestone, relatively pure, containing isolated bodies, croppings, or cappings of reddish-brown garnetiferous limestone	40

Near or beyond the outer edge of the garnetiferous bodies the limestone is almost white crystalline marble, and with the gradual disappearance of the more altered bodies some of it becomes nearly pure. Similarly by tracing individual beds of relatively pure limestone outward from the contact the decrease in the amount of garnet and foreign metamorphic material soon becomes obvious, and as it seems reasonable to infer that the individual limestone beds did not before they were intruded by the granite differ much in purity along the strike in the short distance of 100 feet, it is concluded that the intrusive rock was a liberal contributor to the mineral constituents of the exomorphic part of the contact-metamorphic zone.

In the Washington-Duquesne region the garnet, which is unusually abundant, as a rule constitutes almost the whole of the gangue. It is dark-brownish green with adamantine luster and is stained bright metallic black with iron. It occurs in finely to coarsely crystalline massive aggregates, some of the largest individual crystals being about 2 inches in diameter. As shown by the accompanying analysis of a sample collected from the Empire mine, which closely corresponds with data published in Dana's "System of mineralogy," it is the lime-iron variety known as andradite or black garnet and is relatively pure, compared with the typical composition of andradite shown in analysis 2. The analysis also agrees closely with that of andradite from Morenci, Ariz.[1] More definitely stated mineralogically the garnet is an aluminous andradite and is found by calculation to consist of an isomorphous mixture of about 85 per cent andradite and 15 per cent grossularite.

Analyses of garnet (andradite).

	1	2
SiO_2	37.16	35.5
Al_2O_3	3.47	
Fe_2O_3	28.11	31.5
CaO	30.23	33
MgO	.51	
FeO	None.	
MnO	Present.	
	99.48	100

1. From the Empire mine, Duquesne, Ariz. W. T. Schaller, analyst.
2. Typical composition of andradite.

If the iron ingredients of the deposits were supposed to be derived from the limestone, a most remarkable system of circulation in the limestone and a long period of time would be required to enable the waters to collect and take into solution or suspension the material before it could be deposited. The source of the iron can possibly, at least in the Washington camp, be assigned to the quartz monzonite, which is rich in biotite and hornblende and contains considerable augite, magnetite, and some pyrite and therefore could supply the iron element, for whose concentration in the deposits the fluid magma, its accompanying hydrothermal solutions, and pneumatolytic gases containing the ingredients were admirably adapted.

[1] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Arizona: U. S. Geol. Survey Prof. Paper 43, p. 134, 1905.

The abundance of quartz in or associated with the deposits and the metamorphic zones is likewise largely accounted for by the siliceous character of the quartz monzonite magma.

REPLACEMENT DEPOSITS.

The replacement deposits are geographically and otherwise associated with the Mesozoic intrusive rocks and with the contact-metamorphic deposits above described, but they differ from the contact-metamorphic deposits mineralogically and are apparently later. Instead of copper, as in the contact deposits, their principal metallic constituents are lead and silver. To this class apparently belong in large part the deposits at the Mowry mine, in the Patagonia district, and the Total Wreck mine, in the Empire district.

At Mowry the deposits occur as irregular replacement bodies in the limestone near a mass of quartz monzonite which is regarded as intrusive into the limestone, though the exposed portion of the contact is apparently a fault. In the deep part of the mine the deposits and the limestone in part overlie a mass of gabbro, which apparently intrudes both the limestone and the quartz monzonite. The replacement ore bodies are apparently separated from the quartz monzonite by a nearly vertical 8-foot fissure vein formed on the contact of this rock with the limestone. From the wall of the vein and the fissure the bulk of the replacement deposits, in the form of large tabular sheets, lenses, or lenticular bodies, extend out for 100 feet or more into the limestone and are succeeded by replacement sills or ore beds which extend several hundred feet farther. These ore beds approximately follow the bedding planes of the limestone and are from 1 to 10 feet in thickness. The lenticular bodies are mostly vertical and are pipe or chimney shaped. They lie about parallel with the fissure and in that direction have a known extent of 600 feet, and they extend from the surface to the bottom of the mine, which is 500 feet deep.

The ore consists mainly of the argentiferous ore minerals, cerusite, coarse galena, and anglesite, all contained in a manganiferous and ferruginous gangue composed principally of psilomelane and massive pyrolusite and hematite. The manganese and iron together are said to form about one-fifth of the ore body in volume. There is little if any quartz, and a remarkable feature is the absence of zinc. The ore is mostly oxidized, especially down to or below the 300-foot level, and scarcely any sulphide other than galena, not even pyrite, was found above this level. Copper and iron sulphides first began to appear on the 400-foot level. Much of the ore is a friable argillaceous mixture of silver-bearing cerusite and anglesite, with calcium carbonate and hematite, psilomelane, and pyrolusite.

The galena is for the most part coarsely crystalline. It occurs in lenses and masses of considerable size embedded in the manganiferous gangue, and that associated mainly with pyrolusite, as in the lower workings, is said to form the richest ore, averaging several thousand ounces in silver to the ton. Much of the ore is mottled white, yellow, and greenish, especially with cerusite, anglesite, and malachite. Associated with it, beginning on the 300-foot level, is also a little wulfenite, and on the 400-foot level vanadinite and arsenopyrite appear.

The production of the mine, which is more than $2,000,000, was apparently derived chiefly from the replacement deposits. The ore in general is said to average about $40 to the ton. Some of the galena ores are very rich, and carry, besides about 68 per cent of lead, from 100 to 4,000 ounces in silver and about a dollar in gold to the ton.

From the nature of the ores, the structure of the ore bodies, and the general absence of the metallic minerals in the surrounding rocks from which they might be segregated, it seems most likely that the ores were deposited by ascending metal-bearing solutions that came up along the Mowry fault. First was deposited the tabular vein occupying the fissure next to the quartz monzonite footwall, seemingly as a true fissure vein, and from it ore deposition by metasomatic replacement or by substitution extended stage by stage northward into the hanging-wall limestone, forming successively the nearly vertical tabular ore shoots or bands, alternating with similar intervening layers of the manganese-iron gangue. The invading solutions found the limestone easier of penetration and solution along the bedding planes, whose dip slope was admirably adapted for facilitating the process and along which were formed the ore beds or sills.

As the gabbro seems to be intrusive into the quartz monzonite and the limestone, the solutions which deposited the ores were probably those that followed its intrusion, a view which seems to find support in the basic nature of the deposits and the paucity or absence of quartz. The solutions were probably thermal and deposited the ores at considerable depth, chiefly as sulphides of lead, manganese, and iron. The ore minerals subsequently became concentrated and oxidized to their present state down to the bottom of the mine.

The replacement deposits at the Total Wreck mine, like those at the Mowry, occur in limestone, but they are on a much smaller scale.

TERTIARY (MIOCENE?) DEPOSITS.

The late Tertiary deposits are not abundant. They occur principally as veins in or associated genetically with the middle Tertiary volcanic rocks, which are widely distributed in the area—particularly in the andesite, as at the Gringo mine, in the Wrightson district, and in the rhyolite, as at the Helena mine, in the Helvetia district. The veins occur in irregular or branching fissures. They seem to belong to the late Tertiary epoch of metallization and are probably of Miocene age. The gangue is in the main crudely banded quartz, with some reddish fluorite and associated calcite. The presence of fluorite and calcite, together with some examples of quartz that is pseudomorphic after calcite or some other spar mineral, suggests that, as in similar formations and Tertiary veins in other regions, the fissures here may originally have been occupied by calcite veins, which the present quartz has replaced. Adularia is probably also present, but it has not been observed. The veins locally contain considerable crushed or brecciated rock, which the invading solutions have for the most part silicified and metasomatically altered.

The valuable metals are copper, lead, silver, and gold, with a few sparingly associated zinc minerals. At the Gringo and Helena mines the deposits are worked only for gold, which they are now producing. It is said that where the veins extend also into the diorite, as in the Ivanhoe and Gringo mines, they are of higher tenor in the diorite than in the andesite.

These Tertiary veins are in general deeply oxidized, though in places they contain a little scattered pyrite. None of them have yet been worked below the lower limits of the oxidized zone.

Like most other Tertiary veins of their class in the West, these Miocene (?) deposits seem to have been formed by ascending thermal solutions that followed the extensive eruption and fissuring of the Tertiary lavas. They were formed much nearer the surface than the early Cretaceous deposits. The solutions which deposited the gold and the quartz apparently also dissolved out the preexisting calcite from the fissures and locally by metasomatic action formed replacement ore bodies in the adjoining wall rock.

Besides the gold veins, there occur at other localities deposits of copper ore which seem to be of approximately the same age, such as the deposits of chalcocite and chalcopyrite that occur in the Tertiary rhyolite at Red Mountain, near Patagonia, where they are being developed. The deposits are probably replacement concentrations derived by processes of oxidation and enrichment from the cupriferous pyrite and chalcopyrite disseminated in the rhyolite, seemingly as primary accessories. Certain beds of the rhyolite seem to be more favorable for accumulation of the ore than others.

PLACERS.

Deposits of placer gold have been worked at several localities in the area, notably at Greaterville, in the Greaterville district; at the southwest base of the Grosvenor Hills, near Salero, in the Tyndall district; in Guebabi Canyon, in the Nogales district; near Mowry, in the Patagonia district; and near Patagonia, on Sonoita Creek above the mouth of Alum Canyon, in the Harshaw district.

The most valuable of these deposits are those near Greaterville, from which more than $7,000,000 has been produced. They occupy an equilateral triangle covering about 8 square miles on the lower east slope of the Santa Rita Mountains and are the largest and richest placers in southern Arizona. They were discovered in 1874 by a prospector named Smith, and were worked extensively from 1875 to 1878, since when the production has been moderate.

The deposits have been estimated, by engineers who have examined them, to contain still from $75,000,000 to $100,000,000 in gold, but owing to the presence of considerable overburden, in some places 30 to 40 feet thick, and to lack of water for hydraulicking, they are difficult to work. Apparently they can be worked with profit only on a considerable scale with a dredge or some form of hydraulic machine. The deposits are irregularly distributed, mostly along the present stream courses on or near bedrock, though they also extend up the slopes and benches 20 or 30 feet above the channel. The pebbles in general are small. The gold is mostly coarse and averages about $17 to the ounce fine.

The source of the placer gold is referred to the numerous gold-bearing quartz veins which occur in the granite in the adjoining upper slope of the Santa Rita Range and to similar veins connected with the stocklike mass of granite porphyry which intrudes the sandstones and forms Granite Mountain, at the western border of the placer area. It is also probable that some of the gold may have been derived from veins contained in the Tertiary igneous rocks which have since been removed by erosion.

MINERALOGY.

The gangue minerals of the early deposits as noted are, in the veins, principally quartz with fluorite, barite, and some calcite, though in some veins magnetite is the chief mineral; in the contact-metamorphic deposits, chiefly garnet, quartz, pyroxene, tremolite, wollastonite, magnetite, and calcite, with many other contact-metamorphic minerals. In the late deposits the gangue is principally quartz with fluorite and some calcite. Oxides of iron and manganese are common in both groups of deposits.

In the early deposits the ore minerals are, in the contact-metamorphic deposits, principally chalcopyrite, chalcocite, malachite, azurite, and chrysocolla; in the veins, argentite, horn silver, galena, cerusite, the copper ore minerals above mentioned, zinc blende, native gold, molybdenite, wolframite, and scheelite. In the late deposits the ore minerals are principally native gold and argentite.

The following list gives the minerals that have been observed in association with the deposits in the area:

Minerals occurring in the Patagonia and Nogales quadrangles, Arizona.

Mineral.	Chemical composition.	Cretaceous.			Tertiary.		Quaternary placer deposits.	Nature of mineral.		Districts.												Remarks.
		Contact-metamorphic deposits.	Replacement deposits.	Veins.	Veins.	Replacement deposits.		Primary.	Secondary.	Empire.	Greaterville.	Harshaw.	Helvetia.	Nogales.	Old Baldy.	Palmetto.	Patagonia.	Redrock.	San Cayetano.	Tyndall.	Wrightson.	
Actinolite	Metasilicate of calcium, magnesium, and iron.	+						+					+				+			+		
Agate	Hydrated silica																			+		In basaltic andesite.
Alum	See Alunite		+						+			+				+	+					From pyritic rhyolite.
Alunite	Hydrous sulphate of aluminum and potassium.			+					+							+						In granite porphyry.
Amphibole	Ferromagnesian calcium silicate	+						+		+	+		+				+			+		
Andradite	Calcium-iron orthosilicate (a variety of garnet).	+						+		?			+?				+			+?		Abundant in Washington and Duquesne camps.
Anglesite	Lead sulphate		+						+								+			+		In lead-silver ores.
Apatite	Calcium phosphate							+							+					+		
Aragonite	Calcium carbonate	+	+						+		+						+					
Argentite	Silver sulphide			+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	
Arsenic (native)		+?							+								+					Double Standard mine.
Arsenopyrite	Sulpharsenide of iron			+								+								+	+	
Augite	Calcium-magnesium-aluminum silicate	+						+					+				+					
Azurite	Basic cupric carbonate	+	+	+					+	+	+	+	+		+	+	+	+	+	+	+	
Barite	Barium sulphate			+				+			+	+	+		+		+	+		+	+	Abundant gangue mineral in some deposits.
Bindheimite	Hydrous antimonate of lead		+	+													+					
Bornite	Copper-iron sulphide (Cu_3FeS_3)			+					+	+		+	+		+	+	+			+	+	
Bromargyrite	Silver bromide																			+	+	
Calamine	Hydrous zinc silicate			+		+			+								+					
Calcite	Calcium carbonate	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Cerargyrite	Silver chloride			+					+		+	+		+		+	+	+		+	+	Abundant in oxidized zone.
Cerusite	Lead carbonate		+						+			+					+			+?		
Chalcanthite	Hydrous copper sulphate	+							+				+				+?					
Chalcedony	Hydrous silica				+			+	+?					+						+		In rhyolite in Grosvenor Hills.
Chalcocite	Copper (cuprous) sulphide	+	+	+					+	+		+	+		+	+	+	+	+	+	+	
Chalcopyrite	Copper-iron sulphide ($CuFeS_2$)	+	+	+				+	+	+	+	+	+	+	+	+	+	+	+	+	+	

Chert	Impure chalcedony	+							+?								+					At eastern edge of area in Whetstone Mountains.
Chlorite	Hydrous silicate of aluminum, iron, and magnesia.	+											+							+		
Chloropal	Hydrated iron silicate	+							+								+			+		
Chrysocolla	Hydrous copper silicate	+		+					+	+		+	+		+	+	+			+	+	
Coal	Oxygenated hydrocarbons																					
Copper (native)				+					+				+			+						
Covellite	Copper (cupric) sulphide	+		+					+			+				+		+			?	Three R, Heavy Weight, and other mines.
Cuprite	Copper (cuprous) oxide			+					+	+		+	+			+	+			+	+	Generally abundant.
Diopside	Magnesium-calcium silicate	+						+		+			+				+			+		
Dolomite	Calcium-magnesium carbonate	+?								+	+	+	+				+		+	+		
Embolite	Silver chlorobromide			+					+	+		+	+		+	+	+			+	+	
Epidote	Basic calcium-iron-aluminum orthosilicate	+		+?					+	+		+	+		+		+				+	
Fluorite	Calcium fluoride	+			+			+?	+				+	+							+	
Galenite	Lead sulphide	+		+				+	+	+	+	+	+		+	+	+	+		+	+	
Garnet	Orthosilicate of calcium, magnesium, iron, aluminum, etc. (of very variable composition).	+		+?				+	+?	+		+	+		+		+			+		
Gedrite	Magnesium-iron silicate	+						+									+					
Gold (native)		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	
Gray copper	See Tetrahedrite.																					
Grossularite	Calcium-aluminum orthosilicate (a variety of garnet).	+?						+?	+?	+			+				+			+?		
Gypsum	Hydrous calcium sulphate								+			+					+			+		
Hedenbergite	Metasilicate of calcium, magnesium, and iron (a variety of pyroxene).	+						+									+					
Hematite	Iron sesquioxide	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	
Hornblende	Magnesium-calcium-iron silicate	+						+		+	+	+					+			+		
Hyalite	Hydrous silica			+					+											+		
Hydrocyanite	Cupric sulphate	+?		+					+	+			+		+		+			+		
Ilmenite	Iron titanate	+							+								+			+?		
Jasper	Impure chalcedony			+				+						+								
Kaolin	Hydrous aluminum silicate	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	
Limonite	Iron hydroxide	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	
Magnetite	Iron oxide (ferric and ferrous)			+	+		+	+							+					+		
Malachite	Basic copper carbonate	+	+	+					+	+		+	+		+	+	+	+	+	+	+	
Marcasite	Iron disulphide			+					+			+					+					
Massicot?	Lead-iron oxide	+?	+						+			+					+					
Melanterite	Hydrous ferrous sulphate					+			+			+										
Minium	Lead oxide	+?	+?						+			+					+					
Molybdenite	Molybdenum sulphide	+		+				+		+			+		+		+					
Molybdite	Molybdenum trioxide			+				+		+			+		+		+					
Muscovite	Potassium mica (white)		+	+	+				+		+				+	+				+		
Onyx (lime onyx)	Chalcedony, banded and varicolored								+		+											
Opal (semiopal)	Hydrous silica				+			+?	+											+		In rhyolite.
Orthoclase	Potassium-aluminum disilicate (a monoclinic feldspar).	+		+									+							+		
Proustite	Silver sulpharsenite			+					+				+				+			+		
Psilomelane	Manganese hydrate, usually with barium (composition doubtful).		+	+?					+								+			+		
Pyrargyrite (reported)	Silver sulphantimonate	+							+?			+	+				?			+		

Minerals occurring in the Patagonia and Nogales quadrangles, Arizona—Continued.

Mineral.	Chemical composition.	Cretaceous. Contact-metamorphic deposits.	Cretaceous. Replacement deposits.	Cretaceous. Veins.	Tertiary. Veins.	Tertiary. Replacement deposits.	Quaternary placer deposits.	Nature of mineral. Primary.	Nature of mineral. Secondary.	Districts. Empire.	Greaterville.	Harshaw.	Helvetia.	Nogales.	Old Baldy.	Palmetto.	Patagonia.	Redrock.	San Cayetano.	Tyndall.	Wrightson.	Remarks.
Pyrite	Iron disulphide	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Pyrolusite	Manganese dioxide		+	+?					+								+					
Pyromorphite	Lead chlorophosphate		+	+				+?	+			+								+		
Pyroxene	Metasilicate, chiefly of iron, calcium, and magnesium.	+						+									+					
Pyrrhotite	Iron sulphide ($Fe_{11}S_{12}$)	+		+?				+					+				+					
Quartz	Silica	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
Rhodochrosite	Manganese carbonate			+					+			+								+		Plentiful as gangue mineral.
Scheelite	Calcium tungstate			+				+						+								
Sericite	Chiefly orthosilicate of aluminum and potassium (a form of muscovite).		+	+	+				+		+				+	+				+		In schist and granite.
Siderite	Iron carbonate			+	+				+						+							Gangue mineral.
Silver (native)				+				+?	+			+	+	+			+	+		+		In diorite.
Smithsonite	Zinc carbonate			+					+								+					
Specularite	Iron (ferric) oxide	+						+		+			+				+			+		
Sphalerite	Zinc sulphide	+		+				+					+				+					
Staurolite	Basic iron-aluminum silicate	?							+											+		
Stephanite	Silver sulphantimonate			+					+			+								+		
Stibnite	Antimony sulphide			+					+						+					+		
Sulphur			+	+					+								+					
Tenorite	Copper (cupric) oxide	+		+					+	+		+	+		+	+	+				+	
Tetrahedrite	Copper sulphantimonite (gray copper)	+?		+				+	+?			+			+				+	+		
Tourmaline	Complex silicate of aluminum and boron	+?		+				+							+		+					In diorite and quartz monzonite.
Tremolite	Calcium-magnesium metasilicate	+						+	+?				+				+			+		
Tungstite	Tungsten trioxide			+					+					+								
Uraninite (pitchblende) (reported).	Chiefly lead uranyl uranate; may contain several of the rare-earth metals.			+								+								+		
Utahite	Sulphur trioxide and iron sesquioxide	+		+					+	+												
Vanadinite	Lead chlorvanadate		+	+					+			+					+					
Wolframit	Iron-manganese tungstate			+				+						+								
Wollastonite	Calcium silicate	+						+					+				+			+		
Wulfenite	Lead molybdate			+					+												+	

MINING DISTRICTS, CAMPS, AND PROPERTIES.

There are no legal mining districts in the area. The location, extent, and names of the districts by which its various mining subdivisions, 12 in all, are for the most part known in current usage and which for convenience of reference are used in this report are shown on the accompanying map (Pl. I, in pocket). Beginning on the north they are the Empire, Helvetia, Greaterville, Old Baldy, Tyndall, Wrightson, Redrock, Harshaw, Palmetto, Patagonia, Nogales, and San Cayetano districts.

Owing to the great number of veins and other deposits and the fact that work was generally discontinued in early days when the leaner primary ore was encountered in depth, the area contains a large number of mines, most of them small, and prospects that are capable of production.

HELVETIA DISTRICT.

GENERAL FEATURES.

In recent mining activities and production the Helvetia district ranks among the first in the area. It lies in the north-central part of the Patagonia quadrangle, in the eastern part of Pima County, comprising a northeast-southwest area about 12 miles long and 7 miles wide, or about 90 square miles. It contains the north end of the Santa Rita Mountains, which here rise to about 6,000 feet in elevation and in or near whose axis most of the mines are situated. It extends from Box Canyon on the south to and beyond the Cuprite camp in the head of Pantano Wash on the north and from the west base of the Santa Rita Mountains to Davidson Canyon on the east.

The principal camp is Helvetia, located southwest of the center of the district. At the time of visit this camp had a population of 300 people, mostly Mexicans in the employ of the Helvetia Copper Co. It has good wagon-road, stage, and mail connections with Vail, the nearest station on the Southern Pacific Railroad, 18 miles to the north, and with Tucson, 28 miles to the northwest.

The other camps, mostly small, are Rosemont, 4 miles southeast of Helvetia on the east slope of the range; Tiptop, about 1½ miles north; Blue Jay, 2 miles northeast; Proctor and Deering, in Box Canyon on the south; Beuhman, Cuprite, Pauline, and Metallic, on the north; Helena and Scholefield, on the east, and Ridley, a small camp a mile west of Helvetia. They are mostly connected with one another by wagon roads, and good trails cross the range.

The topography is mostly rough, and in the heart of the range it is rugged. On the west the drainage issues toward the Santa Cruz through steep-sided broad washes and arroyos which in or near the mountains have steep gradients—in the latitude of Helvetia about 1,400 feet to the mile—and some of which emerge from deep canyons. The eastern part of the district is drained through streams with gentler gradients, about 300 feet to the mile, eastward into Davidson Canyon and Cienega Creek.

The geology in places is complex. As described on pages 44–45, a narrow but almost continuous belt of the sedimentary Paleozoic rocks is upturned, folded, and faulted and rests upon the intrusive granite or its allied rocks on the west and is overlain by Mesozoic sediments or younger accumulations on the east. The succession and general relations of the rocks are shown in Plate III, section *A–B* (in pocket).

The district contains 50 or more mines and prospects, nearly all of which are included in the following list:

American.
Backbone.
Beuhman.
Black Horse.
Bulldozer.
Chicago.
Coconino.
Copper Belt.
Copper Duke.
Copper World.
Coyote.
Cuprite.
Curtis.
Eclipse.
Elgin.
Exchange.
Exile King.
Fremont.
Gold Fish.
Golden Gate.
Gray Copper.
Heavy Weight.
Helena.
Henrietta.
Humbug.
Hunter.
Indian Club.
Isle Royal.
Leader.
Little Pete.
Merchant.
Metallic.
Mohawk.
Mohawk Silver (Rosemont).
Mount Leon.
Narragansett.
Noon Day.
Norman Queen.
Old Dick.
Old Frijole.
Old Pap.
Old Put.
Omega.
Omega extension.
Papago.
Pauline.
Peach.
Pickwick.
Pilot.
Queen of Sheba.
Record Excelsior.
Ridley.
Sweet Bye and Bye.
Tiptop.
Wisconsin.

HELVETIA CAMP.

GENERAL FEATURES.

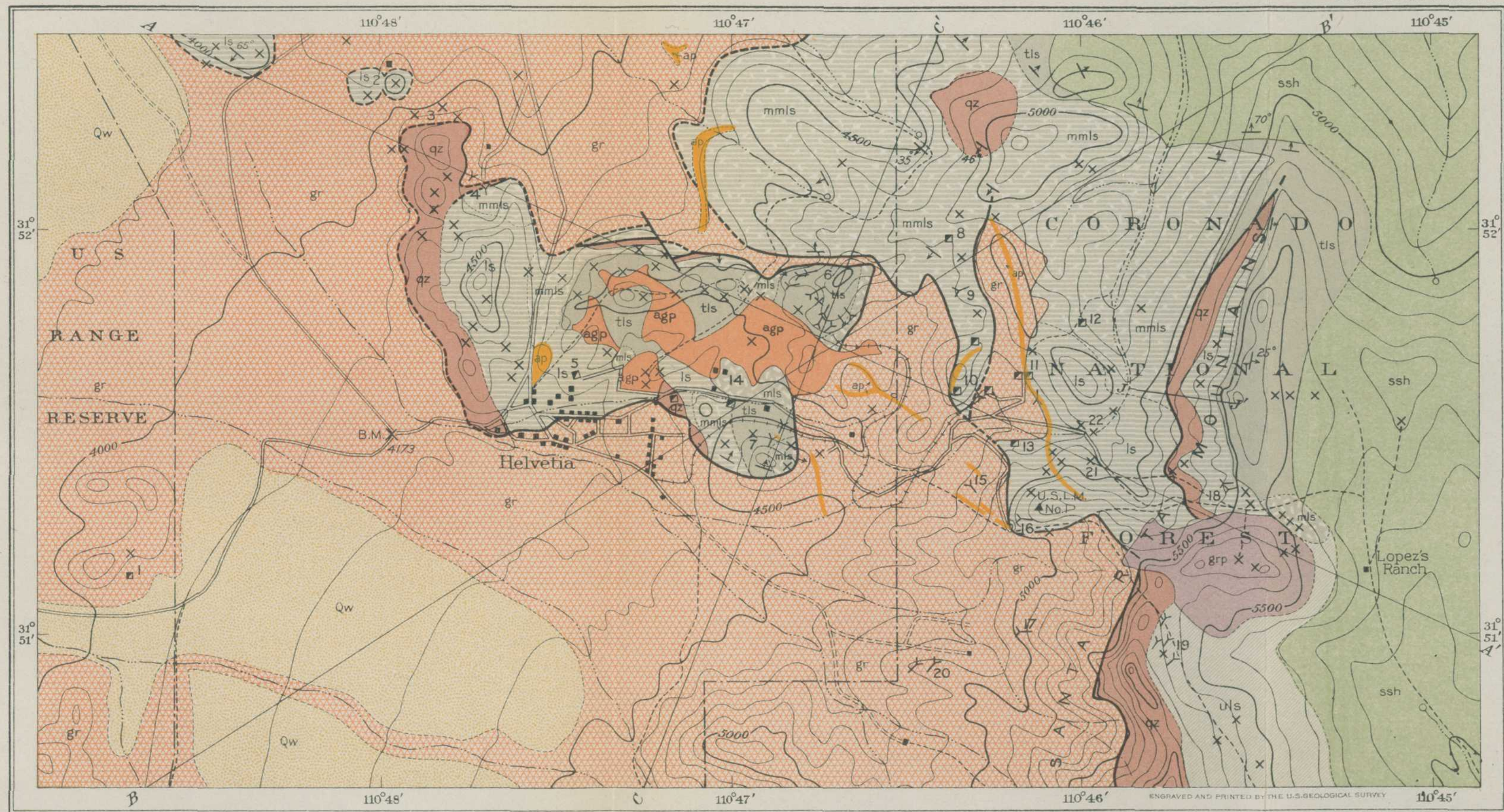
The center of activities, Helvetia camp and its mines, are located at Helvetia, in the upper west slope of the Santa Rita Range between elevations of 4,200 and 5,000 feet. The topography, as shown in Plates I and II (in pocket), is generally rough. In an east-west area about 4 miles long and 3 miles broad, centering near Helvetia, the geology, which is roughly represented on Plate II, and somewhat more in detail on Plates VIII and IX and figure 2, is complicated but interesting. The camp affords excellent examples of contact deposits and of the replacement of limestone by copper ores. The granite occurs in both normal and fault contact with the overlying rocks.

U. S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

BULLETIN 582 PLATE VIII

LIST OF
MINES AND PROSPECTS

1. Ridley
2. Bulldozer
3. Norman Queen and Queen of Sheba
4. Tiptop
5. Elgin
6. Heavy Weight
7. Old Dick
8. Wisconsin
9. Exchange
10. Leader
11. Copper World
12. Black Horse
13. Isle Royal
14. Mohawk
15. Omega extension
16. Omega
17. Old Frijole
18. Exile and King
19. Narragansett
20. Curtice
21. Indian Club
22. Pilot



LEGEND

SEDIMENTARY ROCKS

Qw — Unconsolidated wash (QUATERNARY)

ssh — Thin interbedded red and green sandstone and shale (MESOZOIC)

tls / mls — Thin-bedded dark blue-gray limestone (*Contact-metamorphosed limestone*, mls)

ls / mmls — Massive light-gray to white limestone (*Contact-metamorphosed limestone*, mmls)

uls — Undifferentiated limestone (PALEOZOIC)

qz — Pink to red massive quartzite

IGNEOUS ROCKS (MESOZOIC INTRUSIVES)

agp — Alaskite-granite porphyry

ap — Alaskite aplite dikes

grp — Granite porphyry

gr — Coarse granite (*May include some pre-Cambrian granite*)

Faults

Dip and strike

Contact lines (*a - observed*) (*b - inferred*)

From map of Patagonia quadrangle, Arizona

GEOLOGIC MAP OF HELVETIA CAMP AND VICINITY, ARIZONA

SHOWING LOCATION OF PRINCIPAL MINES AND PROSPECTS, AND LINES ALONG WHICH STRUCTURE SECTIONS HAVE BEEN DRAWN

Geology by F. C. Schrader and J. M. Hill

For sections on lines A-A′, B-B′, and C-C′, see Plate IX
For section J-J′, see Figure 2

1 ½ 0 1 Mile

Contour interval 100 feet
Datum is mean sea level
1914

5 Shaft 3 Tunnel 7 Prospect
(*Numbers refer to list*)

The main structural feature is a thrust fault with gentle dip to the southwest, whose contact with the sedimentary rocks runs in an irregular line from a point near the southeast corner of the area mapped on Plate VIII to the middle of the north line and which has brought the basal granite against the altered overlying Paleozoic limestones for the greater part of the distance. In the southeastern part of the area the Cambrian (?) quartzite stands almost vertical between the granite and the limestone. West of this main fault, in the central part of the basin-like area shown in Plate X, is a body of limestone entirely surrounded by granite. The beds of the limestone dip in toward the center from the north, south, and west, while the east side is cut off by a fault. On the west of this body the Cambrian (?) rocks rest against the granite and are succeeded by limestone in the normal order, but on the other three sides faulting must have taken place, as the basal quartzite is lacking and the granite is

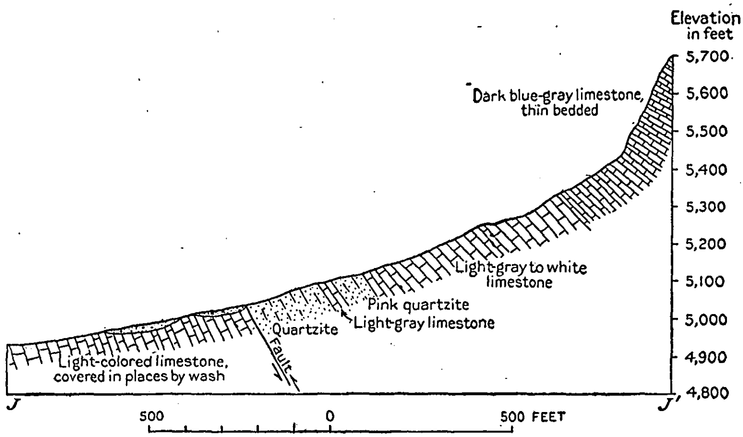


FIGURE 2.—Geologic section along line *J–J'*, Plate VIII.

in contact with crystalline Paleozoic limestone. Near the center of the basin-like area, at a point about midway between the Copper World, Leader, and Isle Royal mines, drill tests sunk to a depth of 600 feet found the first 200 feet to be in granite and the lower 400 feet in crystalline limestone, whose lower limit was not reached. This seems to indicate that unless the granite is an intrusive sill at this point it is overthrust upon the limestones. Farther north in the same tongue this structure is not shown. Granite is present in the lower Copper World workings, where the fault dips steeply to the northeast. The bottom of the syncline was the seat of the intrusion of an acidic magma that formed the very siliceous alaskitic granite porphyry.

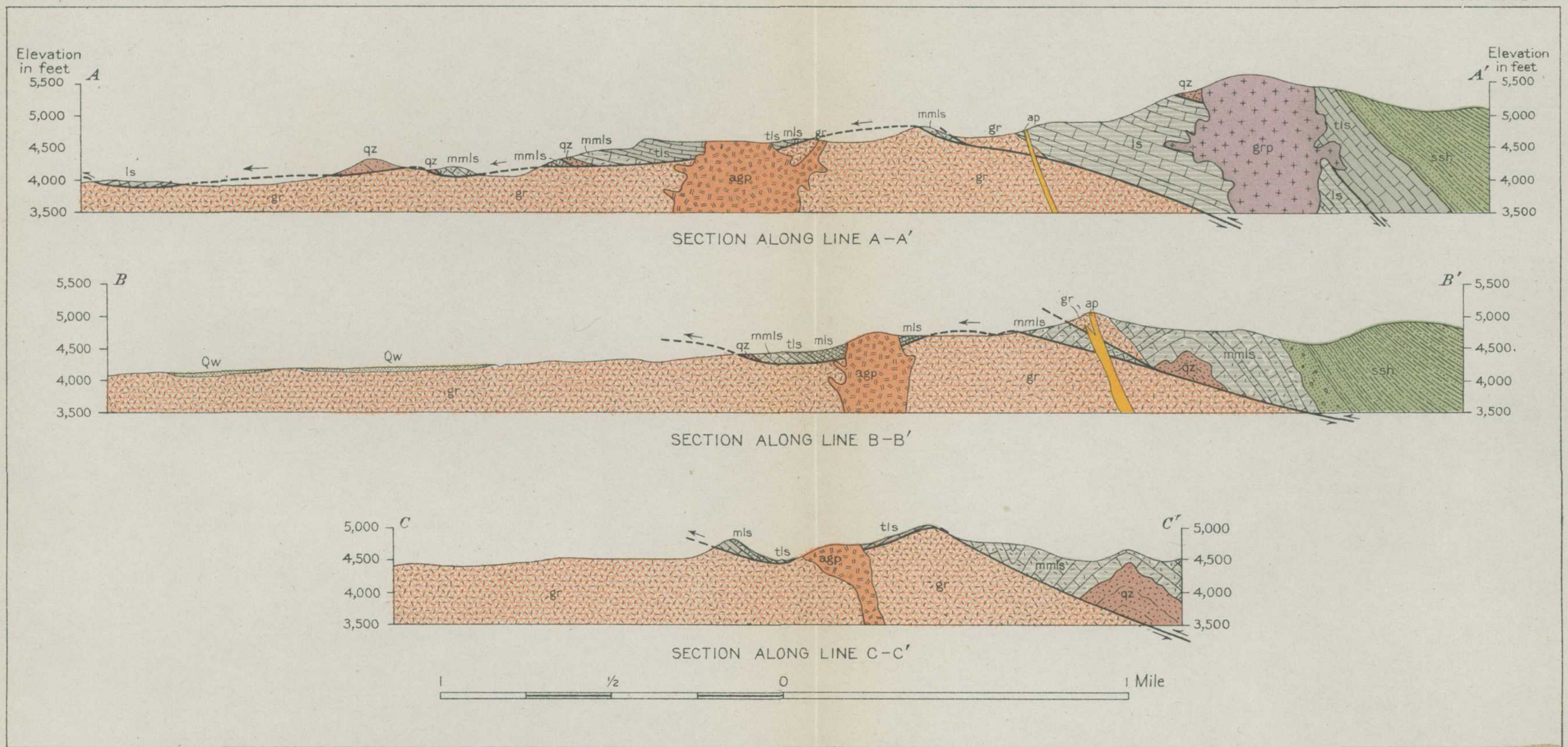
At some time after the faulting and folding took place both the sediments and the granite were freely intruded by dikes, chiefly of the very acidic magma that produced principally the alaskite aplite. Since the intrusion of the various igneous rocks differential movement has produced considerable gouge and material resembling fault breccia along the dikes and elsewhere, and the movement was probably also attended by ore deposition.

The granite occupying the western half of the area is probably pre-Cambrian. It is coarse textured and in places porphyritic, with large feldspar phenocrysts. It is composed of orthoclase (including microcline), quartz, albite-oligoclase, biotite, and hornblende, with magnetite and zircon as accessories. It is cut by two sets of joints trending north and east and by a sheeting which inclines gently to the west but in places is nearly horizontal. Along the faults it is shattered and altered, manganese and iron oxides are developed in the joints, and locally it is epidotized.

Next above the granite come the pink to red Cambrian (?) quartzites, which are mostly heavy bedded and massive and in places considerably altered. As shown on Plate VIII, they occur in three areas. In the area northwest of Helvetia they dip steeply to the east and are much crushed by faulting and folding. In the southeastern area, along the crest of the range, the quartzite is very red, iron stained, and massive and dips steeply to the east. It forms the so-called buttes or high dome-shaped bald knobs that stud the crest of the range, of which Hart Butte and others (Pl. IV, *B*) are examples. In the small area near the north-central part of the district the quartzite is domed and surrounded by the overlying limestone, with quaquaversal dip.

The limestones contain most of the ores of the camp. Owing to movement, profound alteration due largely to contact metamorphism, and intrusion of the igneous rocks their structure in general is very complicated. In most places the original characteristics of the rocks are effaced by silicification, epidotization, and the development of contact-metamorphic minerals resulting in great modifications in composition, texture, and color. The approximate distribution of the limestones is shown on Plate VIII, and their relations in the sections on Plate IX. They are separated into two main groups—thin-bedded dark bluish-gray limestone and massive light-gray to white limestone. Owing to their complexity further subdivision of them could not be undertaken in this work.

On fossil evidence obtained from the dark blue-gray limestone at the crest of the range 2 miles east of Helvetia, as shown in section *J–J′* (fig. 2) and given under "Geology" (p. 50), the limestones are found to be in part at least of Carboniferous (Pennsylvanian) age. The dark-blue limestone in the northeastern flank of Old Dick Hill and that along the ridge north of Helvetia extending from Heavy Weight Hill to Cross Mountain seem also to be of the same age.



GEOLOGIC SECTIONS ALONG LINES A-A′, B-B′, AND C-C′ ON MAP OF HELVETIA CAMP AND VICINITY, PLATE VIII

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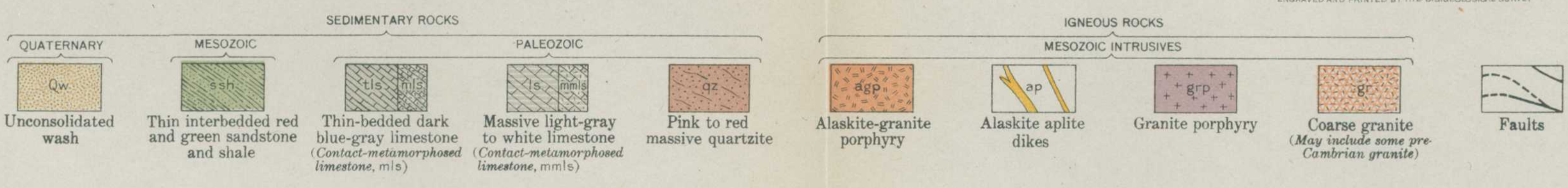
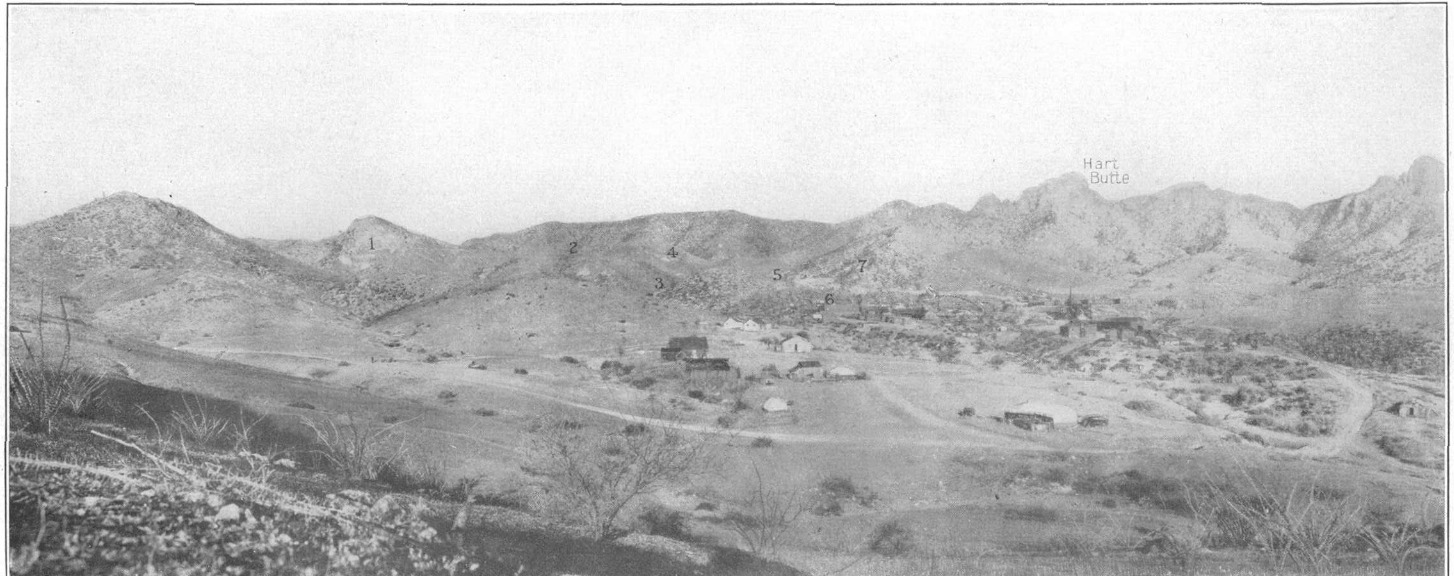




HELVETIA CAMP, BASIN, AND MINES.

Crest of Santa Rita Mountains in background. Looking east from south ridge of Tiptop Mountain, at an elevation of 4,300 feet. 1, Heavy Weight mine; 2, Copper World mine; 3, Mohawk mine; 4, Leader mine; 5, Isle Royal mine; 6, Old Dick mine; 7, Omega mine.

The rest of the limestone area is underlain by much disturbed, locally silicified, and altered rocks of light-gray to white color, which are heavy bedded and massive where they are least altered. As stated under "Geology" (p. 49), these rocks probably include a considerable thickness of Devonian strata.

As shown in section *J–J′* (fig. 2), the dark blue-gray Pennsylvanian limestone seems to be underlain by a considerable thickness of steeply eastward dipping light-gray crystalline limestone with several hundred feet of pink or reddish quartzite in the upper part.

On the ridge in the north-central part of the area and southwest of the neighboring circular mass of quartzite the limestone is greenish gray and thinly laminated, with siliceous cherty layers. The bedding is thin and dips to the southwest at high angles (see Pl. IX, section *C–C′*), and each bed is composed of alternating thin layers of light brownish-gray limestone and light-greenish to white chert.

North and east of the big fault the structure is very complex. North of Heavy Weight Hill the limestone immediately north of the fault dips to the north. About 500 feet from the fault the dip is to the southwest, and there seems to be a synclinal fold whose axis runs northwest, with doming to the northeast, which has brought the quartzite up to the surface.

In the Helvetia basin alteration and faulting of the sedimentary beds are so extensive that little can be made out of the structure beyond the larger features. In Old Dick Hill the beds dip 40°–50° NE. In Heavy Weight Hill the dip is to the southwest at medium angles. In Tiptop Hill, northwest of Helvetia, the beds dip east at relatively steep angles. This structure suggests a basin whose east side is cut off by a fault. The bottom of this synclinal basin is possibly faulted, but the relations here are hidden by the intrusion of the alaskite-granite porphyry.

Along the eastern edge of the area, as shown on Plate VIII, occurs a belt of the overlying Mesozoic interbedded shale and sandstone. These strata are younger than the Mesozoic intrusive rocks and seemingly have nothing to do with the ore deposits of the Helvetia camp or the early period of metallization.

Quaternary deposits of gravel and sand cover the granite in many places south and west of Helvetia and also north of the Helvetia area of limestone, where they are consolidated by lime cement into a conglomerate containing material from all the diverse rock formations occurring within this drainage area and are known as "cement rock."

The principal intrusive rocks of the Helvetia camp, which have played an important part in the formation of the ore deposits, as described under "Geology" (pp. 65–67), consist mainly of the siliceous rocks belonging to the granite porphyry and aplite groups, ranging from alaskite-granite porphyry and alaskite aplite to almost pure alaskitic quartz.

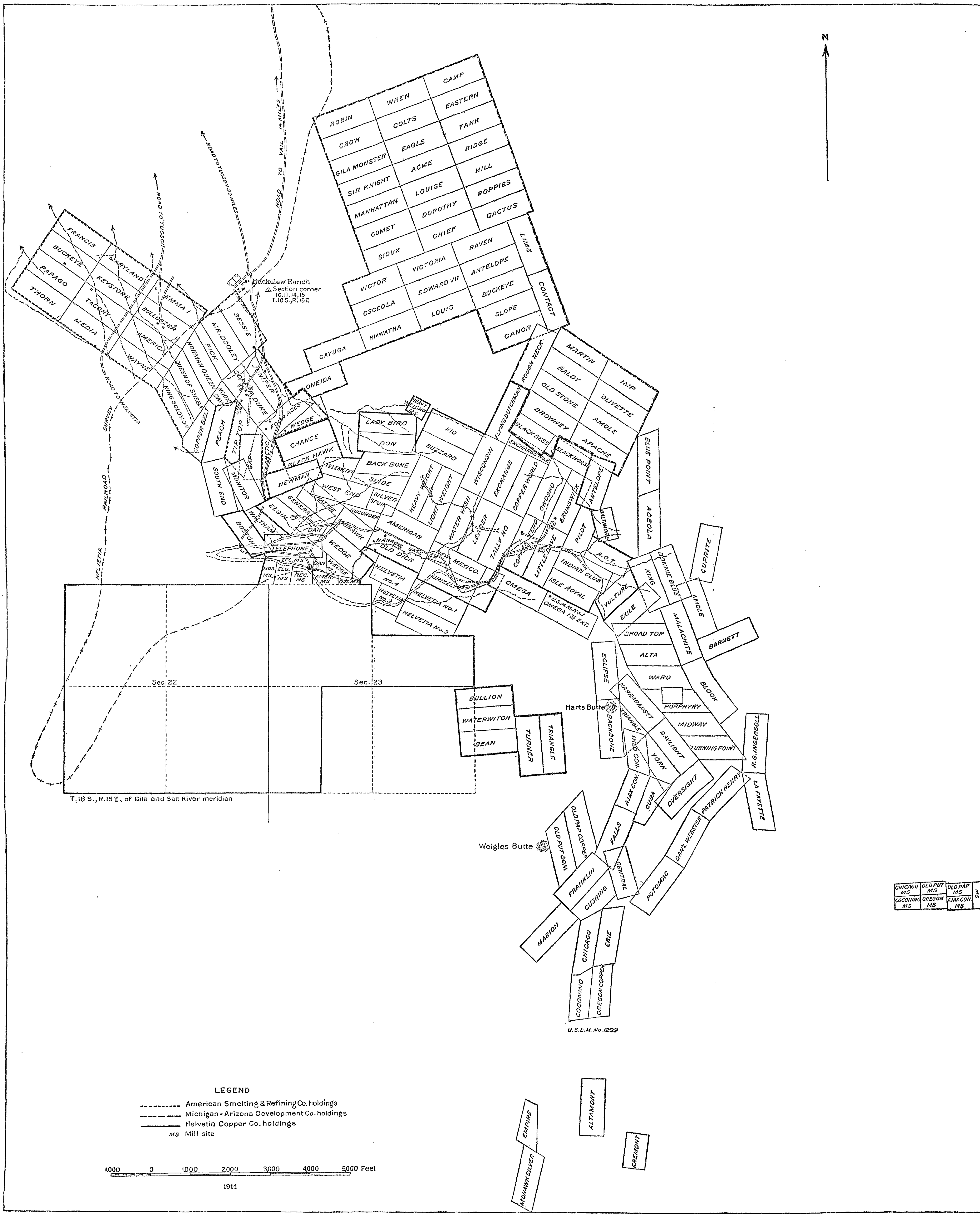
The principal occurrence of the granite porphyry is at the crest of the range 2 miles east of Helvetia. Here a stock forms a prominent butte occupying a circular area about half a mile in diameter. The rock is much sheared and altered and contains numerous copper prospects. A good example of the alaskite-granite porphyry occurs in an irregular body about half a mile northeast of Helvetia, mostly in the limestone area, while examples of the alaskite aplite occur east of the road forks about a quarter of a mile north of town as an intrusive stock or mass and elsewhere as dikes resembling iron-stained quartz veins, of which the largest extends through the Copper World shaft and others pass through the Omega mine in Monument Hill.

Within the above-described area is the Helvetia copper belt, about 1 mile wide and 3 miles long, extending from the Rosemont properties on the east slope of the range northwestward through the Helvetia basin to the Tiptop mine, and comprising nearly all the producing or known workable properties in this district. The location of the ground is shown on the claim map, Plate XI.

Mineral was probably discovered in the Helvetia camp and district before the Civil War, but the records now available do not extend back earlier than the late seventies, when the Old Dick, Heavy Weight, and Tallyho claims of the present Helvetia Copper Co. were discovered by L. M. Grover, though they were not much developed until 1881.

In 1880 the Old Frijole mine, 1½ miles southeast of Helvetia, said to be the oldest mine in the district, was located by Bill Hart and John Weigle, who worked it until 1884. In the early eighties the ores from the Old Dick and other claims on the Helvetia side of the range were treated in a smelter known as the Columbia, located just east of the present Tiptop camp. This was succeeded about 1884 or 1885 by the Mohawk smelter, erected on adjoining ground by the Rosemont Mining & Smelting Co., principally for treating its ores from the Rosemont camp, which were packed across the range to the smelter on the backs of burros. This or a smelter installed here a little later was operated more or less steadily from 1889 to 1902.

In the early nineties the Helvetia Copper Co. of New Jersey, also known as the "Old" Helvetia Co., commenced operations on the group of claims near the town and continued for a period of 10 years, until December 2, 1901. It spent about $800,000 developing the property, built a new smelter and 5 or 6 miles of tramway, and is reported to have produced $400,000 worth of copper ore. The ore as a whole averaged 8 or 10 per cent of copper and contained a small but variable amount of silver and gold. Much of it, especially the



MAP SHOWING THE PRINCIPAL MINING CLAIMS IN HELVETIA CAMP AND VICINITY.

surface ore, was of high grade, and much of that which came from the Leader mine averaged 14 per cent of copper.

In November, 1903, two years after the New Jersey company ceased operations, the present company, the Helvetia Copper Co. of Arizona,[1] with headquarters at Minneapolis, Minn., began to operate the properties, and it continued to do so until 1911. Its principal holdings are the Black Horse, Copper World, Heavy Weight, Isle Royal, Leader, and Old Dick mines. This company, besides doing extensive development work, in 1905 built on the ground a 150-ton copper-matte smelter which was operated during 1906, but as it did not prove a success it was closed early in 1907 and the company shipped its ore during the remainder of its operating period. In 1907 it shipped about $40,000 worth, and in 1908, as stated elsewhere, it shipped to the Old Dominion smelter at Globe about 11,000 tons of ore, valued at about $157,000. At the time of visit (1909) it was producing and shipping at the rate of 60 tons a day to the Old Dominion smelter, hauling it 14 miles by wagon to Vail, on the Southern Pacific Railroad, and was the only company doing much work in the district at that time. It also made a survey for a railroad connecting the mines with Vail, to cost about $280,000, for which it gave bond and procured from the Government the right of way. Its report for July, 1909, shows a net profit of $4.62 a ton on the shipments of 1,434 tons of ore, which contained 156,268 pounds of copper.[2] Of its more recent shipments 275 tons taken from the Black Horse claim averaged 11 per cent of copper.

At the time of visit the company was operating with about 300 men. The miner's wage was $3.50 to $4 a day. The wage for muckers, roadmen, and laborers, all Mexicans, was $2 a day, and the ore was hauled by wagon to Vail, chiefly by Mexicans, for $3 a ton. Haulage by gasoline caterpillar traction engine was also being tried. The source of the machine power used at the mines was fuel oil from Bakersfield, Cal., delivered in camp at a cost of 5 cents a gallon.

In 1910, however, after an output of $109,000 in that year, the force was reduced to only a few men, owing, it is said, to the low price of copper. By July 1, 1911, the mines of the company were reported to have been closed, and soon afterward the pumps were removed from the shafts and the mines placed in charge of a watchman only. Early in 1912 it was reported that the company had sold most of its machinery.

[1] For the first two years of its operations this company was known as the Michigan-Arizona Development Co.

[2] Eng. and Min. Jour., Aug. 28, 1909.

ORE DEPOSITS.

Both fissure veins and contact-metamorphic deposits occur in the Helvetia camp. The fissure veins are principally quartz veins with fluorite, carrying mostly argentiferous galena with minor amounts of copper-bearing minerals and some gold. They occur chiefly in the granite.

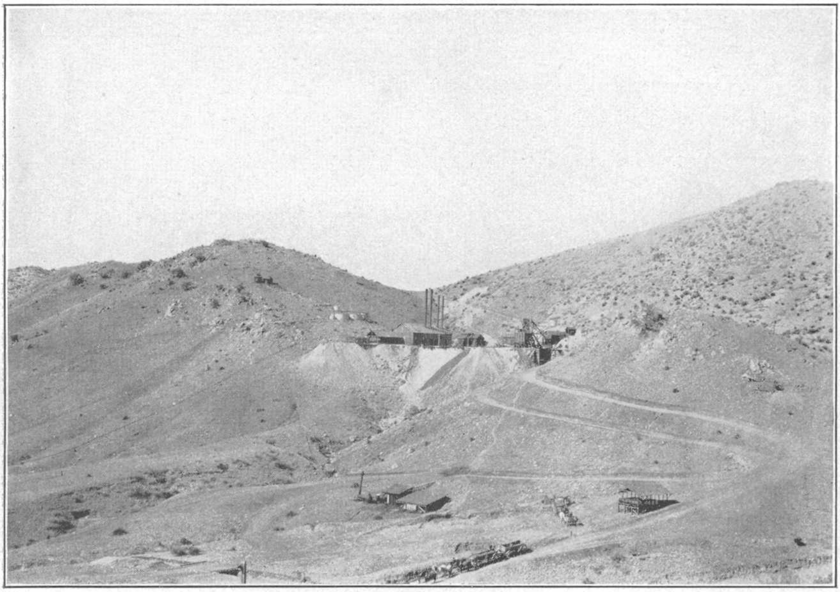
The contact-metamorphic deposits occur mainly as replacement bodies in the limestone near the contact of the granite and the other intrusives, and also as impregnations or metasomatic replacements along the contact of either of these rocks with the other main formation, the quartzite, in the quartzite, along the faults, and, to a less extent, in the granite. Accordingly, most of the contacts and faults represent several north-south zones or bands of metallization. Some of these zones are several miles in length and contain workable ore bodies.

The ores in the eruptive rocks are siliceous and those in the limestone are generally basic. The chief value of the ores is in the copper content of the deposits in the limestone. The gangue is mostly silicated limestone and in part quartz, in places with considerable garnet and calcite.

The outcrop is generally an iron cap composed of a mixture of lime silicates, malachite, azurite, oxides of copper, iron, manganese, and magnetite.

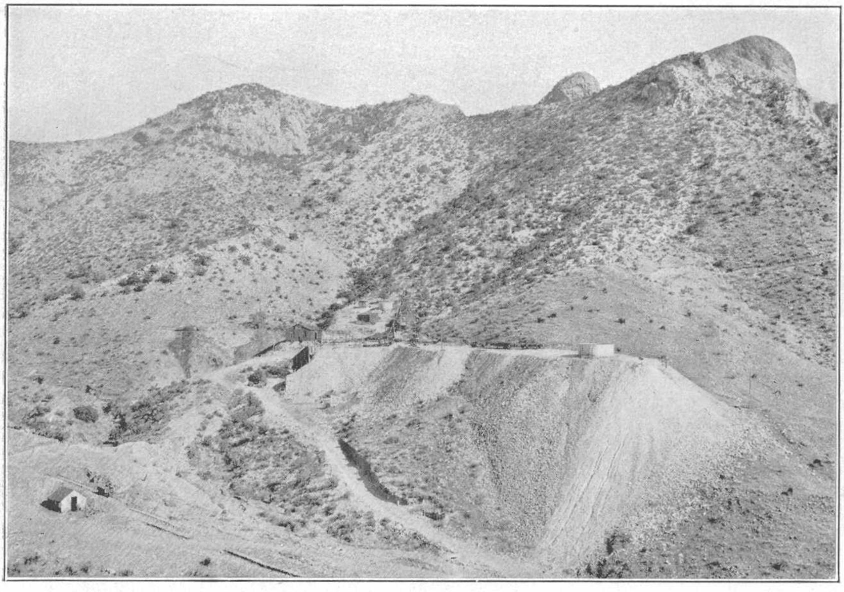
The chief primary ore minerals are cupriferous pyrite and chalcopyrite, but in the oxidized zone, which extends from 100 to 300 feet below the surface and in which the ores are mostly secondary, the ore minerals are chiefly the copper carbonates (malachite and azurite), the copper oxide (cuprite), native copper, the sulphides (chalcopyrite, chalcocite, and tetrahedrite), and some gold and silver. Associated with the ore in places are also some galena, sphalerite, pyrrhotite, and molybdenite. The oxidized ores in general, containing plentiful lime and iron for fluxing without an excess of silica, are basic and free-milling and are generally rich, mostly running from 20 to 25 per cent in copper. The lower limit of the oxidation zone is irregular and ranges from 100 to 300 feet below the surface. Water is encountered in most of the deep mines, and what is regarded as ground-water level was struck a little below the 300-foot level in the Isle Royal mine.

The first sulphide ore which was mined in the early days came from the Leader mine. In 1906 and 1907 sulphide ore was encountered also in the Isle Royal and Copper World mines. The ores that were being mined at the time of visit, chiefly from deposits in the limestone, were largely soft earthy mixtures of copper and iron sulphides and copper carbonates. They contained also some



A. COPPER WORLD MINE.

Looking N. 15° W. from Isle Royal ground.



B. ISLE ROYAL MINE.

Monument Mountain (limestone) at right, Hart Butte (quartzite) in right background, granite porphyry in left middle ground, and Lopez Pass in left background. Looking southeast from above Leader mine.

galena and zinc blende and moderate quantities of silver and gold. The relative proportion of silver and gold to copper is illustrated in the output of the camp for 1909, which was 11,282 tons of ore, valued at $157,038, or an average of $13.91 a ton, and which yielded $597 in gold, 11,698 ounces of silver, and 1,156,604 pounds of copper.

The source of the copper is apparently the cupriferous pyrite and to some extent also the chalcopyrite, which seem to be primary minerals in the intrusive rocks, particularly the granite. The workable deposits here, as in other camps, are the result of concentration or enrichment by which the copper, liberated from the cupriferous pyrite and chalcopyrite when these minerals were broken down in the oxidized zone, was redeposited by descending solutions at favorable points on lower levels, as malachite, azurite, chalcopyrite, chalcocite, chrysocolla, and bornite. The rock most favorable for receiving the ore deposits is the limestone, though not the highly metamorphosed crystalline portion immediately along the contact, as is generally supposed, for this is commonly barren, but the less metamorphosed and unaltered portion, which, being softer, is seemingly more receptive to mineralization and replacement.

An unusual and perhaps unfavorable feature of the Helvetia deposits, examples of which occur at the Copper World mine, in the Black Horse shaft, and in the shaft in the gulch northwest of the Old Dick mine, is the downward infiltration of copper-bearing solutions through bodies of pyrite, forming in these bodies only small seams or veinlets of blue hydrous copper sulphate or chalcanthite and not the usual enriched deposits of copper.

The deposits of the Helvetia, Rosemont, and adjoining camps, taken as a whole, occur mainly in the limestone and do not seem to extend downward into the underlying granite. It is also held by some that even if they do extend into the granite they will not be found to occur there in bodies of workable size. To this view, however, there seems to be some ground for exception, for as the cupriferous pyrite in the granite is largely the source of the copper, the deeper the fissures extend into the granite the better the opportunities they afford for concentration by enrichment, but the most favorable conditions, of course, do not extend much below the oxidized zone, which in most places is not very deep.

COPPER WORLD MINE.

Location and topography.—The Copper World mine (Pl. XII, *A*), which was the principal producing property at the time of visit, is 1¼ miles east of Helvetia, in the upper west slope of the Santa Rita Range at an elevation of about 4,850 feet. It is in a parallel ridge separated from the main axis of the range by a south branch of Sycamore Canyon and is reached by a wagon road of easy grade.

History and production.—The mine was first opened in 1900, but it was later abandoned and reopened in 1906. The early production was moderate. During the two years ending March, 1909, while the mine was doing mostly development work, it produced 10,000 tons of ore that averaged 5.17 per cent of copper, and from October 12, 1908, to March 23, 1909, it had, according to the smelter returns, shipped 3,600 tons that averaged 5.172 per cent of copper. During the year ending August 31, 1909, 269 cars of ore were shipped, containing 999,847 pounds of copper worth $93,842.[1]

To this amount should apparently be added about $8,000, the larger part of the remaining production of the company up to the time when it closed its mines in 1910, making the total production for the mine about 15,000 tons, some of which came from its adjunct, the Black Horse shaft.

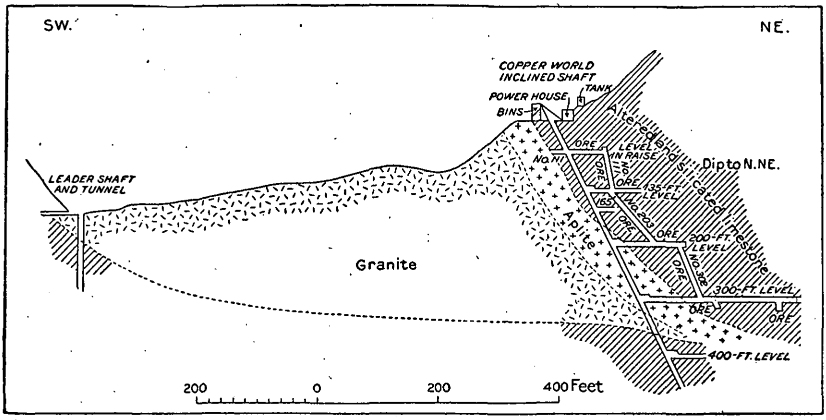
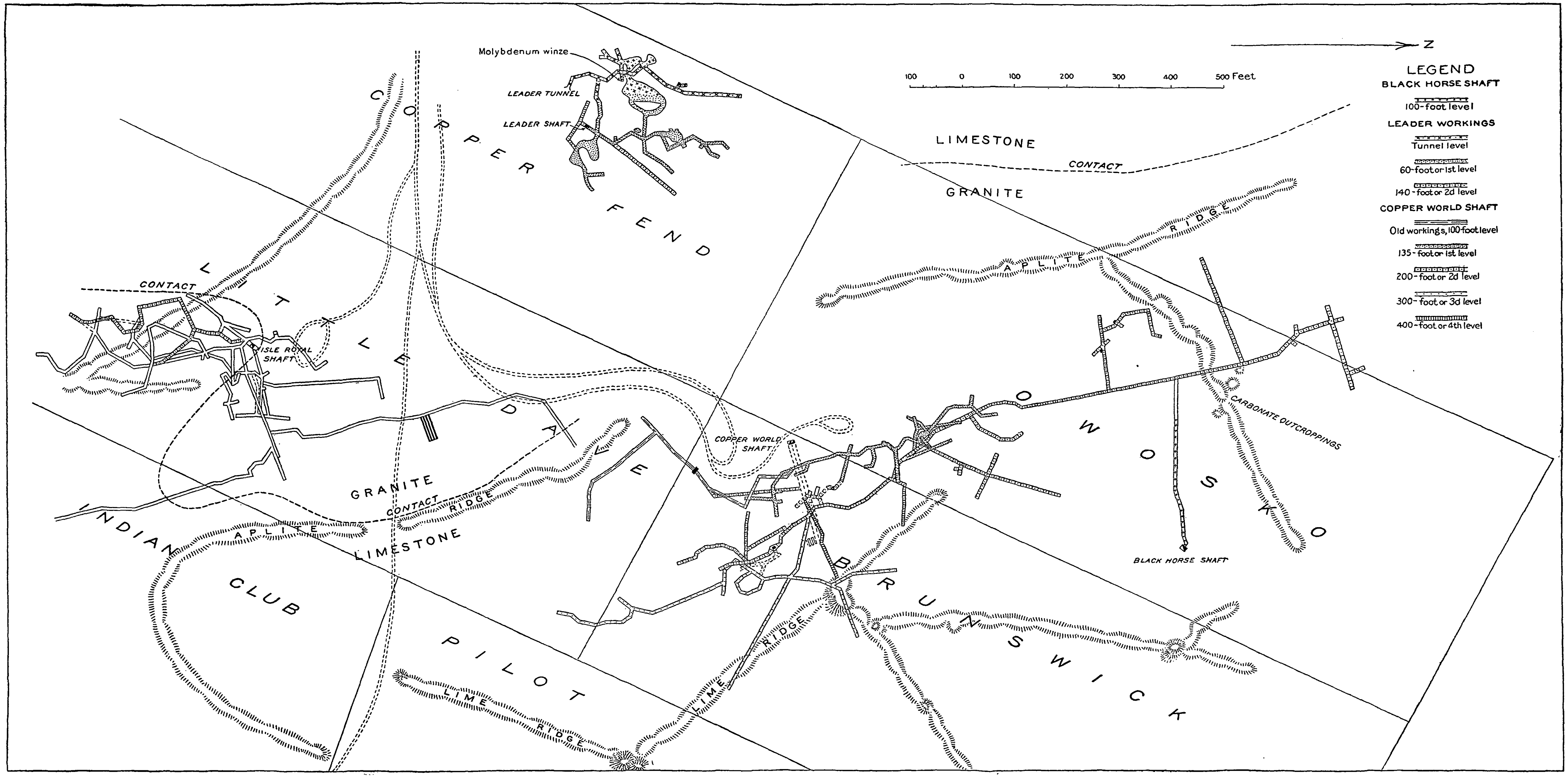


FIGURE 3.—Cross section of Copper World mine on line of Copper World and Leader shafts.

Development and equipment.—The mine contains about 12,000 feet of work. It is opened by an inclined double-compartment shaft to a depth of nearly 500 feet on the incline, or below the 400-foot level. The shaft inclines 68° ENE. and lies principally in altered limestone, as shown in figure 3, which is a cross section of the workings. It contains four levels, of which the first is 135 feet below the surface and the others are spaced 105 feet apart on the incline, or 90 feet vertically. From short crosscuts into the hanging wall the main drifts, which constitute the principal part of the workings, are run north and south, parallel with the formations, and extend for about 1,700 feet.

As shown on the accompanying level map (Pl. XIII), the first level contains about 800 feet of drifts and crosscuts, nearly all to

[1] Eng. and Min. Jour., Nov. 13, 1909.



PLAN OF WORKINGS OF THE COPPER WORLD, ISLE ROYAL, LEADER, AND BLACK HORSE MINES.

the north. The second level contains to the north 1,000 feet of drifts, 800 feet of crosscuts, and a stope up from the 300-foot level, and to the south about 500 feet of work. The third level contains about 1,400 feet of workings, principally drifts to the southeast. About the only work done on the fourth level consists of two short crosscuts aggregating about 200 feet, one to the east and one to the west.

Intermediate between the first and second levels, at 160 feet below the surface, is a sublevel containing about 200 feet of drifts, mostly to the north. The old, abandoned first level, at about 60 feet below the surface, contains about 800 feet of work. From this level down to the third the levels are connected by stopes or inclined winzes, as shown in the cross section (fig. 3).

The mine is dry down to the 300-foot level and very little water is present above the fourth level, where the mine makes about 300 gallons a minute. Owing to the crushed condition of the ground, however, the workings in part have to be timbered.

Geology.—The mine is on the contact between the intrusive granite and the limestone, but a 60-foot dike of the very siliceous alaskite aplite intervenes between the granite and the main workings, which are in the limestone approximately as shown in the cross section (fig. 3).

The prevailing dip, especially in the limestone, is steep to the east-northeast, approximately parallel with the inclined shaft and the upper part of the alaskite aplite dike. A secondary structure dips southeastward at angles which are mostly steep. On the lower levels also a structure which in places seems to represent the bedding of the sedimentary rocks dips 70° W.

Except most of the alaskite aplite the rocks are considerably crushed, shattered, faulted, slickensided, altered, and more or less pyritic and contain in places seams or veinlets and stringers of copper-bearing iron sulphides.

The granite, as shown in specimens from the 200-foot level, is medium to coarse grained, dark gray, and porphyritic, with phenocrysts of reddish orthoclase about 1 inch in maximum diameter, and it contains quartz, a little oligoclase, biotite, hornblende, and considerable dark ferruginous material that seems to be derived from hornblende or other bisilicates. The fractures are filled with calcite and secondary silica and contain also epidote, pyroxene, and other metamorphic minerals in moderate amount.

The limestone, of which both light and dark varieties are present, is almost completely altered, chiefly to a limestone-silicate rock which is mostly greenish-gray, brown, or brownish-gray, more or less massive, fine to medium grained, and composed of pyroxene, principally diopside, massive garnet, calcite, wollastonite, quartz, epidote, and other metamorphic minerals. In some places the limestone is hard and silicified; in others it is leached to a pale greenish-gray or buff-colored soft rock. Locally it contains much cupriferous pyrite, most of it disseminated but some occurring also in seams, veinlets, and small stringers, with which is sparingly associated molybdenite, especially on slickensided surfaces.

The alaskite aplite dike, which practically forms the footwall of the mine, is, where not greatly altered, bluish or drab-gray, and very fine grained or aphanitic. As shown by the microscope, it is composed principally of subangular to angular interlocking grains of quartz with a very small percentage of orthoclase or related feldspar that could not be conclusively investigated in this work. It contains also a little cupriferous pyrite in disseminated form which seems to be primary and some in secondary veinlets and small yellowish aggregates filling seams and fractures.

Ore.—The ore of the Copper World mine consists mainly of soft, earthy, fine-grained, mostly pulverulent chalcopyrite, cupriferous pyrite, and chalcocite, the "black glance." The chalcocite occurs principally as a black coating or film of secondary origin on the chalcopyrite and pyrite and is less plentiful in the lower than in the intermediate and upper levels, as is also the chalcopyrite, which is likewise largely secondary. The ore carries from 1 or 2 to 10 per cent or more of copper and averages about 75 cents to the ton each in gold and silver, but for the latter metals the company receives no returns from the smelter unless the silver content amounts to 2 ounces or more and the gold to 0.05 ounce or more to the ton.

The ore of this mine has been all sulphide from the surface down, the mine being markedly different in this respect from the Old Dick and its neighboring contemporary mines, whose ore consisted mainly of carbonates. This difference seems to be due chiefly to the topographic location of the Copper World in the upper part of a narrow, steep-sided ridge, whose reduction by erosion has apparently about kept pace with the general oxidation. Oxidized streaks or narrow zones, however, are common down to the 200-foot level.

The ore, as indicated on the mine map, is very irregularly distributed. It occurs in pockets and irregular-shaped bodies in the altered limestone, principally in the dark, less crystalline and less intensely altered portion near faults and displacements. No regular ore shoots can be recognized. The general vertical distribution of the ore is roughly indicated in the cross section (fig. 3) and the horizontal distribution on the level map (Pl. XIII). The most productive bodies are on and between the second and third levels.

On the third level the ore occurs south of the inclined shaft, where at the time of visit nearly all the work was being done, as shown on Plate XIII. The country rock is mostly the dark silicified and silicated limestone. Here one of the principal ore bodies occurs in stope 306, represented on the mine map by the circular area inclosed by the drift. The ore body, now mostly stoped out, is about 8 feet in width and has produced much ore. It dips steeply to the east between walls which are fairly well defined. Here also, as shown in the 25-foot upraise near the end of drift 312, occurs a body of good ore 7 feet in maximum width. It dips about 60° E., is opened for a length of 50 feet, and was being stoped to the north and south, but the north face was not in ore. The footwall is altered limestone dipping steeply to the west. East of the drift forks at the 15-foot winze is another ore body several feet thick and 20 feet or more in horizontal extent. It dips 30° N. and has a fairly good hanging wall of dark altered limestone, but the footwall is irregular and composed of altered limestone or perhaps of some kaolinized porphyritic rock.

On the second level the ore lies mostly southeast of the incline, where the stope comes up from the third level. Here just beneath drift 312 is the large stope 308, 40 feet long, 20 feet wide, and 12 feet or more high. The ore body dips steeply to the east-northeast and lies in greatly altered limestone. Ore chutes were also installed to continue stoping above this level, but the ore body was found to become somewhat narrower.

At 120 feet beyond crosscut 223 a small crosscut to the east shows 25 feet of good ore in a crushed quartzite and limestone gangue. In the south workings, in the middle one of the three drifts that radiate from the winze, the altered limestone carries ore stringers 2 to 8 inches in width dipping at angles of 45° and having quartz in association. Pockets of ore 2 to 10 inches in diameter and containing chalcocite or "black copper glance," are also present. The country rock is mostly the dark limestone and is in general more or less pyritic or mineralized. The strata dip 45° SE. In the north drift of the second level, which extends more than 1,200 feet from the shaft and is nearly all prospect and development work, crosscut 213, from which some stopes or upraises have been opened, has produced a small amount of ore, as has also crosscut 221. The 5-foot crosscut west of the center of the curved drift shows a good footwall of siliceous dark limestone dipping 45° E. and an 8-inch band of solid chalcopyrite ore about 4 feet above the wall, the intervening rock consisting of banded limy material. Small pockets of ore also occur here in the light-colored limestone on the hanging wall. Crosscut 212 starts in a good-looking ore body that dips to the east and lies in dark, somewhat mineralized limestone, and 10 feet beyond drift 212 is seen what is probably the continuation of the ore that is 8 inches wide in the right-hand crosscut of the long curved drift. The ore is not very siliceous, but the footwall consists of highly silicified gray limestone.

On the first level good ore occurs in the south drift in the dark limestone hanging wall on the east, with alaskite aplite on the foot-wall. In the north drift, at the C 107 upraise, on the footwall or west side, is a good ore body 8 feet or more wide with well-defined foot-wall, but within a short distance horizontally the ore body thins out. The ground beyond, however, in the face of the drift, is pale-green epidotized, pyritic limestone-silicate rock, approaching in character low-grade ore. In the winze sunk from this level to the second level the rocks are altered and contain pockets or bedlike bodies 6 to 7 feet in maximum thickness from which all constituents except white powdered amorphous silica have been leached out and which, considered in connection with somewhat similar deposits in various stages of alteration encountered in the Tiptop and other mines, later described, seem probably to be derived from or to represent the remnants of completely altered aplitic or perhaps alaskitic dikes.

On the old first level, which is abandoned, the ore occurred principally in the vicinity of the inclined shaft and interruptedly along the drift to the north for a distance of about 300 feet, in the terminal part of a 75-foot crosscut to the east, and in a winze sunk at that point. On the fourth level, so far as learned, no ore has been found.

Origin of the ore and future prospects.—The source of the ore apparently lies in the primary cupriferous pyrite and chalcopyrite contained in the granite. The coarse and porphyritic texture of the granite and the wide extent and intensity of the metamorphism in the limestone are indications that the granite invaded the limestone at considerable depths, where the conditions during a long period were essentially plutonic. These conditions were peculiarly favorable for the importation of the cupriferous material from the granite magma into the limestone and its dissemination by the widely circulating thermal solutions and gases of the magma. These processes may have been later repeated, though on a much smaller scale, by the intrusion of the granite porphyry and still later by that of the aplitic magmas. Subsequent to the deposition of the copper minerals in this way the processes of oxidation and the infiltration of meteoric waters that leached the copper from the granite and the overlying limestone brought large portions if not the bulk of the mineral and were potent agents in concentrating it into the ore bodies as they now occur in the crushed, shattered, and replaced limestone. In these processes of concentration the alaskite aplite dike, which was intruded much later than the granite and after the deformation of the limestone, has been an important physical factor, being a relatively firm and unbroken formation with its dip flattening in depth, so that it performed the office of an impervious stratum in arresting the downward-percolating solutions and causing them to precipitate their mineral burdens, which now form the ore bodies.

This feature occurs more extensively and in greater detail in the Tiptop mine, later described.

But for the barrier interposed by this dike the ore bodies would pretty surely not occupy their present positions and would probably not exist. This is apparently the reason why no deposits have been found on the under or footwall side of the dike on the fourth level, for instance, nor are any likely to be found there unless the dike is cut through by a fault or some considerable displacement, though the limestone below the dike is in every way favorable for their accumulation. The hope of the mine therefore rests in the deposits formed in a zone of moderate width in the limestone on the hanging-wall side of the dike, remote from which workable deposits probably do not occur in the mine, and a falling off of enrichment is indicated by decrease of chalcocite and chalcopyrite on the lower levels. Ore found at greater depth is likely to be mostly primary and of low grade.

BLACK HORSE MINE.

The Black Horse mine, which is practically an adjunct to the Copper World mine, is located in the east fork of Sycamore Canyon about 800 feet north-northeast of the Copper World, on the opposite or east side of the same ridge, at an elevation of about 4,800 feet, the two mines being nearly on the same level. (See Pl. XIII.) It is on a ledge of silicified limestone which dips 80° SW. and seems to contain thin dikes of the aplitic intrusive rock.

The mine is opened by a 100-foot vertical shaft, sunk in altered copper-stained silicated limestone, which southeast of the shaft is heavy bedded, dips 35° SSE., and is cut by a sheeting or cleavage dipping steeply to the north-northwest. From the bottom of the shaft, on the 100-foot level, about 400 feet of drift extends to the west. This drift is near a level of the Copper World mine, from which an upraise is being driven to connect with it.

In the bottom of the shaft the limestone is fine grained and altered, consisting mainly of diopside or related pyroxene, garnet, quartz, and a little calcite.

At 250 feet from the shaft the drift, all in the dark limestone, crosses a north-south vertical ore body from 2 to 7 feet wide, averaging about 5 feet. The ore is soft and consists of chalcopyrite and much greenish-black material, the "black copper glance," which is merely chalcopyrite and cupriferous pyrite coated with secondary chalcocite. The ore body is stoped for 20 feet to the north and 40 feet upward. The better grade of the ore is said to be the black glance, much of which runs 25 per cent in copper.

At 280 feet from the shaft is a second ore body about 2 feet wide, which trends nearly north and is more or less banded. Bunches of ore are also present but mostly in association with the larger bodies. The terminal 75 feet of the drift is filled with storage ore, which is to be hoisted through the Copper World mine.

LEADER MINE.

The Leader mine is about 1⅕ miles east of Helvetia and one-eighth of a mile west of the Copper World mine (Pl. XIII), at an elevation of about 4,700 feet. It is the southeast slope of a low hill known as Leader Hill and is easy of access, having both wagon and railroad connections with Helvetia and the smelter.

This mine was among the early discoveries of the camp and is one of its leading producers. It produced a large amount of ore in the early days, much of which is said to have averaged 14 per cent in copper. The various chambers and particularly the large stope east of the tunnel, which descends at an angle of about 40°, indicate that a large amount of ore has been removed. The mine still contains and is now producing considerable low-grade copper ore.

The mine is opened by tunnel and shafts and contains three levels—the "tunnel level," the "first" or 60-foot level, and the "second" or 140-foot level, shown in Plate XIII. The workings aggregate 2,000 feet or more. The present main entrance is the so-called tunnel or long drift, about 400 feet in length, which extends irregularly northward, in part along the strike, and follows the principal ore bodies. From it laterals, including chambers, stopes, and inclines, extend to the right and left, and winzes and upraises have been made at several points. Some of the winzes connect with the lower levels, but at the time of visit these and the shafts were mostly filled with water.

The mine is on the granite and limestone contact, which seems to be faulted and dips 40° NE., as does also the limestone, which is much disturbed, shattered, altered, iron-stained, somewhat pyritic, and in part wet and cavernous. The limestone is for the most part changed to a brownish or greenish silicated rock ranging in character from one composed principally of garnet to one containing mainly pyroxene or epidote. Much of it is banded with seams of copper carbonate. In places, however, it is merely crystalline or completely marmarized. At the mouth of the tunnel the granite overlies the limestone and dips to the northeast.

The ore is principally sulphide material, consisting of cupriferous pyrite and chalcopyrite. It occurs in the altered limestone and in places is associated with a little quartz gangue. West of the tunnel, with which it is nearly coextensive, it occurs mainly as a 4-foot bed of solid sulphide ore dipping about 40° E., conformably with the limestone in which it is seemingly interbedded. The ore in this bed is medium grained and mostly of low grade, carrying only about 2 per cent of copper.

As shown in the main chamber west of the tunnel and elsewhere there also occur smaller beds or veinlike bodies of better-grade sulphide. This chamber shows two such veins, of which the larger is from 1 foot to 2¼ feet in thickness. At about 80 feet from the face of the tunnel the limestone, here altered principally to reddish gray or brown garnet and pyroxene, contains several flat-lying ore lenses, the largest about 2½ feet in thickness.

Owing to the generally low dip or flatness of the deposits and their nearness to the surface, the company plans to sink shafts and work them at a lower level. The ground, largely by reason of the fault on which the mine is located, is soft and breaks easily.

Molybdenite, which is sparingly present in nearly all the ores of the Helvetia camp, is plentiful in much of the Leader ore, and in one place, of which the following description has been published,[1] it occurs in seemingly workable amount:

> The molybdenite occurs at a point about 150 feet in from the mouth of the [main] tunnel, in dull-brownish and greenish to yellowish mineralized garnetiferous silicified limestone and quartz.
>
> The rock is more or less massive. It varies from fine to medium grained and is composed essentially of pale-greenish garnet, which corresponds to grossularite and occurs in grains and imperfect crystals. The mineral next in abundance is quartz, which seems to be of two periods. The remaining secondary metamorphic minerals observed are calcite, magnetite (or ilmenite), and epidote, which are present only in small amount. The latest mineral in general is quartz. After the rock had been severely crushed and fractured the cracks and openings became filled with quartz, which occurs in macroscopic and microscopic lenses, irregular bodies, and veins. The smaller veins have in general a direction roughly parallel with the ore bed and connect variously with the larger bodies or lenses, in places forming a closely woven reticulating meshwork, with garnet filling the interspaces.
>
> At the tunnel level a tabular vein or seam of copper ore with quartz gangue inclines eastward at an angle of about 40° and is opened on the incline by what is known as the Molybdenite winze. In the vicinity of the level the vein is only a few inches in width but with it, on either side, is associated from 1 to 3 feet or more of the above-described mineralized limestone, which contains chalcopyrite, pyrite, coarse calcite, and quartz, and which is a low-grade copper ore.
>
> In the incline at a depth of 35 or 40 feet below the level, however, conditions change. Here molybdenite occurs in both the vein and the inclosing rock, mingled with the chalcopyrite and pyrite. In the next 8 or 10 feet below the dip flattens somewhat, the chalcopyrite and pyrite decrease greatly, and there is a more than corresponding increase in the amount of molybdenite, so that the deposit is there a relatively pure molybdenite ore and seems to constitute a body or ore bed at least 3 or 4 and probably 6 or 7 feet in thickness. Owing to the presence of water in the shaft sunk at the end of the incline, examination could not be made across the entire bed. So far as observed there seemed to be no detrimental intermingling of chalcopyrite.

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[1] Schrader, F. C., and Hill, J. M., Some occurrences of molybdenite in the Santa Rita and Patagonia mountains, Arizona: U. S. Geol. Survey Bull. 430, pp. 156–157, 1910.

The molybdenite occurs in lenses, irregular bodies or bunches, and crystal aggregates embedded in and associated with both the rock and the quartz. It is mostly fine grained, but some of the crystal plates range up to one-half inch or more in maximum diameter.

Bodies of the molybdenite inclosed in the middle of some of the quartz veins indicate that deposition of this ore probably continued after that of the quartz, with which the molybdenite seems to be in the main contemporaneous. Like the quartz, it was probably deposited by thermal solutions that accompanied or followed the intrusion of the aplite dikes or granite porphyry.

A considerable amount of molybdenite can be seen on a large dump of low-grade copper ore at the entrance to the mine, and a smaller pile of 8 or 10 tons of molybdenite ore is reported to average 6½ per cent of molybdenum. At the time of visit in 1909 the company was planning to mine the deposit commercially and expected to produce ore with a very much higher percentage of molybdenum.

ISLE ROYAL MINE.

The Isle Royal mine, 1¼ miles east of Helvetia, is 1,000 feet south of the Copper World mine. (See Pl. XIII.) It is near the axis of the range, in the north slope of the spur of Monument Mountain, whose southwest slope contains the Omega mine. The slope, as shown in Plate XII, *B*, is steep, but the mine is easily reached by a wagon road of moderate grade.

The deposit was discovered and located by C. E. Hughes in the early eighties, but it received only surface development, at times when copper commanded a good price or money was needed by the owner, until the present company took hold of the property. This company in 1904 sunk a shaft to the fourth level and encountered a large body or chimney of ore extending from the 100-foot to the 300-foot level. In 1905 operations were suspended, but about three years later the company sunk a shaft from the 400-foot to the 800-foot level, did much other work, and stoped out considerable ore, until the ore apparently began to play out or became too low in grade, and then the mine was closed.

The production of the mine is about 30,000 tons of medium-grade ore, which was treated in the Helvetia camp.

The mine is developed mainly by an 800-foot double-compartment vertical shaft and about 4,000 feet of work distributed on seven levels, mostly on the 800, 300, and 400 foot levels, as shown on Plate XIII and figure 4, there being no development on the 700-foot level. It is the deepest mine in the area.

The mine is located on the contact between Paleozoic limestone and Mesozoic granite, near a fault which is shown in the deep part of the mine. The shaft is sunk to a depth of 450 feet in the limestone; the lower 350 feet is in the underlying granite. The contact dips 68° N. and in the bottom of the mine it is 120 feet west of the shaft. No aplitic dikes, it is said, occur in the mine. The alaskite aplite dike of the Copper World mine, however, lies near by on the east and probably exerted a favorable influence on the ore deposition, as may

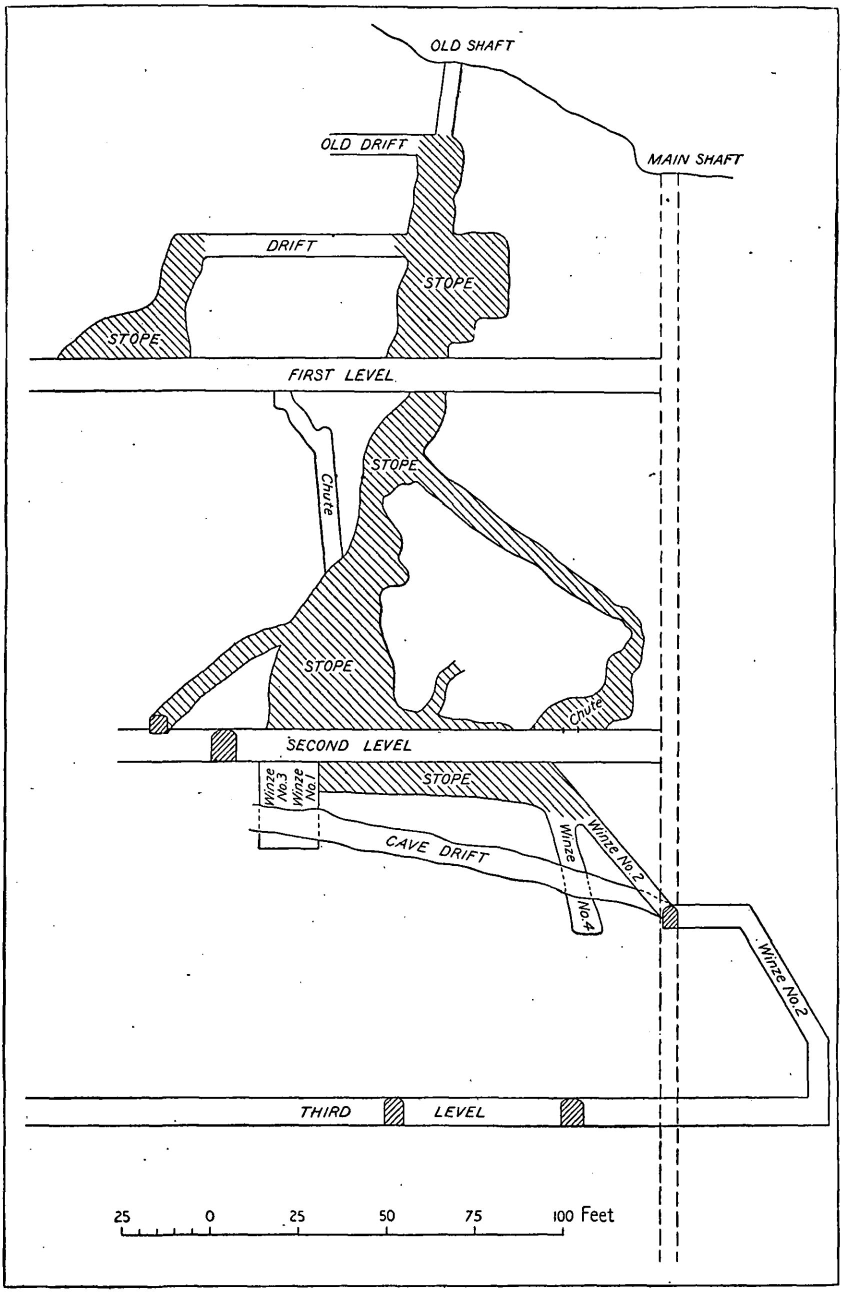


Figure 4.—Longitudinal section of Isle Royal mine.

have also the stock of granite porphyry not far distant. Ground water was encountered and now stands at a little below the 300-foot level, but the mine does not make more than 75 gallons of water a minute.

In the oxidized zone, which extends from the surface to a depth of 330 feet, the ore, including the large chimney-like body extending from the 100-foot to the 300-foot level, is all copper carbonates (malachite and azurite) and is contained in relatively firm limestone.

Good copper sulphide ore, consisting principally of cupriferous pyrite and chalcopyrite, was encountered in moderate-sized bodies on the 400-foot level and continued and was stoped down to the 600-foot level, below which, particularly in the granite, the ore, it is said, seemed to pinch out.

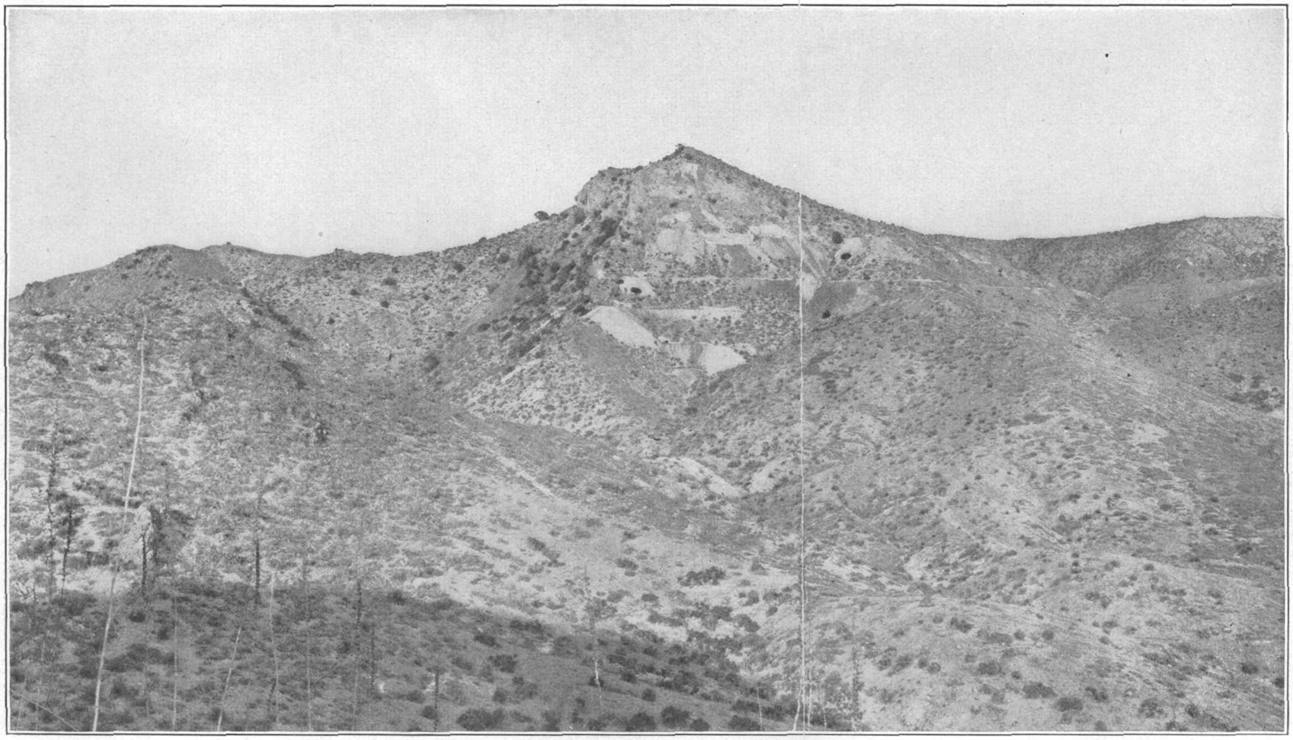
On the 800-foot level, as shown on the map, 1,500 feet or more of exploratory work was done without obtaining encouraging results. In the limestone in the north drift, however, a fault was encountered and followed and a 160-foot winze was sunk upon it, but only a moderate amount of ore was found, and this has never been developed. Except for a reported large body of low-grade ore said to be opened along the stopes in the upper levels (fig. 4), the mine seems to be about worked out. The lower levels were filled with water and the mine was not enterable at the time of visit.

HEAVY WEIGHT MINE.

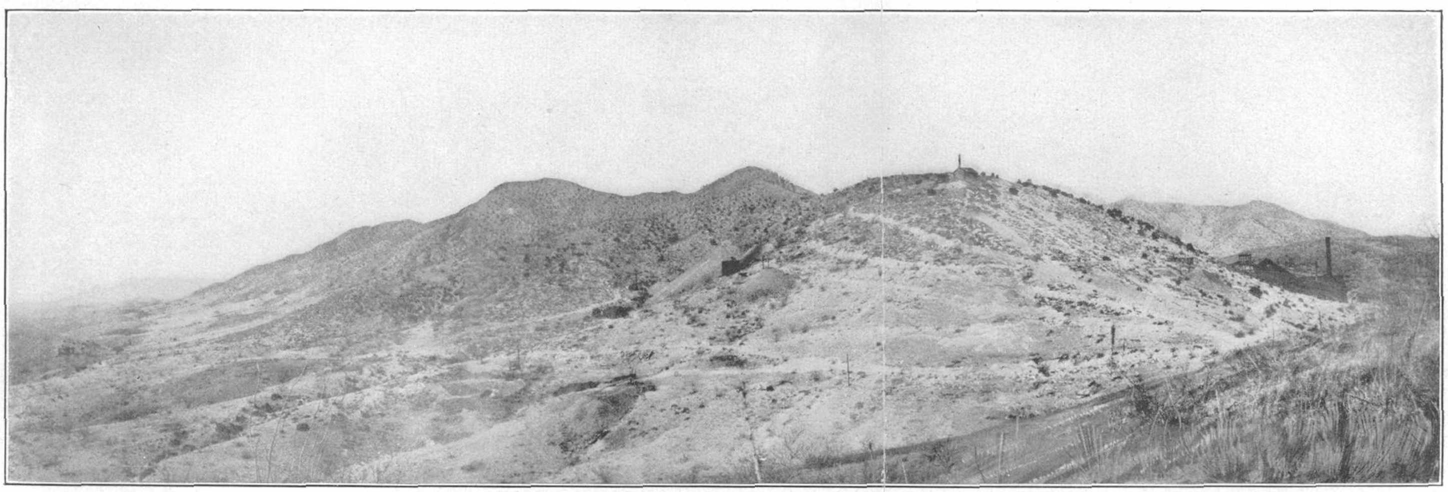
The Heavy Weight mine is about three-fourths of a mile northeast of the Helvetia and half a mile northeast of the Copper World and Leader mines. It is in the steep southwest slope of a low knob called Heavy Weight Hill, at the east end of a transverse ridge or spur which is in part separated from the main range by Sycamore Canyon (Pl. XIV, *A*). It is on the Heavy Weight and Light Weight claims, shown in Plate XI. It is reached by a wagon road, and a railroad extends to the south base of the hill.

The mine was opened late in the eighties, at about the same time as the Old Dick mine (p. 113), and has had a similar history. It was a very heavy contributor to the output of the camp from 1889 until 1902, when it was closed, owing, it is said, to the decline in the market value of copper. The mine is developed by 3,000 feet or more of work, mostly on or between the three levels shown on the accompanying level map, figure 5. Some of the stoping in the upper levels is shown in figure 6.

The mine is on the contact between the limestone and a reddish-gray intrusive rock of the granite porphyry group, and the rocks have locally been considerably disturbed, sheared, and faulted. The intrusive rock has a fine granular groundmass of orthoclase, oligoclase, quartz, and hornblende in which rest phenocrysts, some 0.4 inch long, of oligoclase, orthoclase, and quartz. Though not differ-



A. HEAVY WEIGHT MINE.
Fault scarp at left. Looking N. 80° E.



B. TOTAL WRECK MINE AND MILL.
Looking west.

entiated from the alaskite-granite porphyry on the map, it corresponds closely to what might be called granodiorite porphyry. It is shown typically in tunnel No. 5. Elsewhere—for instance in tun-

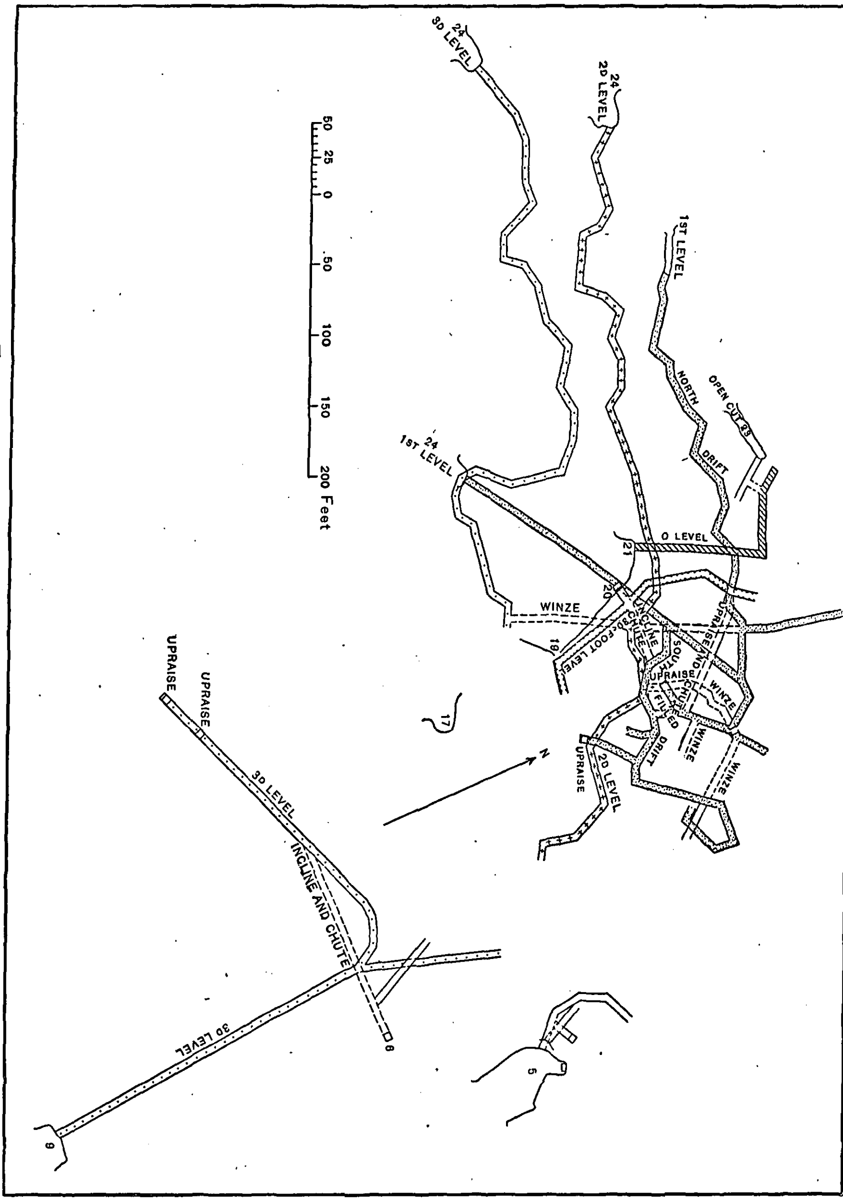


FIGURE 5.—Plan of workings of Heavy Weight mine.

nel No. 9, where it extends in for 120 feet—this same rock is intensely pressed and sheared and is locally called trachyte. In general it underlies the limestone, which, as seen in tunnel No. 5, is the dark limestone and, as shown in sections *B–B′* and *C–C′* (Pl. IX), has in general a southeasterly or southerly dip. In places, about 120 feet in from the portal of tunnel No. 9, the limestone is underlain by a greatly pressed and altered black rock which seems to be a diorite and with which it is probably in thrust-fault contact.

In the first several hundred feet of tunnel No. 24, on the second level, the granite porphyry overlies the dark limestone with steep fault contact, the hade being about 25° SSW. There is much slickensiding, and gouge has been formed from both the limestone and the granite porphyry.

On the southeast slope of Heavy Weight Hill, as shown on the map, the limestone is also considerably contact metamorphosed by

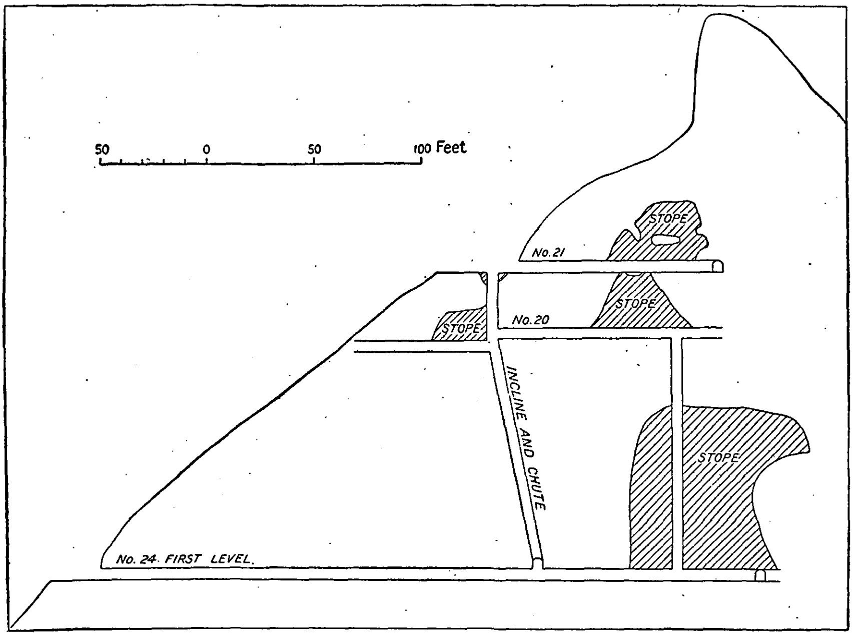


FIGURE 6.—Longitudinal section of Heavy Weight mine.

the granite, which is probably the chief source of the ore deposits. The mine has always been dry.

The ores of the Heavy Weight mine, as seen on the dump and at at a few points underground, consist principally of the common sulphides and carbonates of copper, in about equal amount. They are in general more siliceous and garnetiferous than the ores in the other mines of the Helvetia group.

In tunnel 21, on the alaskite-granite porphyry contact, occurs a 3-foot veinlike body of ore consisting principally of green and brown iron-stained malachite, and in tunnel 24 of the first level, as shown by widely scattered material on the large dump, the limestone contains good chalcopyrite ore liberally coated and stained with secondary bornite and covellite.

Along the faulted granite and limestone contact extending from the Heavy Weight mine westward across the Backbone, Blackhawk, and Wedge claims on the north side of Cross Ridge to the Tiptop mine, nearly a mile distant, there are some good-looking prospects, and it is held by former officials of the company which exploited the ground that a continuous ledge connects the two mines and contains valuable quantities of copper most of the way, but the correctness of the latter part of this assertion seems doubtful.

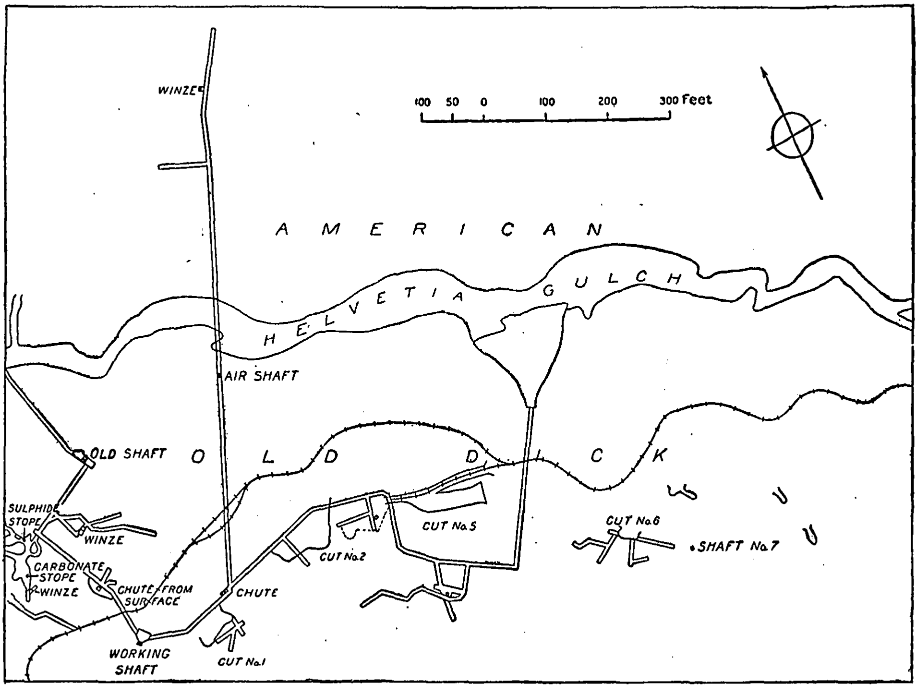


FIGURE 7.—Plan of workings of Old Dick mine.

OLD DICK MINE.

The Old Dick mine is located in the curve of the railroad about half a mile east of Helvetia, in the northerly slope of a detached spur or foothill at an elevation of about 4,500 feet. (See Pls. IV, *B*, and VIII.) It is on the Old Dick and American claims and is one of the oldest mines in the camp. It was opened in 1899 and worked until 1902 and was reopened in 1905 and worked until August, 1907. During the latter period it furnished about all the carbonate and oxidized ores of the camp. Since then, owing to the decline in the price of copper, no work has been done and the underground workings were not enterable at the time of visit. Figures giving the production are not available, but the mine is known to have been one of the heaviest producers in the camp.

The property is developed by 3,000 feet or more of work, mostly on the first level, approximately as shown in figure 7. Besides the levels there are several shafts and large quarry-like open cuts.

The mine, as shown on the geologic map, lies in the southern part of a limestone area about one-fourth of a mile in diameter surrounded by the intrusive granite and alaskite-granite porphyry. The limestone (see sections *C–C′* and *B–B′*, Pl. IX) dips to the north and northeast at medium angles. Toward the west it is mostly white or light, but toward the east it is dark. In the lower part of the mine it rests upon the granite, with which it seems to be in thrust-fault contact, as the ore apparently does not extend downward into the granite. In the main working shaft the granite is encountered at about 110 feet below the surface. There is some water in the bottom of the mine, which makes at the rate of about 25 gallons a minute along the granite and limestone contact.

The ore of the Old Dick mine practically all came from the oxidized zone near the surface, where it occurred as replacement deposits in the limestone and was almost entirely the copper carbonates malachite and azurite, with some red copper oxide or cuprite and generally considerable iron oxide.

Most of the croppings are of the iron-cap type, being composed of the above-named materials, with the surrounding limestone widely and profusely stained with copper carbonate and iron oxide. There are in general two ore zones separated by a few feet of limestone, with which the ore bodies in general are crudely conformable, trending west-northwesterly with northerly dip, but some ore bodies are vertical or chimney-like and form good examples of the ore replacing the limestone. Some bodies of good ore are reported to have been 10 to 15 feet in width. Much of the ore from this mine treated in the Helvetia smelter in early days was of high grade, averaging 14 per cent or more in copper. Some large bodies of 3 per cent copper ore were utilized as flux in treating ores of other mines. Sulphide ore, consisting of solid chalcopyrite, occurs in the bottom of the mine, notably on or in the granite, but not in workable amount, nor was any ore found in the long crosscut which extends 900 feet to the north-northeast in the light limestone. The deeper deposits and also in places the adjoining limestone are traversed by seams or veinlets and are coated with an efflorescence of bluestone or chalcanthite.

MOHAWK MINE.

The Mohawk mine is about a third of a mile northwest of Helvetia and a quarter of a mile northwest of the Old Dick mine, in Helvetia Wash, on the 4,400-foot contour. (See Pls. IV, *B*, and VIII.) It is on the Mohawk claim, which joins the Old Dick claim on the west. The ore zone or body is in limestone, apparently on the northwesterly continuation of the Old Dick lode, on the contact of the limestone and alaskite-granite porphyry, and trends about east. This zone of mineralization in its westward continuation probably contains the Elgin prospect, belonging to the Helvetia Copper Co., which is nearly half a mile from the Mohawk and which produced some ore from 1899 to 1902. However, owing to the irregularity in the geology and mineralization, there seems to be no evidence that it extends to the Tiptop mine, nearly a mile to the northwest, as is commonly asserted.

The Mohawk mine was discovered and located in the early eighties by John Wiegel, but except in the open cut, from which some good 20 per cent copper ore was soon shipped, little development work was done on it until it was purchased by the present owners, the Lewisohns, or Rosemont Copper Co., in 1896. It is their main property on the west side of the range. They sunk a shaft and opened about 400 feet of drift on the 100-foot level. Just off from the shaft on and below this level, beneath the outcrop shown in the small hill by the roadside southeast of the mine, they found two bunches or bodies of ore from which they took out 3,000 tons. On encountering the underlying granite on the 200-foot level and finding no ore, they closed the mine about 1900, and have never resumed operations.

The ore all occurs in or near the garnetiferous limestone, in bodies that average about 4 feet in width, the maximum being about 11 feet, with little if any quartz in the gangue. It was nearly all yellow copper sulphide (chalcopyrite) and was of good grade, not being lowered in grade by iron pyrite, as in neighboring mines. It contained in places a little zinc blende but not enough to be injurious. The ore is said to have averaged 12 per cent in copper. About 500 tons of it, after being roasted on the dump at the mine, was packed over the range on burros and treated in the Rosemont smelter, averaging 22 per cent in copper.

OMEGA MINE.

The Omega mine is nearly $1\frac{1}{2}$ miles east of Helvetia and a quarter of a mile south of the Isle Royal mine, in the steep southwest slope of Monument Mountain, at an elevation of about 5,100 feet (Pls. VIII and X). The property joins the Isle Royal on the southwest and the United States location monument No. 1 is located on the Omega First Extension claim.

The property comprises two claims, the Omega and Omega Extension. It belongs to the Zeckendorfs, who have owned it since the early eighties. Up to 1909 they had shipped 2,000 tons of ore. It is said to be one of the oldest producing properties in Pima County, as the first copper produced in any considerable quantity in the county came from this mine in 1884. Its early owners are said to

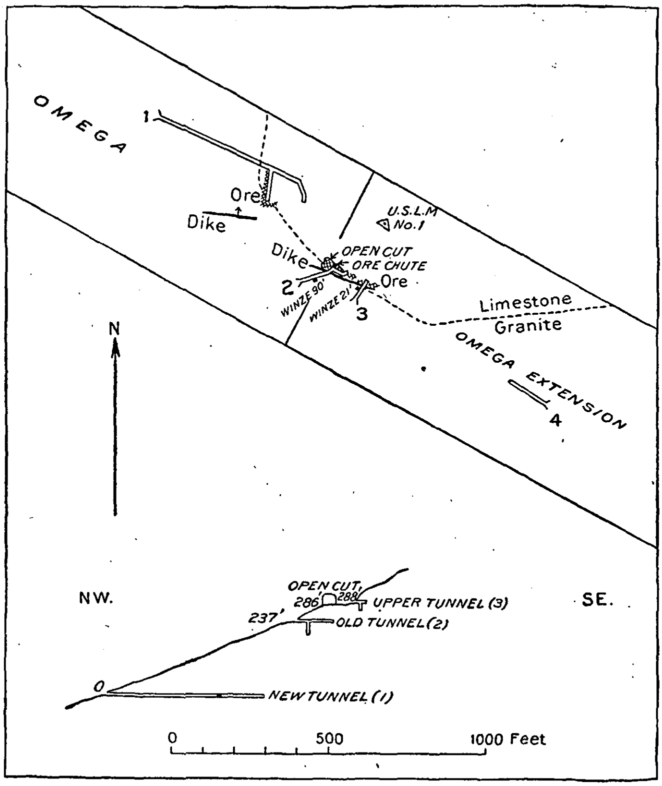


FIGURE 8.—Plan and longitudinal projection of workings of Omega mine.

have had a smelter at Helvetia in the late seventies. It was a producer and shipper of ore in 1907.

It is developed by four tunnels, a shaft, a winze, an open cut, and minor openings aggregating nearly 2,000 feet of work, comprised in a vertical range of 300 feet and distributed as shown in figure 8.

The mine is on a faulted contact of coarse granite intruded into the Paleozoic limestone. The limestone, which is in part mineralized, much epidotized, and otherwise altered, is usually crystalline and near the contact dips 30° NE. The granite for a distance of nearly 100 feet from the contact is sheared and altered and contains subordinate faults, dipping in all directions, especially to the north and to the south. At the joints occur much limonite, manganese oxide, and mica. Aplite dikes are also intruded along the contact between the granite and the limestone in places, as shown by extensive croppings and in tunnels 3 and 4.

The ore is mostly a soft earthy mixture of copper and iron sulphides, with the manganese, copper, and iron-ore minerals of the oxidized zone. In the upper tunnel, however, at the ore chute, occurs a lens of almost pure massive pyrite and chalcopyrite, which in places is coated with limonite.

In the 118-foot drift that extends to the south on the contact in tunnel 1 there is said to be a 2-foot vein of pyrite and chalcopyrite with gouge on either wall, and at the face of the drift, next to a very siliceous dike, which is probably an aplitic rock, occurs a band of epidotized granite 10 feet wide containing considerable pyrite and chalcopyrite.

Tunnel 2, in the easterly part of its course just beyond the chute, traverses a zone of faulted and crushed crystalline and partly epidotized limestone in which occurs considerable soft earthy ore, apparently a mixture of copper carbonates and sulphides with pyrite.

OTHER PROSPECTS.

Among the dozen or more additional prospects in or near the Helvetia camp only a few can be referred to here.

INDIAN CLUB.

The Indian Club prospect is located in the gulch southeast of the Copper World mine, about 700 feet east of the Isle Royal mine, at an elevation of 4,940 feet. It is east of the Copper World alaskite aplite dike, in altered, faulted, sheared, and crushed limestone which dips about 45° N. and which along the displacement zones is silicified but elsewhere crystalline.

The prospect is opened by a 40-foot and an 80-foot tunnel, shallow shafts, winzes, and cuts on two or more levels. It produced some surface ore in the early days, mostly from the upper workings, much of which was a high-grade pulverulent mixture of copper carbonates and chalcocite.

PILOT CLAIM.

The Pilot claim joins the Indian Club on the north and is opened principally by a 70-foot shaft in silicated altered limestone, in which the ore occurs in veinlets containing chalcocite and copper oxides. Open cuts on the claim have produced some rich carbonate ores.

ECLIPSE GROUP.[1]

The Eclipse group of "copper-gold mines," comprising the Eclipse, Backbone, and Triangle claims, of which the Eclipse claim is patented, lies at the rugged crest of the Santa Rita Range at an elevation of about 5,000 feet, between the Helvetia properties on the west and the Rosemont properties on the east. It extends within 700 feet of the Isle Royal ground and is accessible by trail from both Helvetia and Rosemont. It is owned by G. E. Dunbar, of Kalamazoo, Mich. It lies largely on the contact of the upfaulted cupriferous quartzite on the west and the overlying limestone on the east, locally known as the second contact. The limestone along the contact is well mineralized for a width of 20 feet or more and contains the metals indicated in the croppings by a ferruginous copper carbonate gossan or iron cap. The impervious quartzite footwall was seemingly an important physical factor in the concentration of the ore.

At one point the ledge is opened on the Eclipse to a depth of 150 feet, and a crosscut at the bottom of the shaft is said to show a width of 37 feet of vein material with ore minerals mixed through it, of which the 15 feet next to the footwall assays 9.3 per cent of copper and the 4 feet next to the footwall is said to be compact solid sulphide ore containing some glance, a good ore for smelting. An average sample of this ore assayed by the Arizona School of Mines yielded 24 per cent in copper, but the gold and silver were not determined. The ore mined from a similar ore bed 1½ to 2 feet wide in the shaft on the Triangle claim and marketed in Tucson is said to have averaged from 18 to 20 per cent in copper and half an ounce in gold to the ton. The Backbone claim is said to have a 5-foot bed of shipping ore and in places a low-grade lode about 100 feet wide.

The ore taken out in doing the assessment work on the group in 1906 and run by the Helvetia smelter is reported to have yielded about 14 per cent of copper and half an ounce in silver to the ton.

CURTIS CLAIM.

The Curtis claim, owned by Lauterback & Murphy, of Helvetia, is 1⅛ miles southeast of Helvetia. It is opened at an elevation of about 4,900 feet by two tunnels 70 and 90 feet long and about 50 feet apart, in granite. The tunnels are connected by an inclined winze at the faces.

The workings expose a 15-inch fissure vein dipping 10°–20° SE., about parallel with the nearly horizontal sheeting in the granite.

[1] For most of the material here submitted on the Eclipse group the writer is indebted to a manuscript report by Prof. W. P. Blake, and to oral information furnished by Messrs. Thomas Deering and W. B. McCleary.

The vein is composed of drusy banded quartz containing galena, chalcopyrite, and argentite (?), all more or less coated with azurite, malachite, and cuprite. There is some postmineral gouge on either wall, and that on the hanging wall contains considerable muscovite. The ore is reported to average 6 per cent in lead, 8 per cent in copper, and 86 ounces in silver to the ton.

SILVER SPUR (OLD FRIJOLE) MINE.

The Silver Spur, formerly the Old Frijole mine, is located 1¾ miles southeast of Helvetia, at an elevation of 4,900 feet. It is the oldest property in the camp, having been discovered in the late seventies. It was first worked by Hart & Weigel in the early eighties, and is said to have produced $40,000 worth of silver ore. It is opened in the old workings by a 100-foot shaft that is inclined 30° ESE. on a quartz fissure vein in the granite, with levels spaced 30 feet apart. The vein follows a fault and, as shown in the lower part of the shaft, is associated with an aplite dike. In the upper 50 feet of the shaft it consists principally of 4 inches of massive mineral-bearing white quartz, but it narrows below the 60-foot level and pinches to a mere seam in the bottom of the shaft. The ore minerals contained in the quartz are mainly fine-grained dark galena and gray copper, and the ore is stained with lead and copper carbonates and limonite.

At about 300 feet south of the old workings and 200 feet above them, the present workings in a short tunnel have encountered a small, nearly flat-lying quartz vein containing galena, gray copper, and small amounts of pyrite and chalcopyrite.

EXILE AND KING CLAIMS.

The Exile and King claims of the Rosemont Copper Co. are 1¾ miles east of Helvetia, near the crest of the Santa Rita Range. The north end of the Exile overlaps the King. The principal openings are just north of the Helvetia-Rosemont trail and are near together, at an elevation of about 5,400 feet. They consist of several short tunnels, the largest about 150 feet in length, winzes, and stopes. The southern work, seemingly on the King claim, shows a 12-foot ledge of altered, sheared, silicified, epidotized, mineralized limestone next to the contact with the intrusive alaskite-granite porphyry (?), dipping steeply to the north. The ledge contains stringers and pockets of oxidized iron and copper ores.

To the north of this work a 100-foot tunnel extending eastward exposes a similar 10-foot ore body dipping to the south in an opposite direction to the dip of the adjoining unmineralized crystalline limestone. Here the ore consists of malachite, azurite, cuprite, limonite, and a little pyrite and chalcopyrite in a gangue of altered limestone.

About 200 feet northeast of this locality, in dark crystalline limestone, is a large open cut 100 feet long, 30 feet wide, and 20 feet deep that shows in its lower part a 10-foot bed of highly altered, very siliceous epidotized and mineralized limestone. The ore consists principally of limonite, malachite, azurite, and cuprite scattered throughout the bed. On some of the joints occurs later quartz which carries pyrite and chalcopyrite.

TIPTOP CAMP.

LOCATION AND TOPOGRAPHY.

The Tiptop group, comprising the Tiptop, Copper Duke, and Bulldozer mines and sundry prospects, is located about three-fourths of a mile north of Helvetia, in the northwest slope of a prominent foothill, known as Tiptop Mountain, which is connected with the Santa Rita Range by a cross ridge. The mines are mostly close together and are contained in the group of four claims shown in Plate XI. They are owned by the Tiptop Copper Co., of Philadelphia. The Tiptop camp is about half a mile north of the mines, on open, gently sloping lower ground at the forks of the Tucson and Vail wagon roads, as shown on Plates I (in pocket) and VIII.

TIPTOP MINE.

The Tiptop mine, the most easterly and the largest of the group, is located in the northwest slope of Tiptop Mountain at an elevation of about 4,300 feet, but little above the edge of the Santa Cruz Valley bajada. The mountain rises about 1,000 feet higher.

The mine was discovered and located about 1898, but little work was done until 1903, when the Tiptop Copper Co., the present owner, took a bond on the property and began to mine. Besides doing much development work on the upper level this company drove the lower tunnel and encountered good ore, which was shipped steadily at the rate of about 1,000 tons a month from March, 1904, to June, 1905, and again from September until late in December, 1906, when the mine was bonded to the American Smelter & Refining Co. for $75,000. This company only broke ore between stopes 6 and 7, from which it shipped about 300 tons, and after holding the property for nine months relinquished it in November, 1907, to the Tiptop Co., which to the time of writing (September, 1912) with a small force of men has kept up the assessment work on the property and opened some new ore bodies.

The mine is opened by tunnels and developed by more than 4,000 feet of underground work, distributed principally on two levels spaced 100 feet apart vertically, as shown in figures 9 and 10. Some of the stopes are large. The known production is over 22,000 tons of ore, which was practically all shipped to the American Smelting & Refining Co. at El Paso.

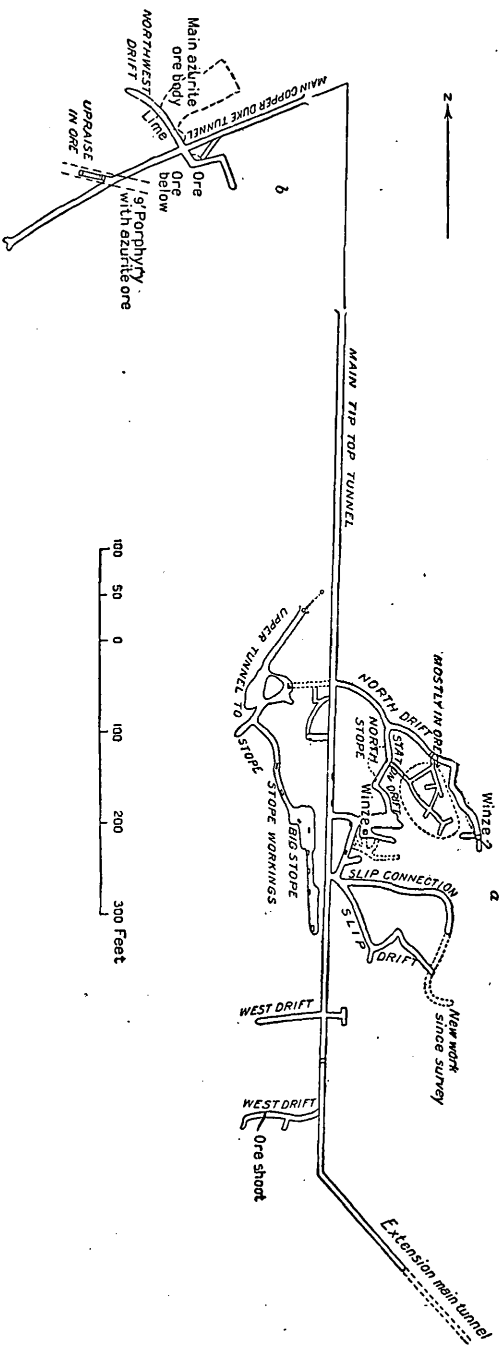


FIGURE 9.—Plan of workings of Tiptop and Copper Duke mines. *a*, Tiptop mine; *b*, Copper Duke mine.

The mine, as shown in Plate VIII, is on the granite and limestone contact, and the Paleozoic quartzite is also present near by. The rocks are all much shattered, faulted, and altered. The dip in general seems to be southeasterly, into the mountain, while the contact dips to the south or, as seen between the granite and quartzite in the lower tunnel at 400 feet in from the portal, to the southwest. The limestone is principally the dark variety and is usually very siliceous. Dikes of aplite, quartz diorite, and quartz monzonite cut the granite and other rocks near by, and what seems to be altered aplite occurs in the mine. In the north base of Tiptop Mountain and Copper Duke Hill a gray-black rock is intruded along the contact. The mine in general is dry, but the large winze on the lower level is full of water.

The ore in most respects is similar to that of the Helvetia mines except that it contains more iron. In the lower part of the mine it consists principally of copper sulphides; in the upper part it is mostly copper carbonates. The ore in general is said to average about 6½ per cent of copper, half an ounce of silver to the ton, 25 per cent of iron, and 33 per cent of silica. Of the sulphide ore the better grade, some of which runs 25 to 36 per cent in copper, is the fine-grained earthy, more or less pulverulent type. The coarse-grained ore, though good looking, usually carries a large proportion of iron.

Though the ore occurs to a considerable extent in association with faults or displacements, which have in a measure determined its position, its characteristic mode of occurrence is in irregular pockets, bunches, and bodies in the crushed and altered limestone, associated with underlying beds of quartzite or stringers of quartz which acted as impervious barriers to arrest the downward progress of the percolating mineral-bearing solutions that deposited the ore. The simplest example of this process is perhaps in stope 6, where a dozen or so square sets of timber stand on a floor of almost hori-

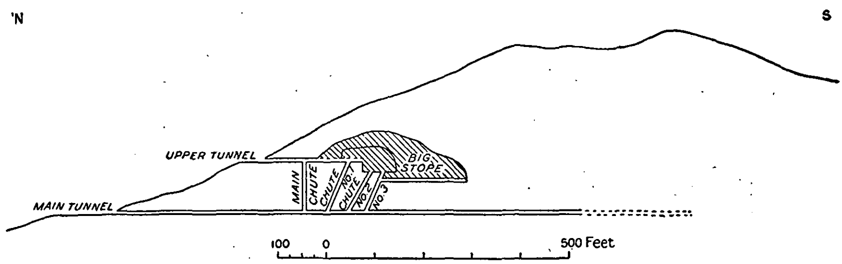


FIGURE 10.—Longitudinal section of Tiptop mine.

zontally faulted quartzite, above which the ore is stoped out. So pronounced is the influence of this footwall feature throughout the mine that in many places very thin quartz stringers dipping at nearly all angles and in every conceivable direction separate overlying good workable 4 to 7 per cent ore bodies from underlying barren limestone.

As in the Copper World mine, the aplite dikes and beds of quartzite, besides causing the solutions to precipitate their mineral load, were also a factor in aiding them to dissolve the limestone by damming them back and increasing the time during which they might act on the rock.

The quartz stringers and seams occur with such irregularity that no rule can be prescribed for the operator except that by following the stringers and seams and keeping near the quartzite footwall good ore bodies are frequently encountered.

The main ore bodies, running about 6 per cent in copper, lie in the crushed and altered limestone next to the quartzite footwall, but richer stringers, some of them carrying from 10 to 25 per cent in copper, make into the hanging wall. Stope A, or "Little's" stope, at 30 feet above the lower tunnel, contains stringers of black sulphide ore 3 to 6 feet wide and 30 feet long, running 36 per cent copper, and higher up occurs carbonate ore with hematite, etc. In the same stope, about midway between the two levels, the limestone rests on the quartzite, with the contact dipping 60° S., and the basal 30 feet of limestone is altered, silicated, and mineralized to an ore body that averages about 4 per cent in copper and is nearly all carbonates or oxidized material. It is mottled with dark rusty-brown iron stain and green malachite. In one place an ore body is underlain by two downwardly-converging footwalls of quartzite, which form a nearly V-shaped trough and delimit the downward extension of the ore body. The carbonate ore in general was passed by when the richer sulphide, which absorbed the attention of the operators, was first encountered.

Higher up in the stope between the lower and upper tunnels, 30 feet east of the quartzite footwall, is a vertical fault contact of the dark crushed limestone bearing carbonate ore, on the west, with the lighter-greenish silicated limestone in which the ore is all sulphide and occurs mostly in bunches, on the east.

In the upper tunnel occurs a cross pyritic or "iron" ledge about 80 feet in width, containing ore in bunches at 50 feet in from the portal, and an upraise to the surface east of a point 65 feet in from the tunnel mouth is principally in 9 per cent ore. The main raise also contains good bunches of sulphide ore, some 3 feet wide and averaging 9 per cent in copper.

A new body of sulphide ore, much the same as that seen in other parts of the mine, has been exposed in recent workings northeast of the hoist and winze on the lower level. The ore accompanies faults and disturbances and occurs in pockets and fissures with numerous quartz stringers extending through the mass. It is mostly soft and friable, somewhat resembling concentrates.

COPPER DUKE MINE.

The Copper Duke mine is located just west of the Tiptop mine, on the same general contact, in the east side of Copper Duke Hill, a northwest foothill of Tiptop Mountain. It is developed by a tunnel, crosscuts, shallow shafts, and a winze (fig. 9). It was discovered in the early seventies and was located in 1898, about the same time as the Tiptop mine, but the first important development work, the driving of the tunnel westerly, was done in 1903. The crosscuts were run in 1904, and 400 tons of ore was shipped.

The ore was mostly stoped from the altered limestone on the north a short distance in from the mouth of the tunnel, in what is known as the main azurite ore body. It was chiefly malachite and azurite with some chrysocolla. It was shipped to the El Paso smelter and ranged from 10 to 50 per cent in copper, averaging 35 per cent, and carried some silver.

The underlying granite as seen in the shallow shaft and winze appears to be relatively barren.

BULLDOZER MINE.

The Bulldozer mine is located mainly in the northwest side of Bulldozer Hill, a low northwest foothill of Copper Duke Hill, at an elevation of about 4,100 feet. The hill rises about 80 feet above the surrounding lowland. It is but a few hundred feet in diameter and consists principally of massive crushed gray to dark malachite-bearing limestone mounted on a 20-foot pedestal of granite. It is on the Bulldozer claim, which is patented ground.

The limestone on the southeast, at the only place where the bedding was identifiable, dips 45° a little east of south. Much of the rock is epidotized and silicated beyond recognition.

The mine is developed principally by a 90-foot tunnel driven toward the east and containing a 40-foot winze and by several shafts and large open cuts. The deepest shaft is 115 feet deep and from it a 100-foot drift has been run to the west and a 130-foot crosscut to the south. Other shafts contain inclines, some of them 60 feet or more in extent. The two principal open cuts are on the north and are each about 60 feet long and 25 feet wide, with a 25-foot vertical face. The work was about all done between 1879 and 1883, after which no mining to speak of was done until the purchase of the mine by the Tiptop Co., which worked it on several occasions. The production was not learned, but it was not large. On the dump lie about 500 tons of chiefly malachite ore containing 4 per cent copper and 1,200 tons of smelter slag said to contain 2 per cent copper. Much slag, it is said, was also hauled away by the Helvetia Co. and used as flux.

The ore is mostly malachite and azurite with some black copper oxide, a little chrysocolla, and here and there a little native copper. Most of the workings were not enterable, but caved shafts and other openings show bodies of ore 6 to 8 feet wide in the crushed and altered limestone, some of them within 10 or 20 feet of the surface. The face of one of the open cuts shows much good-looking ore in greatly altered and crushed limestone, some of which resembles caliche.

Apparently no considerable thickness of limestone is present at or near the mine, and there are no indications of the ore extending downward into the underlying granite.

OTHER PROSPECTS.

The principal remaining prospects of the Tiptop camp are the Noonday, Queen of Sheba, King Solomon, Copper Belt, Mount Leon, and America, opened by 100 to several hundred feet of work each and mostly making good showings. Some of them are principally in altered or disintegrated granite and are said to carry, besides copper, about $6 in gold to the ton.

NOONDAY PROSPECT.

The Noonday prospect, just west of the Tiptop mine and southwest of the Copper Duke, is on a thrust fault and is opened by shafts and drifts to a depth of 70 feet. The first 50 feet lies in crushed and silicified limestone or aplite and is more or less impregnated with copper carbonate ore associated with rusty iron oxide and hematite. In the face and on the footwall side of the 25-foot drift to the east on the 70-foot level is a 1½-foot vein of good-looking sulphide ore, composed mainly of chalcopyrite and pyrite.

PEACH PROSPECT.

In connection with the Tiptop group, by reason of its location, may be mentioned the Peach prospect, a patented claim located to the south of the Noonday and owned by the Rosemont Copper Co. It is opened by a shaft to a depth of 60 feet and some drifts, the work all being in altered and highly mineralized limestone containing considerable blue, green, and black copper carbonates, some chalcopyrite and chrysocolla, and much brown iron stain.

As the beds of upfaulted quartzite form the footwall on the west, it seems reasonable to attribute this high degree of mineralization to leaching of the copper from deposits that were contained in the limestone, which formerly overlay the quartzite higher up—for instance, on the adjoining Copper Belt claim and nearby on the northwest—but which has since been removed by erosion. Concentration of these minerals is due to waters percolating down the dip plane of the quartzite and depositing their mineral burden at lower levels in the adjoining limestone.

HENRIETTA PROSPECT.

The Henrietta prospect is in a low isolated hill about half a mile north of Tiptop. It was located in 1905. The hill is composed of coarse porphyritic granite which is freely intruded by north-south dikes and small bodies of aplitic rock, which in turn, together with the country rock, were intruded by east-west dikes of medium-grained diorite and granodiorite. Still later the whole was intruded by northeast-southwest amphibolite dikes.

The prospect is in the southwest side of the hill, on a quartz lode which is 20 to 30 feet wide and dips 60° NW. The lode at the prospect consists of three parallel quartz veins separated by two narrow bands or horses of granite country rock. On the hanging-wall side it is associated with a dike or intrusion of typical aplite 150 feet wide, and on the footwall side it is partly intruded by an amphibolite dike 20 feet or more wide.

At about 50 feet above the base of the hill the ledge is opened by a 16-foot cut with a 7-foot vertical face. Here the quartz is mostly bright red, and an average sample of it in the hanging-wall side toward the aplite is said to carry about $8 in gold and 7 ounces in silver to the ton. Lower down the slope, on the trend of the hanging wall, a 45-foot shaft sunk partly in altered granite, quartz, and the associated amphibolite dike shows 5 feet of granitic material heavily stained with copper carbonate and containing some chalcopyrite and pyrite. This material is said to average as a whole 4 per cent in copper and 45 ounces in silver and $6 in gold to the ton. The shaft portion of the prospect looks more auspicious toward the northwest than toward the northeast.

RIDLEY MINE.

The Ridley mine is located a mile southwest of Helvetia, in a low foothill in the United States Range Reserve, on the Old Baldy wagon road, at an elevation of 4,060 feet. (See Pl. VIII.) The mine is on one of a group of six claims owned by C. B. Ridley. It is of special interest in that it is on a fissure vein deposited in the granite remote from the limestone or any other sedimentary rocks, and forms an exception to the rule that in the Helvetia camp and vicinity workable deposits are restricted to the limestone.

The country rock is granite intruded by dikes and small stocks or masses of aplite and containing quartz veins, which are generally associated with the aplite. The mine is on one of these veins that dips 50° E. The vein is about 4 feet in width and is in most places separated from either wall, which is slickensided, by a sheet of gouge. It is opened principally by a 150-foot inclined shaft and a short tunnel, with short drifts on the 50-foot and 105-foot levels, as shown in figure 11. On both walls, which are good and well defined, the granite is considerably altered, crushed, and sheared. On the hanging wall it is yellowish gray and similar to the normal country rock. On the footwall it is dark greenish-gray and contains much secondary chlorite, muscovite, quartz, and some dark minerals, chiefly biotite and hornblende.

The mine is dry nearly to the bottom, where, however, the sump contains 5 feet of water that seems to be permanent. The value of the ore, which unfortunately contains several nonessential metalliferous minerals, is principally in copper and lead. Sulphides were encountered at about 40 feet below the surface, and in the south drift on the 50-foot level the quartz, which is drusy and stained with limonite and copper carbonates, carries dark massive galena and chalcopyrite. Just below this level the sulphides become more plentiful, and in a short drift to the south on the 105-foot level the entire vein, which contains sulphides, is a fair concentrating ore and on the hanging-wall side contains a 10-inch pay streak, mostly of shipping grade. The pay streak consists of alternate bands of mixed sulphides and quartz, the sulphides being pyrite, chalcopyrite,

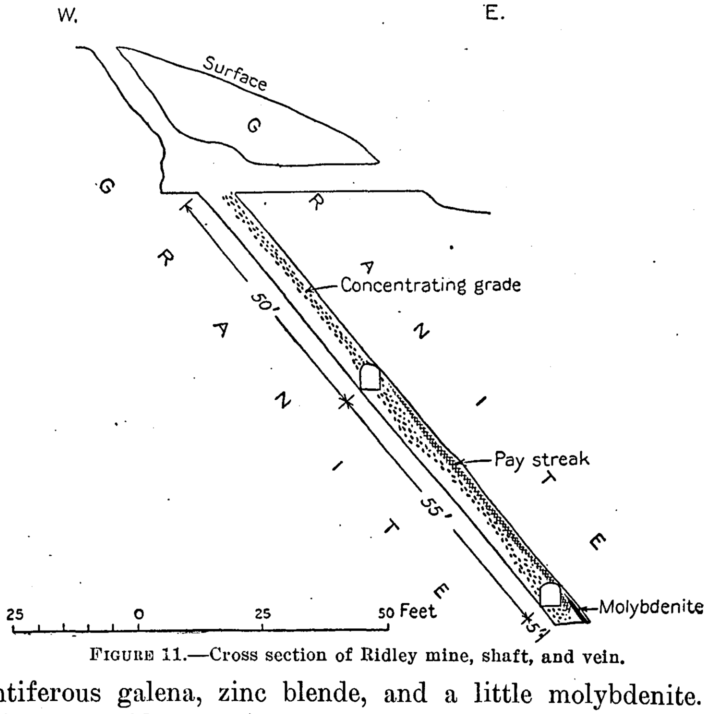


FIGURE 11.—Cross section of Ridley mine, shaft, and vein.

argentiferous galena, zinc blende, and a little molybdenite. The principal sulphides, particularly the pyrite and chalcopyrite, occur in places individually in separate bands. It is said that this grade of ore, of which there is about a ton on the dump, averages about 6.5 per cent of copper, 3.5 per cent of lead, 3 per cent of zinc, and 30 ounces in silver, and $1.50 in gold to the ton.

In the lower drift a little molybdenite is scattered through the sulphide ore. In the sump at water level between the pay streak and the hanging wall occurs a $\frac{1}{8}$-inch to 1-inch band of gougelike material composed of muscovite, quartz, pyrite, and molybdenite, and in a few places this band widens to 4 inches and constitutes a good ore of molybdenite, as described in an earlier report.[1] Its concentration, however, may be difficult owing to its mixture with mica.

[1] Schrader, F. C., and Hill, J. M., Some occurrences of molybdenite in the Santa Rita and Patagonia mountains, Arizona: U. S. Geol. Survey Bull. 430, p. 157, 1910.

ROSEMONT CAMP.

GENERAL FEATURES.

The Rosemont camp is located in the southeastern part of the Helvetia district, about 4 miles southeast of Helvetia, on the east side of the Santa Rita Range, in Barrel Canyon. At one time it was a flourishing village, but since the closing of the Lewisohn mines and smelter it has been almost deserted. It contains a score or more of properties, some of which are capable of production. Some of the claims were located in the late seventies or early eighties, and in 1896 passed from the hands of the Rosemont Mining & Smelting Co. into the possession of Lewisohn Bros., of New York City. Several of the chief claims, such as the Chicago, were worked in an exploratory way for the next 10 years. Recently the Lewisohns are reported to have also taken a two-year bond on the Narragansett group under development stipulations, and the Mueller group of five claims has been bonded on similar conditions.

The properties are mostly in the upper east slope of the range and are reached by trail, some of them joining the Helvetia properties at the crest (Pl. XI). They are chiefly in the Paleozoic limestone, which is in places highly garnetiferous and epidotized and which in the middle slope of the range passes beneath Mesozoic sediments of wide extent. The limestone is in general much faulted and crushed, and the fault planes and structure dip steeply to the south. Here and there it shows also horizontal displacement. It is locally intruded by the Mesozoic granular rocks, some of which, as the diorite on the Murphy claim, are heavily impregnated with pyrite, cupriferous pyrite, and chalcopyrite.

The following list comprises the properties which contain from 100 to several hundred feet of work, but only a few of them can be described here:

McCormick.	Jumper.	Old Put.
Narragansett.	Chicago.	Fremont.
Eclipse.	Gray Copper.	Record Excelsior.
Merchant.	Pickwick.	Mohawk Silver.
Hunter.	Coconino.	Golden Gate.
Dick Murphy.	Sweet Bye and Bye.	Gold Fish.
Humming Bird.	Old Pap.	

NARRAGANSETT CLAIM.

The Narragansett claim is located near the crest of the range at an elevation of 5,500 to 5,600 feet and joins the Eclipse group on the east. It is owned by J. K. Brown, who discovered it in the late seventies. It is in limestone, which is mostly crushed and altered, and is opened near the center of the claim by several inclined shafts, tunnels, and winzes to a depth of nearly 300 feet. The main incline, which is 125 feet deep, dips 40° SW. It is on a 20-foot ore bed formed on a fault plane and is in ore all the way down. The ore bed seems to be a mass of crushed and altered limestone impregnated with copper carbonates and iron oxides. It is locally parallel banded. The ore on the dump contains huge bowlders of iron ore and of copper glance coated with iron oxide.

The dump at the northwest tunnel contains about 75 tons, mostly of iron ore, but with sufficient chalcocite and copper carbonates to run by estimate about 3 per cent in copper.

CHICAGO PROSPECT.

The Chicago claim, located 1 mile south of the Narragansett claim, is one of the oldest in the camp, and in the early days produced some rich surface ore which was smelted in the Columbia furnace, about a mile north of Helvetia. It is opened principally by a 100-foot shaft sunk in limestone on the contact of a dike of granite porphyry along which there is a fault zone of crushed material and contact-metamorphic minerals showing large fragments of limestone containing pyrite, chalcopyrite, malachite, and cuprite. A good body of sulphide ore is said to occur in the bottom of the shaft, which at the time of visit was filled with water within 20 feet of the surface.

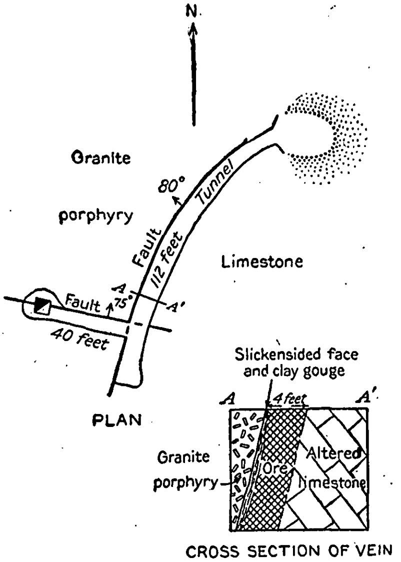


FIGURE 12.—Plan of tunnel and cross section of vein on Pickwick prospect.

PICKWICK PROSPECT.

The Pickwick prospect, owned by McCleary and partners, consists principally of a 4-foot ore body lying along a fault plane which dips 80° NW. between intrusive altered granite porphyry on the hanging wall and limestone country rock on the footwall (fig. 12). The ore minerals are largely cuprite, malachite, and azurite contained in a gangue of crushed and altered limestone and porphyry, but at a point 100 feet in from the portal of the tunnel, where the tunnel and the main fault are intersected bv an east-west or cross fault, there occurs a considerable accumulation of carbonate copper ores, with some chalcocite.

COCONINO CLAIM.

The Coconino claim of the Rosemont Copper Co. trends north and joins the south end of the Chicago claim. The work is all badly caved but shows a 12-foot zone of crushed, silicified, and mineralized limestone which dips to the north under a hanging wall of granite porphyry. In this zone there is developed some epidote with quartz, calcite, and the ore minerals cuprite, malachite, azurite, and chrysocolla. Postmineral movement is shown by a north-south fault dipping 60° E., which cuts the crushed zone. Three large open cuts on the property show considerable east-west and north-south faulting and mineralization along the fault lines. In a cut about 100 feet southeast of the main group of openings occurs a zone of crushed limestone over what appears to be a dome of silicified limestone containing cuprite and copper carbonates. This ore is capped by granite porphyry.

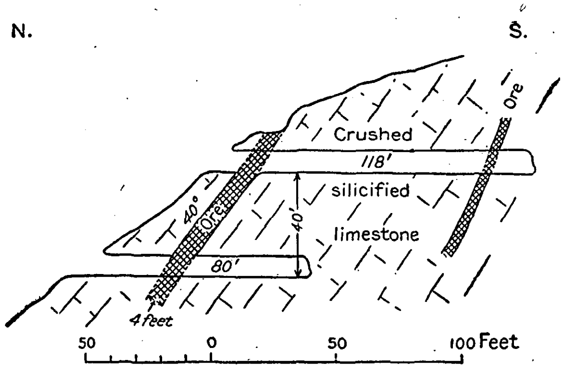


FIGURE 13.—Cross section of Sweet Bye and Bye mine.

SWEET BYE AND BYE CLAIM.

The Sweet Bye and Bye claim, about 1½ miles southwest of Rosemont, is owned by William Powers, of Patagonia, and is developed by two tunnels. The upper tunnel, at an elevation of 5,400 feet, extends south 118 feet in altered, crushed, and silicified limestone and crosses numerous east-west slip planes and two zones of more marked faulting along which copper carbonates are deposited (fig. 13). A fault at the mouth of the tunnel dips 40° N. At 25 feet in from the mouth a winze, 40 feet deep, connects with the lower level and is apparently all in ore, which consists of a more or less banded mixture of quartz, cuprite, malachite, azurite, chrysocolla, and an undetermined white to gray earthy mineral. At the winze there is a crushed mineralized zone about 3 feet wide containing copper carbonates, of which a belt about 6 inches in width shows the banded nature and order of deposition of the siliceous carbonate ore, the order being the same from both walls, with malachite next to the walls and cuprite in the middle of the belt. The carbonates are mixed with silica and the vein has suffered movement, as it shows crushed material separated by veinlets of quartz. A similar but less heavily mineralized zone occurs at 98 feet in from the mouth of the tunnel.

OLD PAP CLAIM.

The Old Pap claim, the property of the Rosemont Copper Co., is opened by a tunnel at an elevation of 5,660 feet on the east side of the crest of the Santa Rita Mountains, just south of Weigle Butte. The tunnel runs N. 17° W. along a fault in altered, sheared, and mineralized quartzite and ends in granite (fig. 14). At 118 feet from the mouth it crosses an east-west fault dipping to the south, and drifts are turned both ways on the fault. This fault zone is marked by much silicification of crushed granite and quartzite which carries copper carbonates, cuprite, and chrysocolla in a somewhat banded structure due to movement. A winze is sunk in this mineralized zone at the end of the east drift. From the mouth of the tunnel to the main fault the rock is much crushed and contains copper carbonates scattered through the shattered material and on joint and shear planes.

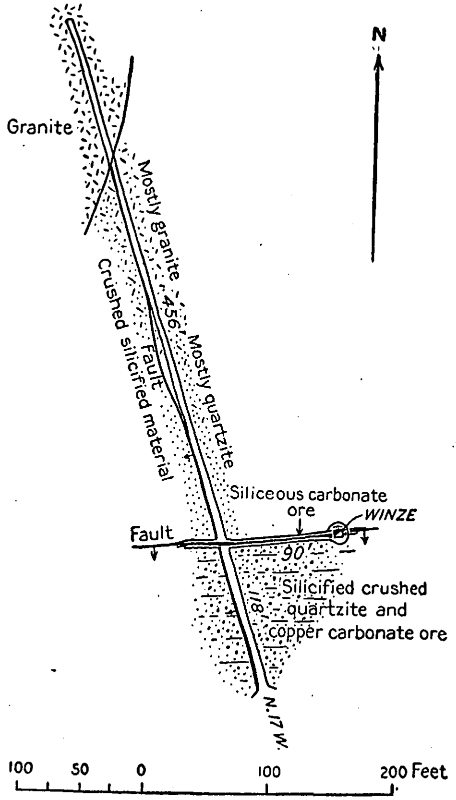


FIGURE 14.—Plan of Old Pap tunnel.

An open cut 75 feet above the mouth of the shaft is apparently located on the fault seen in the tunnel and shows a very siliceous mixture of oxidized copper ores.

OLD PUT CLAIM.

The Old Put claim of the Rosemont Copper Co. joins the west side of the Old Pap claim. The development on this claim is located about 100 feet above the Old Pap tunnel and a little northwest of the mouth of the tunnel known as No. 29. A 65-foot tunnel runs N. 64° W. in much shattered iron-stained quartzite which is impregnated with copper oxides and carbonates. At the end of the tunnel there is a large stope or chamber about 100 by 50 feet and 25 feet high, the walls of which consist of crushed, shattered, and mineralized quartzite. Carbonate ores from this claim were smelted in the early days at the Mohawk smelter.

GOLDEN GATE GROUP.

The Golden Gate group of claims lies 2½ miles southwest of Rosemont, along the ridge running northwestward from Deering camp and in the valley west of the ridge. The upper work is located along the Deering-Helvetia trail, about a mile northwest of the camp. Here there is a 40-foot incline on what appears to be a depositional contact of dull-red sandy shale and overlying limestone. This contact dips 45° E. At the bottom of the incline there is a 20-foot crosscut whose face is in unaltered light-gray limestone. Along this contact movement has produced a shear zone about 15 feet wide composed of shattered altered limestone and sandy shale. In this zone, which is heavily iron stained, occur stringers and bunches of galena and a little malachite or azurite in films along slickensided surfaces. A little gold can be obtained from panning almost any of the more heavily iron-stained croppings, or from the siliceous pockets at the surface, which show considerable limonite and cerusite.

BLUE JAY MINE.

The Blue Jay mine is 2 miles north of Helvetia and 12 miles south of Vail, on a northwest spur of the Santa Rita Mountains, in the south fork of Sycamore Canyon, at an elevation of 4,400 feet (Pl. II, in pocket). It is in the south side of the canyon, in a northward-sloping hill, and is reached by wagon road from Stone's ranch on the northwest and by trail from the southwest. The topography of the country is hilly but not rugged.

The mine was discovered in 1881. In 1882 it was sold to the present owner, the Iowa Mining & Development Co., of Cedar Rapids, Iowa, and in 1884 a roll mill for treating the ore was built in the canyon half a mile to the north, but the mill was not a success and the company began shipping the ore to Benson. From the discovery cut, 30 feet long and 5 feet deep, on the upper west slope of the hill, considerable ore, seemingly mostly cerargyrite, averaging 800 ounces in silver to the ton, was taken out in the early days. Included in the early shipments were three carloads of ore which averaged $60 to the ton above expenses, and 250 tons of good second-grade ore was sold to the Tucson Sampling Works. At present the ore is shipped to El Paso. The mine was an almost steady producer on a small scale from the time of its discovery to 1902 but was not a paying mine. In 1902 it was worked under lease and produced from the porphyritic streak contained in the middle of the main vein four carloads of ore that averaged 140 ounces in silver and $8 in gold to the ton. Since 1902 little but development work has been done with a small force of men, except that in 1907 five carloads of ore that averaged 300 ounces in silver and $8 in gold to the ton was mined and shipped.

The mine is developed by four tunnels, several shafts, drifts, crosscuts, stopes, and winzes aggregating 3,000 feet or more of work. The main and lowest tunnel is a crosscut tunnel. It opens on the northeast in limestone at an elevation of 4,380 feet and runs S. 54° W. three-fourths of the way through the hill, ending in granite porphyry at 100 feet below the surface and 25 feet beyond the main vein. From a point near the middle of its length a 150-foot winze is sunk to the vein.

The remaining three tunnels all open on the northwest slope of the hill and run southeastward. The lowest is the Pickett tunnel, at an elevation of 4,430 feet. It is on the main vein and is 300 feet long. The Southwest tunnel, at 4,510 feet, is on the Southwest vein and has a length of 150 feet. The Crooked tunnel, at 4,520 feet, follows a lamprophyric dike for a distance of 160 feet and extends through the hill.

The principal shaft is the Wells shaft, located at an elevation of 4,410 feet, or about 60 feet lower than the main crosscut tunnel, and several hundred feet distant horizontally from its face. It is 110 feet deep and about 500 feet of drifts and crosscuts have been run from it, but it has not produced much ore and is not connected with the tunnel workings below.

The mine is principally in the dark-blue or black Carboniferous (?) limestone, on or near its contact with intrusive siliceous granite porphyry. The contact trends east, but the limestone dips steeply to the northwest and is cut by dikes of dark-greenish lamprophyric greenstone porphyry that dip steeply to the northeast and are associated with the veins and ores. At the mine the dikes are thin, rarely exceeding 4 feet in thickness, but a mile to the north, on the opposite side of the canyon, there is a reported 40-foot dike of the same rock trending northwestward, up the slope of the hill. The diorite and granophyric dikes of Henrietta Hill also occur near by on the west. Schists and rocks resembling graywacke and arkose, seemingly older than the limestone, occur near by in the canyon on the north.

The deposits occur in the dark limestone country rock, to which they seem to be restricted. None of them were observed to extend into the granite and, according to the reports of the operators, none occur in the granite. They occur principally in two veins or lodes which dip steeply to the northeast and are associated with the lamprophyric dikes. The main vein dips about 75° NE., but the dip flattens locally with increase in depth, and as seen in the workings in the main crosscut tunnel extending beyond the faces of the drifts to the east and to the west and upward into the stopes the vein is from 6 to 18 feet in width, averaging about 10 feet. It consists of sulphide-bearing altered limestone or calcareous quartz and in places contains smaller sulphide veins carrying chiefly silver and gold. From the tunnel level the vein is stoped upward in places to a distance of 50 feet, and it is also encountered at 150 feet below the tunnel level, in the bottom of the winze. It is opened by half a dozen cuts and open works extending from the base to the top of the hill on the southwest and similarly but to a less extent on the northeast. From the top of the hill to the bottom of the winze the vein thus has a known vertical extent of about 350 feet.

In the Crooked tunnel, where the vein throughout is associated with a lamprophyric dike and both dike and vein are greatly crushed, the ore occurs mostly on the footwall side of the vein within a width of 3 or 4 feet, but the richest ore is found in the hanging-wall side in the form of dark iron-gray or blackish shoots from 1 to 6 inches in width. From this tunnel level down to the shaft and to the Pickett tunnel the ore is mostly stoped out, and some good ore has been stoped also from the Southwest tunnel, on the Southwest vein, where both the vein and the associated lamprophyric porphyry dike are considerably more oxidized and the vein is locally split by the dike and contains relatively more quartz.

The ore of the mine in general averages about 100 ounces or more in silver and from $4 to $25 in gold to the ton; and a considerable portion of it exceeds 300 ounces in silver to the ton. The ore minerals are principally argentite and gold, but in the early surface workings the silver mineral seems to have been mostly horn silver or cerargyrite. The ore contains in places considerable cerusite, a little pyrite, a trace of galena, and some copper stain but not copper in appreciable amount.

BEUHMAN HILL AND VICINITY.

CUPRITE MINE.

The Cuprite mine is located at the extreme north end of the Santa Rita Mountains, 7 miles northeast of Helvetia and 8 miles south of Vail, the nearest station on the Southern Pacific Railroad, with which there are good wagon-road connections (Pl. I, in pocket). It is on open ground near the head of a southern tributary of Pantano Wash, at an elevation of 4,050 feet, at the east base of Beuhman Hill, a dome-shaped hill that rises 500 feet above the surrounding surface.

The mine was discovered and located in 1899 by Louis Ezekiel and is owned by him and F. W. Fish, of Tucson. It has been worked nearly every year since, mostly under lease. It is developed principally on the 60 and 100-foot levels and by four shafts, the deepest 120 feet deep, drifts, and crosscuts, aggregating about 700 feet of work. The 100-foot level comprises more than 200 feet of workings.

The mine has produced about 2,000 tons of good-grade copper ore, mostly within a few years after it was located. The ore was shipped to El Paso and Douglas.

The mine is on the west edge of a north-south mineralized zone, locally called the Black Horse ledge. It is principally in altered silicated limestone on or near its contact with underlying quartzite. Granite and aplite have been introduced near by and are probably present in the mine. The quartzite is provisionally referred to the Cambrian, but may be as young as Carboniferous.

The granite as exposed in the properties to the north of the mine is a medium-grained eugranitic monzonitic rock, composed of orthoclase and albite-oligoclase in about equal amount, quartz, and biotite, with apatite and titanite as accessories.

The quartzite, as shown by a series of shallow shafts extending southward from the mine, is cupriferous, as is also the granite in a shaft of the same series about half a mile from the mine. The shaft near the house and store, which seems to be on or associated with an aplitic porphyry dike in the quartzite, is said to end in bornite ore of good grade, and the well 40 feet deep near by is reported to end in ore of fair grade containing principally chalcopyrite. Just over the saddle northwest of the mine occurs a dike of lamprophyric greenstone porphyry overlying shaly slate, and it seems likely that a somewhat similar greenstone which forms a considerable part of the south slope of the hill to the west may occur in the mine.

The mine is on two veins or ledges at or near their point of intersection, principally in or near the altered mineralized garnetiferous limestone. One vein dips about 30° N. and the other 43° SE. The latter is the larger and stronger. It more nearly parallels the contact and extends upon the Wedge claim, to the north. Its ore mineral is almost wholly relatively pure chalcopyrite, but the east-west ledge contains, besides the usual copper carbonates and sulphides, a considerable mixture of iron and some molybdenite, the latter mineral occurring, it is said, in small kidneys disseminated through the ore. Almost the whole of the mine's production came from this vein, from a large ore body lying mainly east of the main shaft, in or near the garnetiferous zone. The body was first encountered in the shaft at 90 feet below the surface, and the shaft continues in it all the way to the bottom, at 120 feet, and does not reach its lower limits. The same is true of the 90-foot drift which extends to the east on the

100-foot level. The ore which was mined here averaged 6 per cent in copper, and some hand-sorted carload lots ran 12 per cent. Later shipments from the dump carried 4 to 5.5 per cent. The bulk of the ore, however, which remains in the mine at this place, and which is said to be a large quantity, is of low grade, averaging but 2.5 to 3 per cent in copper, and the dump of 1,000 tons now at the mine contains, it is said, about 2.5 per cent.

In the mine there is said to be present generally throughout the ore bodies a whitish talclike substance impregnated with chalcopyrite, pyrite, and some bornite. On the lower level is a body with principally a limonite replacement gangue which, it is said, averaged 14 per cent in copper.

The ore as seen on the weathered dump at the mine is mostly a mixture of fine-grained chalcopyrite and pyrite contained in a gangue of gray-brown garnetiferous limestone silicate and largely coated or stained with malachite, azurite, limonite, black copper oxide, and some secondary chalcocite. A little bornite and molybdenite are also present. The molybdenite occurs in streaks and in small lenses nearly half an inch in maximum width. The ore is heavy, owing largely to its iron and garnet content. Besides its copper it averages about 4 ounces in silver and 55 cents in gold to the ton.

This mine could probably be profitably worked with a small concentrating plant on the ground, for which the water supply is seemingly ample. Water now stands at the 60-foot level in the mine and within 20 feet of the surface in the 40-foot well.

COPPER ALECK AND ADJACENT PROSPECTS.

In the low foothill area adjoining the Cuprite mine on the north and occupied principally by light crystalline limestone and intrusive dikes and stocks of very fine grained acidic biotite granite, occur a number of promising copper prospects—the Copper Aleck, Black Horse, Nevada, Green Monument, Coyote, and others whose names were not learned. These prospects, like the Cuprite mine, are on or associated with the contact of the intrusive granite, aplite, or lamprophyric rocks with the limestone. They are opened by shafts 40 to 50 feet deep, short tunnels, and cuts, and some of them have produced and shipped small amounts of ore.

Most of the ore, as seen, for example, in the Black Horse, opened to a depth of 50 feet north of the Cuprite mine, is copper carbonate and occurs principally in bunches in a garnetiferous gangue, but in some prospects, such as the Copper Aleck, the ore is principally chalcopyrite, pyrite, and black copper oxide and mostly assays 10 per cent in copper.

The Copper Aleck deposit is an ore bed in white limestone. It dips to the east-northeast, has a known extent by croppings of about one-fourth of a mile northwestward to the Nevada claim, and is associated with the fine-grained intrusive granite which is apparently the principal mineralizer of the area. The outlying so-called "iron hills" extending from 1 to 4 miles to the northeast are outcrops of this rock.

NEW YORK MINE.

The New York or Beuhman mine is situated in the west slope of Beuhman Hill, three-fourths of a mile west of the Cuprite mine. The camp, located at the base of the hill, is reached by wagon road from Vail. The property comprises eight claims, known as the New York group, and is owned by the New York Copper Co., of Tucson. It was worked in the early days for silver, but the silver content was found to be too low to be profitable, and it is now being exploited for copper with moderately encouraging indications but has not yet produced anything commercially. The mine is opened principally by two tunnels and a shaft comprised within a vertical range of 500 feet. The new tunnel now being driven to crosscut the ledge is at an elevation of about 3,850 feet and extends N. 75° E. for 210 feet. The first half is in diorite and the rest in very hard brown garnetiferous silicated limestone which dips northeastward into the hill.

The country rock is principally the silicated garnetiferous limestone, freely intruded by fine-grained dark diorite and granite porphyry.

The mine is on a north-northwest mineralized contact and shear zone about 200 feet in width between the intrusive diorite and limestone, and near by is a large granite porphyry dike with which it is thought to be genetically connected. The zone locally contains much calcite, epidotized quartz, manganese, iron oxide, pyrite, chalcopyrite, and some copper carbonates, some bodies of which range from 2 to 4 per cent in copper, but the general hardness and tightness of the formations is not regarded as favorable for ore deposition.

The old tunnel, located at an elevation of 4,270 feet, several hundred feet to the north and 420 feet above the main tunnel, runs S. 54° E., in the direction of a prominent black dikelike cropping farther up the hill. It is said to have a length of 400 feet, to be branched, and to contain considerable crosscut work and drifting, but it was not enterable at the time of visit. It is mostly in the diorite, but the first 20 feet is in the granite porphyry dike, which is deformed along with the diorite by a westward-dipping sheeting. The tunnel starts beside and nearly parallels another 25-foot greenish epidotized dike, in which in a 12-foot cut 25 feet above the mouth of the tunnel the rock is mineralized, ferruginous, and cupriferous, with considerable malachite stain, and a few tons of it is piled aside for ore. At 50 feet farther up the slope on the same ledge there are an opening and a pile of dark-brown and greenish copper-stained ore in which the gangue seems to be principally hematite and silicate rock material in which chalcopyrite and pyrite are disseminated. Here the principal part of the mineralized and stained portion of the ledge dips 75° SSW.

On the slope between the new and the old tunnels occur bowlders of mixed coarsely crystalline calcite quartz and green fluorite containing some antimony, all derived from the ledge above. One of the upper prospects east of the 80-foot shaft, which is beyond the face of the new tunnel, shows good streaks of chalcopyrite in the epidotized greenstone dike.

PAULINE MINE.

The Pauline mine is a mile southeast of the Cuprite mine, on open ground, and is accessible by wagon road from Vail.

The country rock is the dark Carboniferous (?) garnet-bearing limestone. It is freely intruded by dikes and stocks of an aplitic rock and in the vicinity of the mine, especially to the south, is well mineralized. The material from the surface openings contains gold, silver, copper, lead, zinc, molybdenite, and antimony. In the region surrounding the mine the limestone is overlain by dark-greenish Mesozoic rocks which here are principally shale.

The property was located in 1902. It comprises 12 claims known as the Pauline group, after the claim on which the most development has been done. It is opened principally by a 150-foot shaft and a short crosscut. It has produced a small amount of lead ore containing principally galena and lead carbonate, obtained near the surface. In depth the deposit becomes copper ore.

The vein or principal part of the ledge has a width of 7 feet, and dips 45° N. It is crudely banded and contains principally chalcopyrite and pyrite, with a little chalcocite, galena, specularite, zinc blende, antimony, and molybdenite in an altered limestone silicate gangue, which is composed largely of massive garnet with interstitial quartz and contains some chloropal. Epidote and muscovite, or secondary mica, fill the fractures in the gangue. The ore contains also about 4 ounces in silver and an appreciable amount of gold to the ton.

The copper sulphide ore, it is said, was first encountered at a depth of 60 feet. No copper carbonates have appeared in the mine. Water was also encountered at this same depth, but the mine makes only 25 gallons of water a day.

HELENA MINE.

The Helena mine is located in the eastern part of the Helvetia district, 5 miles east-northeast of Helvetia, 2 miles west of Davidson

Canyon, and a mile north of the Scholefield ranch (Pl. II, in pocket). It is reached by wagon road ascending Helena Wash from Davidson Canyon on the east or from the Scholefield ranch on the south. The nearest railroad station is Pantano, 12 miles to the northeast. The mine is at an elevation of 4,550 feet in the toe of the long ridge extending southward from Mount Fagan. The country is generally open but is scored by washes and arroyos which, though of moderate depth, are in places impassable.

The mine was discovered in 1894 and is now owned by the Rosemont Mining & Milling Co., with headquarters at Denver, Colo., and Gardner, Mass. It is developed principally by drifts or so-called tunnels, inclines, winzes, raises, stopes, and shafts aggregating by estimate about 500 feet of work. The work is mostly comprised within a vertical range of 150 feet and in a north-south belt about 500 feet long.

The main drift is about 250 feet in length. It is driven northerly into the hill and on the vein, except that for the last 90 or 100 feet it seems to be in massive rhyolite. From the drift considerable ground is stoped upward 30 feet or more, to or nearly to the surface, and a 40-foot inclined winze is sunk. The winze is half filled with water.

The camp and mill are supplied with water flowing by gravity through a 2½-inch pipe from the creek above. Mexican labor is employed at the mine at $2 a day and is reported to be satisfactory.

The country rock, as shown on the map (Pl. II, in pocket), is a close-grained reddish rhyolite of Tertiary age, intrusive into the dark-green shale and sandstone, of which it contains inclusions and which seem to belong to the Mesozoic. The sedimentary rocks underlie the mill, the greenish shale cropping out just south of it, and the sandstone is exposed just below at the upper end of the camp near the superintendent's house. These rocks are cut by a northeast vertical sheeting.

The rhyolite consists principally of crystals of orthoclase, quartz, biotite, and a little oligoclase, ranging from those that are nearly invisible to small macroscopic phenocrysts, all embedded in a reddish-brown iron-stained felsitic to glassy groundmass having flow structure. It is cut by a close sheeting dipping steeply to the north-northwest, and it is also sheeted horizontally and in places seems to be amygdaloidal or agglomeratic. It shows, particularly along the veins, evidence of faulting and metasomatic alteration in which the rock minerals were almost completely replaced by quartz. This replacement process was followed by deformation, fracturing, and crushing, and these in turn were succeeded by recementation with silica, which traverses the rock in various directions as quartz veinlets, stringers, and seams.

The deposits occur in the rhyolite near its contact with the sedimentary rocks. They are contained in two or more fissure veins or ledges which dip to the west. The main vein has a width of about 7 feet and occupies a fault fissure along which the rhyolite has been considerably fractured and crushed. It dips 40°–60° W., and the ore shoots pitch to the north. It has a known extent of about 150 feet vertically and about 500 feet horizontally and a reported extension of half a mile or more to the north of the mine, where a number of good prospects are located along its course. It consists principally of iron-stained, reddish-brown, or lavender-colored crushed and silicified rhyolite and quartz. The quartz is mostly dark gray and impure, and much of it has obviously replaced rhyolite. Some of it, however, is milky white or of greasy luster and shows by its pseudomorphic structure that it has replaced calcite, which, though now absent, must formerly have been present in the vein. The vein, so far as present development extends, is in general well oxidized. In some places near the surface, however, the gangue contains also white pyrite, seemingly marcasite, which will probably increase in amount with depth, and the ore will accordingly become less oxidized and leaner. In places the vein is traversed by mostly parallel later quartz stringers, veinlets, and seams nearly three-fourths of an inch in maximum width. Only a few of these deviate from a course parallel with the vein, trending diagonally downward from the hanging wall into the vein.

The croppings consist in the main of the vein material just described but are more extensively oxidized and stained dark with manganese and iron. They are not generally prominent but are weathered even with the surface or below it and largely occupy a shallow trench between the adjoining higher wall rock on either side. The wall rock, being hardened by silicification, in places crops out boldly, particularly on the hanging-wall side, where it forms a ridge 40 feet in width and contains bowldery agglomeratic silicified material.

Disseminated more or less throughout the vein and the croppings just described is gold, the only valuable metal of the mine. It is free milling and much of it is macroscopic, occurring in foils or wirelike pieces as much as one-eighth of an inch in length. The richer ore is contained in the more oxidized ferruginous dark reddish-brown cellular or honeycombed portion of the vein, and in a 1 to 2 inch "pay streak" of whitish argillaceous or talcose material which is generally present and is said to average about $350 to the ton.

The deposits of the Helena mine seem to owe their origin to thermal solutions that circulated after the intrusion, fracturing, faulting, and fissuring of the rhyolite and are of the late Tertiary (Miocene?) epoch of metallization.

Other seemingly workable ledges, similar to the Helena vein, are said to occur within a belt about a mile wide lying west and northwest of the Helena property and paralleling its trend.

EMPIRE DISTRICT.

GENERAL FEATURES.

The Empire district, named from the Empire Mountains, about which it centers, lies in the northeastern part of the Patagonia quadrangle, east of the Helvetia district, in the eastern part of Pima County. It extends from Davidson Canyon eastward to Cienega Creek, 7 miles distant (Pl. I, in pocket). The district contains six mining camps—the California, Montana, Lavery, Total Wreck, Copper or Hilton, and Prospect.

The dominant topographic feature in the district consists of the Empire Mountains, which form an outlier of the Santa Rita Range. The mountains trend northeastward through the district, have a length of about 7 miles and a width of about 4 miles, and rise to a maximum elevation of 5,360 feet, or about 500 feet above the surrounding surface. Structurally they consist mainly of a southeastward-dipping monocline of the Paleozoic limestone and quartzite in descending order, underlain by intrusive granite and flanked, overlapped, and surrounded by the Mesozoic sediments (Pls. II and III, in pocket) described under "Geology," with patches of rhyolite in Davidson Canyon on the west. The topography is generally rough.

Nearly all the mineral deposits of the district occur in association with the contact of the Paleozoic limestone with the granite or other intrusive rocks. The granite, which seems to be genetically related to the deposits, is in general a medium-grained biotite-bearing rock and contains also some hornblende.

The deposits are nearly all argentiferous lead and copper bearing ores. They were first discovered in the late seventies. Since early in the eighties, besides the production of the Total Wreck mine, occasional small shipments of ore have been made from sundry small mines almost annually. The principal veins produce silver, lead, and copper ore. The principal camps, all small, are the California camp, at Andrade's ranch, on the northwest; the Total Wreck, on the east; and the Copper camp, at Hilton's ranch, toward the south. They are reached by wagon road from Pantano, the nearest railroad station on the northwest, from which they are respectively 6, 7, and 8½ miles distant. The following is a list of the mines and principal prospects in the district:

California.	Forty-nine.	Red Cloud.
Chief.	Hilton ranch vein.	Roosevelt.
Copper Point.	Jerome No. 2.	Total Wreck.
Cottonwood.	Lavery.	Verde Queen.
Empire.	Montana.	

TOTAL WRECK MINE.

Location.—The Total Wreck mine is 7 miles south of Pantano, the nearest station on the Southern Pacific Railroad, to which there is a good wagon road. It is on Cienega Creek at the east base of the Empire Mountains, in the northeast end of a long ridge, at an elevation of about 4,600 feet (Pls. I, II, and III, in pocket).

History and production.—The mine was discovered in 1879 by John Dilden, a cowboy, and later was relocated and passed into the

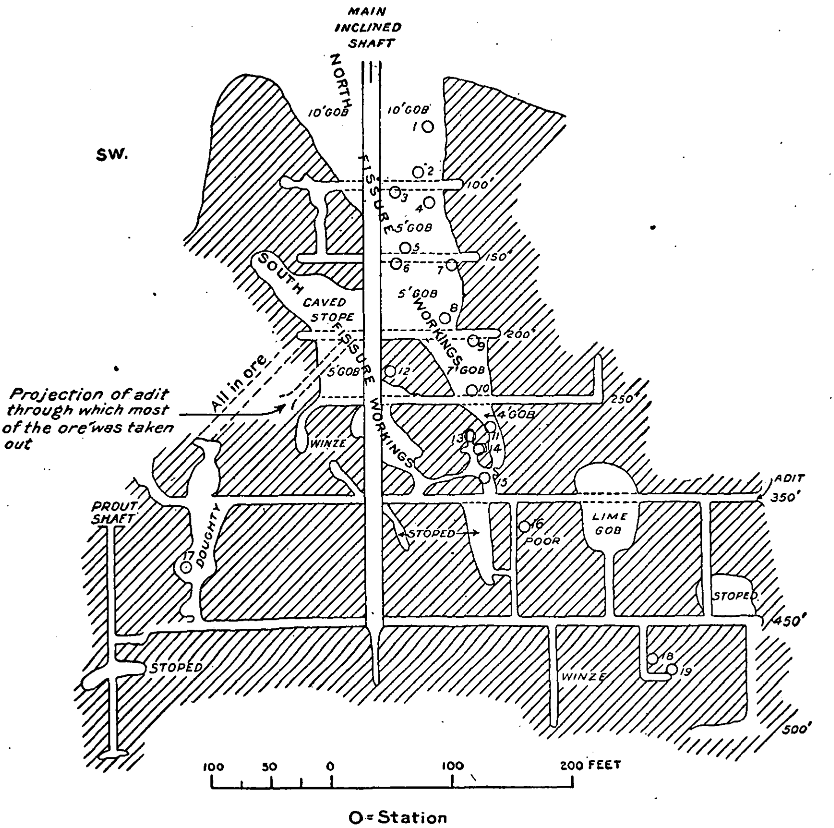


FIGURE 15.—Diagrammatic longitudinal section of Total Wreck mine on dip of main vein.

hands of the Empire Mining & Development Co., which installed a 70-ton milling plant and beginning in 1881 operated the mine and mill for a year and a half on rich surface ore. In 1882 the manager reported 50,000 tons of ore in sight,[1] but after the production of 7,500 tons of ore the mine and plant were closed. Soon afterward the mine was sold for taxes and purchased by Vail & Gates, of Tucson, who still own it. It was idle until 1907, but was then

[1] Blake, W. P., Mining in Arizona: Report of the Governor of Arizona for 1899, p. 116.

worked by C. T. Roberts, who found several thousand tons of low-grade ore remaining in old workings, discovered some new bodies, and shipped considerable ore until March, 1908. In March, 1909, the property was bonded to E. P. Drew, of Tucson, and work was resumed on a small scale. Some ore, in part high-grade lead-silver ore, was produced, but early in 1911 it was reported that the work had been discontinued. The production, which so far as learned seems

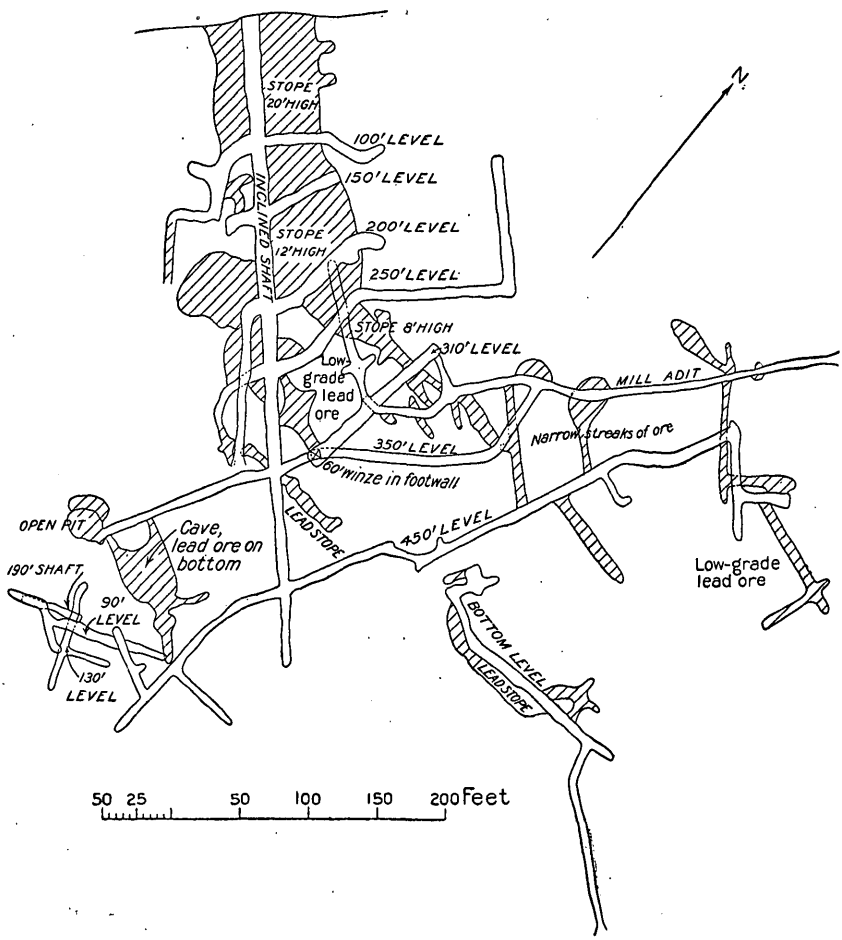


FIGURE 16.—Plan of underground workings, Total Wreck mine.

to be more than 10,000 tons, was mostly made prior to 1902, especially in 1881 and 1882, when the mill was in operation, and a five months' run is said to have produced over $450,000, or about 7,500 tons.[1]

Developments and equipment.—The mine is well developed to a depth of about 500 feet by shafts, tunnels, drifts, inclines, winzes,

[1] Hamilton, Patrick, The resources of Arizona, 2d ed., p. 131, San Francisco, 1883.

and stopes aggregating about 5,000 feet of work. (See figs. 15 and 16.) Some of the principal openings are shaft No. 4, which is 460 feet deep and is inclined 35° S., following the footwall of the principal vein; a main working tunnel tapping the shaft at a depth of 200 feet; and a 250-foot tunnel intersecting the vein on the 200-foot level. The deepest vertical shafts are the Front and Roberts shafts, respectively 185 and 200 feet deep, on the lower slope of the hill. The levels in general lie about 50 feet apart vertically. They run northeast and contain several hundred feet of drifts in both directions. Tunnel No. 1 is 600 feet long and has an upraise to the surface at the breast, a drift to the stope on the southeast, and a 50-foot winze containing a drift to the north and to the east. Shaft No. 2 is 175 feet deep and has a drift to the south on the 80-foot level and drifts to the north and south from the bottom. Tunnel No. 3 is 250 feet long, runs northwest to the breast 80 feet below the surface, and contains stoping to the northwest along vein No. 2. The main crosscut, in the bottom of the mine, runs north and is 800 feet long.

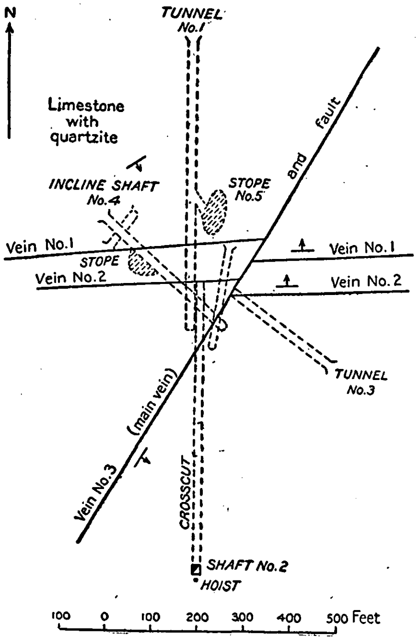


FIGURE 17.—Diagrammatic plan of veins of Total Wreck mine.

The property comprises a group of seven claims, some of which are patented. The principal equipments are a 20-stamp 70-ton mill and a 300-horsepower engine. The machinery and plant are well preserved. The camp and mill were supplied with water pumped from a spring 4 miles to the south.

Geology.—The mine is in the dark-bluish medium to heavy bedded Carboniferous limestone, which is interstratified with heavy to thin beds of light-gray quartzite. The rocks in general dip about 35° SSE., which is approximately the inclination of the east and south slopes of the hill in which the mine is located (Pl. XIV, *B*). They are shown in a much better preserved state in the mill tunnel than in any other part of the mine. They are much faulted, for the most part horizontally, and somewhat folded and contain one or more systems of fissures, of which the principal ones dip steeply to the north. These rocks are intruded by small dikes and stringers of diorite. The limestone is apparently the same as that at the Blue Jay mine and in the dark ridge east of the Copper World mine. It is in general only slightly crystalline and contains some fossil remains, of which a fragment collected as stated on page 50 has been identified as a bryozoan and probably Tabulipora, from the Pennsylvanian.

The mine is dry, and no water has ever been encountered in it.

Deposits.—The deposits occur principally in three so-called veins and replacement ore beds, which are irregular zones, as represented in figure 17. They are mostly in or associated with fissures, especially fissures of the east-west system, of which the two most important are represented in figure 15. The fissures are about 90 feet apart. They have a steep northerly dip, and the ore bodies occur on their northerly or hanging-wall side, mostly in the limestone and usually above beds of quartzite. Some of the deposits extend from the fissures along the bedding planes of the limestone as blanket veins or ore beds. Examples illustrating the relations of the ore bodies to the fissures and the quartzite and limestone bedding planes are shown in figure 18, in which *a* shows also the leached zone in the fissure extending to a depth of about 250 feet, and *b* shows faulting denoted by change in dip and offset of the quartzite beds along the fissure.

The fissure or vein portion of the beds is more or less uniformly about 6 or 8 feet wide, but the width of the zone, comprising the fissure vein and the replacement ore body in the adjoining limestone, is many times greater, being in places nearly 100 feet, as shown in figure 18, *a*. The deposits extend from the surface to the bottom of the mine, where their lower limits have not yet been reached. Though some good-looking ore bodies occur in the deeper part of the mine, practically all the ore which was profitably worked was found between the surface and the 350-foot level.

The ore is an argentiferous lead ore which carries also a little copper in the deep part of the mine. It is contained in a mineralized, altered, more or less crushed limestone gangue with calcite and infiltrated quartz in porous or honeycombed masses of various forms. It is stained reddish brown, yellowish, greenish, or blackish by oxides of iron and manganese and carbonates of lead and copper. With it in places, as shown on the 450-foot level, are associated 40 or 50 feet of breccia and some light-colored argillaceous gougelike material, locally called Chinese talc, which is probably kaolin.

The ore is practically all oxidized, scarcely more than a trace of sulphide having yet been found even in the deepest part of the mine. The principal ore minerals are silver chloride (cerargyrite or horn silver), lead carbonate (cerusite), wulfenite (lead molybdate), mala-

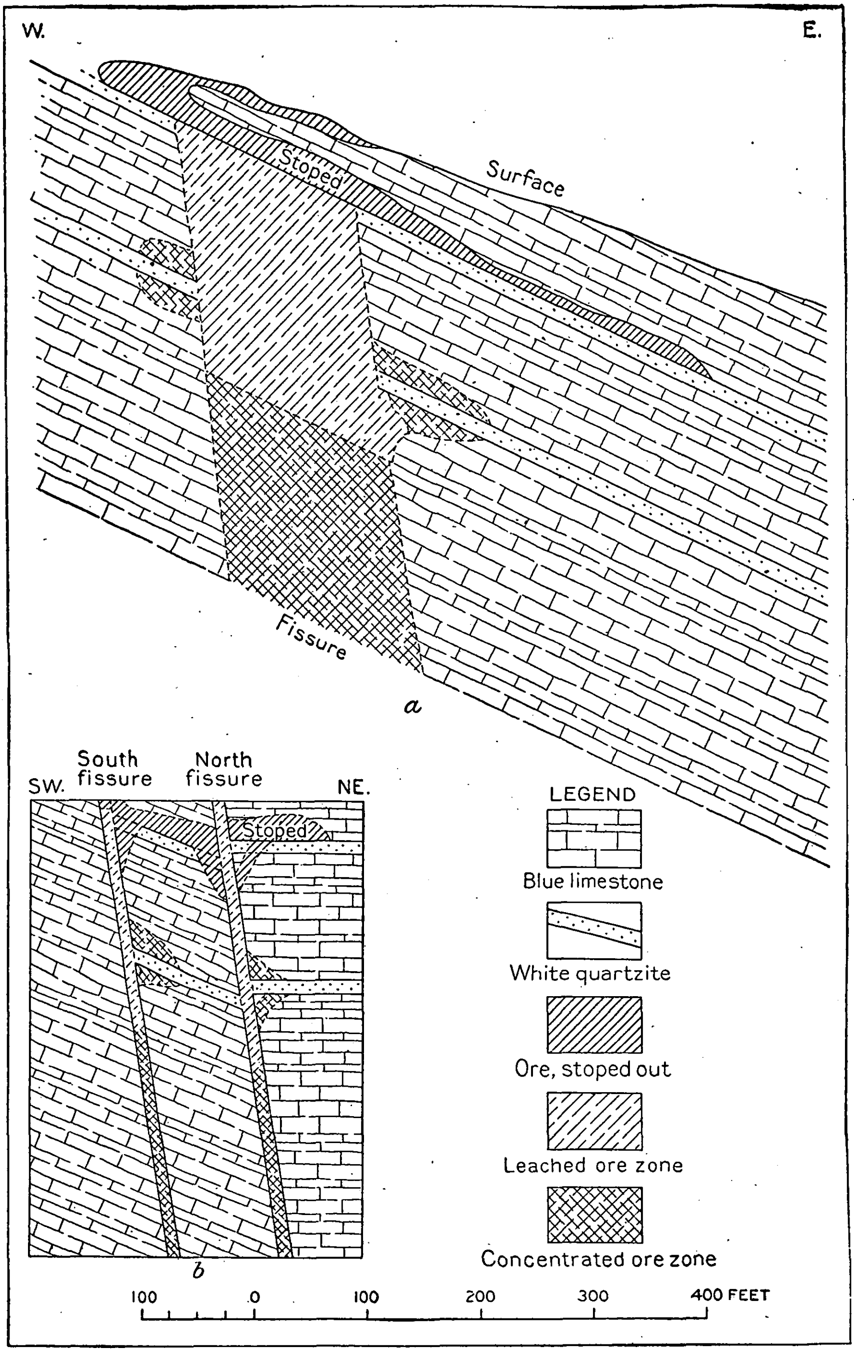


FIGURE 18.—Sections of fissures and ore bodies in Total Wreck mine. *a*, Oblique section near surface; *b*, cross section on 350-foot level.

chite, azurite, chrysocolla, and a little chalcopyrite, and perhaps lead oxides. The associated minerals are hematite, limonite, vanadinite, jarosite, siderite, and manganese oxides.

In the surface ore, much of which is very rich, the principal mineral was cerargyrite. In the lower part of the mine, however, silver is only sparingly present or absent, and copper, principally in the form of carbonates, occurs in its place. The principal vein is said to be 5 feet wide, to contain considerable lead molybdate, and to average 4 per cent copper, 12 per cent lead, and 12 ounces in silver to the ton.

The early ore is said to have averaged in mill tests about $60 to the ton. During the operation of the mill in the early eighties it was worked to 84 per cent, and the tailings were concentrated and saved. The cost of mining and milling was reported to be about $8 a ton.

The deposits seem to owe their origin to circulating thermal solutions that accompanied or followed the intrusion of the underlying granite. Subsequently, so far as the workings now extend, the deposits have become concentrated by percolation of meteoric waters in the oxidized zone. In the processes of formation and concentration of the ore the underlying quartzite beds which separate the limestones into a series of subdivisions were important physical agents in aiding mineral precipitation by arresting the downward progress of the solutions.

The mine seems to contain considerable good ore, but most of it is probably of low grade. As some leads seem to have been lost on the lower levels, the deeper part of the mine should receive detailed examination before operations are resumed on any large scale.

COPPER CAMP.

GENERAL FEATURES.

The Copper camp is located 3 miles southwest of the Total Wreck mine near the center of the Empire Mountains, in a north-south belt about a mile wide and 3 miles long, mostly in the west side of an irregular open valley or embayment that extends northward into the heart of the range and is known as the Basin. The principal settlement is near the Hilton ranch, in the northern part of the belt at an elevation of about 5,000 feet. It is reached by a wagon road of easy grade leaving the Pantano road about a mile north of the Total Wreck mine. The deposits are in the same limestone belt as those of the Total Wreck mine and extend from the granite contact on the north through the foothills and into the lowland on the south. The rocks are principally the dark limestone with interbedded quartzites, about the same as at the Total Wreck mine. They dip in general about 45° SSE. or S. They are faulted, folded, and intruded by the granite batholith on the northwest, the characteristic zone of contact metamorphism being well developed and the two rocks welded together in places. They are cut by dikes of the same granite and by aplite, rhyolite, and greenish lamprophyric rocks. The clearest examples of the intrusive character of the granite found in the area occur in this camp, at the Copper Point mine and elsewhere.

Mineral was discovered here in 1879. The camp contains half a dozen or more small mines, some on patented ground, which from time to time have made small shipments of ore aggregating 40 or 50 carloads. At present assessment work is kept up on about 40 other claims.

VEINS AND ORES.

The deposits contain copper, lead, and silver and occur mostly in three veins or lodes located roughly about 1,600 feet apart. The veins trend in a northeasterly direction through the belt and dip steeply to the northwest, across the bedding of the rocks, into the mountains.

The southeast vein gives off a branch, known as the Gopher vein, which extends obliquely to the south-southwest and south from the point of junction. Both the Gopher vein and the east vein are intersected by the Jerome vein, a mile and a half in length, forming a sort of linked or coarse stockwork system. The west vein contains almost exclusively copper, but the middle and east veins contain copper, lead, and silver ore.

VERDE QUEEN MINE.

The Verde Queen property owned by the Verde Queen Copper Co., of Winona, Wis., comprises a group of seven or eight claims located longitudinally and contiguously in the southeast part of the camp. They are on the east vein, which was discovered about 1881. The claims were all located about the same time in 1896 and 1897. The property produced considerable ore in 1897 and 1898 and from 1905 to 1908, most of which was shipped to the El Paso smelter.

At the principal opening, the Verde Queen, the vein or lode has a width of about 25 feet and dips 80° SE. It is in the gray limestone, and a bed of quartzite forms the footwall. It is opened principally by a 280-foot shaft and three levels, located 50, 150, and 280 feet below the surface and containing respectively 75, 125, and 50 feet of drifts. The ore contains chiefly copper, silver, and lead in the form of the usual copper carbonates, silver chloride, and lead molybdate, in a yellowish-brown gangue composed of utahite, hydrous sulphate of iron, and a little quartz. Much of it carries from \$4 to \$7 in gold to the ton. The mine, which was not enterable at the time of visit, is said to contain considerable good ore in sight.

On the adjoining Chief claim the vein is in crystalline limestone associated with a rhyolite dike and also in the bottom of the mine with a greenish lamprophyric-looking dike. It is about 4 feet in width, dips about 60° N., and is opened by a 100-foot shaft, 200 feet of drifts, and levels, aggregating about 500 feet of work. This claim produced 1,000 tons of ore in 1907 and 1908. The shaft is equipped with a horse winze hoist and is now sinking. The ore averages $40 to the ton. It contains about 12 per cent each of copper and lead, 2 ounces of silver and $3 in gold to the ton, and a trace of zinc. The copper is mostly in the carbonate form.

The rhyolite dike which occurs here is from 2 to 25 feet in width and extends diagonally through the camp and, it is said, for long distances across the adjoining country, cutting both the limestone and the granite with steep dip. Many openings are made on it. It generally shows indications of mineral on both walls, those on the under or footwall side being reported to be the best. Associated with it in the granite a quarter of a mile west and northwest of the Hilton ranch are some good-looking silver and copper prospects.

HILTON GROUP.

Adjoining the southern part of the Verde Queen property on the west is a group of a dozen or more claims owned principally by M. P. Hilton, a pioneer resident of the camp. Some of them present good showings and have produced some ore, among which are the Jerome No. 2 and the Forty-nine.

JEROME NO. 2 MINE.

The Jerome No. 2 mine joins the Verde Queen property last described on the west but is farther up the slope, at an elevation of about 4,900 feet. It is on the Jerome vein or lode, which here has a width of about 40 feet and is a contact deposit in hanging-wall limestone with quartzite forming the footwall. It is opened by a 65-foot shaft with a crosscut at the bottom. The vein seems to contain considerable ore, which is all oxidized, in a yellowish-brown utahite gangue and is said to average 10 per cent in lead, 11 per cent in zinc, and 8 ounces in silver and $1.50 in gold to the ton. The zinc is in the carbonate form. About 40 tons of the ore lies on the dump.

FORTY-NINE CLAIM.

The Forty-nine claim, which joins the Jerome No. 2 on the south and is on patented ground, has produced some ore and has about 350 tons of ore on the dump. The vein is about 8 feet in width and is opened principally by a 116-foot shaft and a drift.

RED CLOUD MINE.

The Red Cloud mine, owned by T. W. Wagner and C. McCullough, residents of the camp, contains in the dark limestone a 3-foot bed of dark-brown iron-stained ore dipping 50° SE. It has produced and shipped considerable ore averaging 17 per cent of lead and about 400 ounces in silver to the ton. The ore is all oxidized and contains much silver chloride and iron oxide. Some good ore lies on the dump and there is apparently considerable ore in the mine.

The Old Glory claim, owned by the same persons as the Red Cloud, is said to be a promising property.

HILTON RANCH VEIN.

Just east of the Hilton ranch buildings, in the granite, lies a 4-inch quartz vein that contains chalcocite ("black petanque"), a little malachite, and galena, and in places is said to run 400 ounces in silver to the ton. It is opened by a 150-foot tunnel, with a 60-foot winze at the breast.

COPPER POINT PROSPECT.

The Copper Point prospect, located about a mile northeast of the Hilton ranch, on the contact of the intrusive granite and limestone, is on an 8-inch vein with garnetiferous epidotized ferruginous gangue containing chiefly chalcopyrite, pyrite, some secondary chalcocite, a little copper carbonate, and specularite. This ore is said to average 20 per cent in copper and 20 ounces in silver and $3 in gold to the ton. Some chalcopyrite occurs also in the granite near the contact.

DAVIDSON CANYON AND VICINITY.

CALIFORNIA MINE.

The California mine, also called the Mann mine, is in the northwest corner of the Empire district, 6 miles west of Pantano, at the Andrade ranch, on the Davidson Canyon road, at an elevation of about 3,800 feet. The deposit was discovered about 1880 and during several years produced considerable surface ore. It was worked down to 60 feet below the surface, where water was encountered and work was discontinued. In 1904 it was bonded to the Bradford Development Co., of Los Angeles, which relinquished it in 1905. It is now owned by Andrade, Schley & Dement, of Tucson.

The ore produced was nearly all copper carbonate, but included some good-grade copper sulphide. Most of it was sold to the Tucson smelter and some to the El Paso smelter. It averaged, it is said, about 21.5 per cent of copper and $6 in gold to the ton. The mine is opened principally by a shaft sunk in granite on the north side of and

25 feet above an adjoining gulch (Pl. I, in pocket); another shaft, inclined 65° NE., 60 feet or more distant on the opposite side of the gulch; and a 30-foot tunnel from which at 6 feet above the gulch issues a large stream of water.

The mine is on the limestone and granite contact, and dikes or masses of granitic aplite are also intruded near by. It is mainly in the massive white crystalline limestone, which just to the southwest forms vertical bluffs 30 feet high on either side of Davidson Canyon. A little farther upstream the limestone is underlain by dull-greenish quartzite or siliceous shale, and on the northwest, between the mine and the Andrade ranch, it is overlain, apparently unconformably, by a 20-foot covering of the dark limestone which is seemingly infolded with it. A quarter of a mile south of the mine there is a white limestone or marble quarry. The rocks are all considerably crushed, show lateral disturbance or thrust faulting, and are cut by a sheeting-like structure dipping 30° NW. The granite is seamed in the same direction by limy bands and stringers along the structure planes. The granite is a dark-gray fine-grained rock and seems to be the source of the mineral deposits.

The deposits, to judge from the iron and manganese stained siliceous croppings, are contained principally in a northeast-southwest ledge about 70 feet wide, dipping 60° or more to the west-northwest and showing lateral faulting. As seen in the south or inclined shaft sunk near the middle of the ledge they consist of a northwesterly zone of crudely banded iron and copper stained material in which the middle 2 or 3 feet contains considerable malachite, azurite, lead-copper oxide, and some chalcopyrite.

At 250 feet southeast of the deposit just described occurs a second and smaller ferruginous silicified 3-foot ledge which dips 70° NW., conformably with the inclosing limestone.

The mine seems to contain some workable ore, but much water is present and will make mining difficult. The ore seems to be restricted to the limestone, which, to judge from the exposure of the underlying quartzite and shale formation near by on the south, probably does not extend more than 200 feet in depth, unless the rocks are disturbed.

MONTANA MINE.

The Montana mine is about 1½ miles south of the California mine, on the Davidson Canyon road. The deposit was discovered and located about 1890 as the Black Diamond. It was relocated in 1894 by John Dement and Otto Schley, the present owners, who developed it chiefly by a 90-foot 30° incline and shipped from it 10 tons of principally sulphide ore that averaged 9 per cent in copper.

The mine is on a mineralized fault or shear zone, which is 20 feet or more wide and marks the contact between the dark limestone and the light limestone, both of which are brecciated. At the end of the tunnel the upper 3 feet or more of the ledge, consisting of reddish-brown iron and copper stained material, dips 50° W., and the incline, which has produced most of the ore, is sunk diagonally upon it, descending 30° NE. The gangue associated with the ore in the lower part of the incline is said to be 6 or 7 feet of limy talcose or koalin-like material. The ore on the dump is mostly of the brown and yellowish oxidized ferruginous type, lean in sulphides.

LAVERY MINE.

The Lavery mine, a mile east of the Montana mine, is in the west slope of the Empire Mountains, in granite at an elevation of about 4,300 feet. It was not visited in this work but is said to have shipped about a thousand tons of ore.

GREATERVILLE DISTRICT.

GENERAL FEATURES.

The Greaterville district occupies the north-central part of the Santa Rita Mountains and adjoins the Helvetia district on the south. It is about 6 miles wide and extends from Box Canyon southward across the Pima-Santa Cruz County line to Old Baldy Peak, 7 miles distant and 9,432 feet in elevation. It is traversed in its western half by the crest of the Santa Rita Mountains.

The western part of the district is generally rugged and on the southwest comprises some of the highest and roughest country of the area. It drains westward to Santa Cruz River, mainly through Sawmill and Box canyons. The eastern slope is also generally rough, being scored by many canyons, gulches, arroyos, and washes that drain eastward into Cienega Creek.

The bedrock, as shown on Plate II (in pocket), consists in the northern part mainly of granite, including the axis of the range, on the west and Cambrian (?) quartzite on the east, against both of which is faulted a northwest-southeast belt of Devonian limestone on the south, which in turn, beginning on the east, is succeeded by overlying Mesozoic sediments, andesite, and rhyolite, the last rising to the summit of Old Baldy Peak. Both the granite and the Paleozoic and Mesozoic sediments are intruded by dikes and masses of rhyolite and granite porphyry, and a conspicuous stock of granite porphyry, known as Granite Mountain, occurs a mile and a quarter southwest of Greaterville. Granite Mountain is knob-shaped and about half a mile in diameter. It rises 500 feet above the surrounding surface and is associated with the mineral deposits. Quaternary gravels overlie the granite on the northwest and the Mesozoic and other formations on the east.

The principal camp is Greaterville, a small place in the eastern part of the district, 3 miles east of the crest of the Santa Rita Range, at an elevation of 5,280 feet. It has a store and a post office and a tri-weekly mail service from Helvetia by way of Rosemont. The nearest railway station is Sonoita, 8½ miles to the southeast, on the Nogales branch of the Southern Pacific Railroad. It is 13 miles distant by wagon road by way of the Kane ranch, or 9 miles by trail.

The district contains both lode and placer deposits, but the attention of the miner has been attracted chiefly to the placers, and the mining history of the district is essentially the history of placer mining about Greaterville. (See p. 158.) Mineral was discovered in the district at least as early as the early seventies and probably in the sixties. Early in 1874 some rich gold and silver cerusite ore from the Yuba mine, freighted to San Francisco by ox team, is reported to have yielded a net profit of $90 to the ton. Soon afterward the St. Louis mine was located and produced some ore, and the later part of the same year witnessed the discovery of the gold placers, which soon occasioned an influx of more than 200 men. Their numbers also stimulated lode mining by lessening the danger of attack by the Indians.

LODE DEPOSITS.

The lode deposits occur as quartz-calcite veins in the granite and the sedimentary rocks surrounding Granite Mountain. The veins are commonly banded, and where they occur in the granite or associated with the granitic rocks they usually contain as a gangue mineral also barite.

The ore minerals in the veins are galena, pyrite, chalcopyrite, sphalerite, gold, and silver. The richest ores are the surface argentiferous lead-carbonate ores carrying free gold and horn silver, but as the oxidized zone is shallow the ore begins to decrease in value at depths of about 20 or 30 feet.

The veins are opened at a dozen small mines or good-looking prospects, most of which have produced some ore. These are named below:

- Anderson (Conglomerate).
- Enzenberg (Mountain King).
- Hardscrabble.
- Friez (Gold Bug).
- Hancock.
- Hughes.
- Quebec.
- Royal Mountain.
- St. Louis.
- Summit.
- Yuba.
- Wisconsin.

ANDERSON PROSPECT.

The Anderson prospect, also known as the Conglomerate mine, is 2½ miles south-southwest of Greaterville, near the top of the limestone ridge on the south side of Fish Canyon at an elevation of 5,640 feet. The owner, J. E. Anderson, reports having shipped from it 19 tons of galena that assayed 68 per cent of lead and 54 ounces in silver to the ton. It is opened principally by a 50-foot shaft on a nearly vertical northwest-southeast brecciated and silicified contact zone between the granite and the limestone. The ore minerals are principally galena and cerusite, with a little chalcopyrite and horn silver, occurring in pockets and small bowlders scattered through the zone. Oxidation extends to the bottom of the shaft.

ENZENBERG MINE.

The Enzenberg or Mountain King mine is located at an elevation of 5,950 feet on the southeast flank of Castle Dome, 3 miles northwest of Greaterville. It is on a southwestward-dipping quartz vein which is in the granite and is associated with a 2-foot rhyolite dike. The vein is opened by a 65-foot tunnel and shows two kinds of mineralization, pyrite with a little chalcopyrite having been formed on the footwall side and dark massive galena and sphalerite with minor amounts of pyrite on the hanging-wall side. The ore is all well banded. Several feet of water stands in the tunnel.

FRIEZ PROSPECT.

The Friez prospect, also known as the Gold Bug, is on Enzenberg Canyon at an elevation of 5,560 feet, in the coarse granite country rock. As shown in the bottom of the canyon, the granite is cut by two north-south rhyolitic dikes about 20 feet apart, between which the granite, being of finer grain than usual and pyritic, is meshed or converted into a close stockwork by innumerable iron-stained mineralized drusy quartz veins extending in all directions and containing pyrite and some chalcopyrite. This mineralized stockwork, with decrease in development toward the periphery, extends laterally 150 feet east of the eastern dike, which, like the granite, is also pyritic, and longitudinally 400 feet north and 500 feet south of the canyon, giving way to the normal country-rock granite. It seems likely that the western dike, which is a dense white siliceous rock and sharply delimits the deposits on the west, has caused the mineralization.

HANCOCK MINE.

The Hancock mine is 2 miles west of Greaterville and a mile east of the Mountain King mine. It is on a 3-foot quartz vein in granite. The vein dips to the west and is opened mainly by a 100-foot shaft which shows galena and pyrite. The mine was worked by W. M. Robinson in 1885 and is reported to have shipped some rich ore carrying lead carbonate and horn silver.

HUGHES MINE.

The Hughes mine is in the crest of the Santa Rita Range 1½ miles south of Melendreth Pass on a 6-foot quartz vein in the granite. It is opened mainly by a 45-foot shaft which shows lean sulphides beginning within 5 or 6 feet of the surface. It was worked in the middle eighties, three arrastres being employed to grind out the surface ore, which, it is said, averaged about $100 to the ton in silver and gold.

QUEBEC MINE.

The Quebec mine, located in 1883, is 1½ miles southwest of Greaterville, west of Granite Mountain, in Nigger Gulch, at an elevation of 5,840 feet. The workings consist of a 50-foot shaft and a 100-foot tunnel with a 50-foot upraise from the breast to the surface and a 20-foot winze to a 50-foot drift and a 25-foot winze at the end of the drift. The mine is on a northwest-southeast 4-foot vein in coarse dark porphyritic granite. The vein is about vertical, is well banded, and is composed mainly of an iron-stained quartz-calcite-barite gangue in which the metallic minerals galena, zinc blende, pyrite, and chalcopyrite occur principally in pockets and bands. Some of the ore shipped to El Paso in early days is said to have averaged 100 ounces in silver and a little gold to the ton, the gold content being higher in portions of the vein in which the calcite-barite part of the gangue predominated over the quartz.

ROYAL MOUNTAIN MINE.

The Royal Mountain mine lies about 2 miles southwest of Greaterville, on a small gulch one-eighth of a mile north of Fish Canyon, at an elevation of 5,655 feet. It is opened by a 75-foot crosscut tunnel, two 80-foot shafts, and drifts. The ore body is a 2-foot quartz-barite vein, dipping 30° SW., in granite. The croppings are stained with iron and in places with copper carbonates, which are said to carry some silver. The ore contains principally argentiferous galena, which begins to be mixed with the oxidized lead-carbonate ore within a few feet of the surface. A little sphalerite is also present.

ST. LOUIS MINE.

The St. Louis mine is about three-fourths of a mile west of Greaterville, at the southeast base of Granite Mountain, on the east side of St. Louis Gulch, near its junction with Hughes Gulch, at an elevation of 5,495 feet. It was located in 1874 and was developed in 1886 by a 75-foot shaft and drifts. At that time it shipped ore to the El Paso smelter, some of which is said to have averaged 40 per cent of lead and 75 ounces in silver and about 12 ounces in gold to the ton. It is on a compound vein or lode about 8 feet wide, composed of quartz veins and numerous small rhyolite dikes and contained in a northeast-southwest shear zone about 800 feet wide and 3,000 feet long, in altered shales, hornfels, and silicified dolomitic limestone. This zone lies at the southeast base of Granite Mountain, and the intrusion of the granite porphyry forming the mountain deformed and metamorphosed the sediments. The veins in the lode are linked and form a stockwork. The lode dips 45° SE., away from the mountain, about parallel with the inclosing rocks, and its dip seems to flatten in depth on receding from the mountain. Almost throughout the extent of the lode occur numerous mineral-bearing quartz stringers and it is asserted that practically all the lode material is good milling ore.

Near the middle of the lode is a 2 to 3 foot band, composed almost entirely of quartz, in which the metallic minerals are more concentrated, and with a little sorting this ore becomes of fair smelter grade.

The metallic minerals are argentiferous galena and sphalerite, with some pyrite and chalcopyrite. They occur also in small quantities at the surface and in the iron-stained croppings, where fairly large nuggets of native gold are said to have been found.

On the Fulton claim, south of St. Louis, the lode is about 20 feet wide and is opened by a 60-foot and a 100-foot shaft. Here it shows considerable surface mineralization, which, however, is less concentrated than on the St. Louis ground.

SUMMIT MINE.

The Summit mine is just west of Melendreth Pass, on the trail descending Sawmill Canyon, at an elevation of 5,700 feet. It is opened by an incline of unknown depth sunk on a quartz vein 1 to 2 feet wide that dips 75° W. The ore as seen on the dump contains galena, tetrahedrite (gray copper), malachite, and azurite rather widely disseminated through the quartz gangue. The sulphides begin at the surface.

YUBA MINE.

The Yuba mine is 2 miles west of Greaterville, on the north side of the upper end of Hughes Gulch, at an elevation of 5,850 feet. It was located in 1874, and from it, in the eighties, were shipped some surface ores that are said to have averaged $1 a pound in gold and silver. The total production is several thousand dollars.

The property contains three quartz veins, dipping about 55° S., in coarse sheared granite. The south vein is about 3 feet wide, the middle one about 2½ feet, and the north one of less width. In the longitude of the mine the veins are about parallel and 100 feet apart, but at 700 feet to the east they unite into one ledge. The mine is on the southern or main vein, no work other than stripping having been done on the other two. It is opened mainly by four inclined shafts sunk on the vein, the deepest of which is said to be about 100 feet. Water stands within 15 feet of the surface. The vein is composed of white "bull" quartz, with a little barite and calcite in places. It is banded and shows comb structure, but these features are locally destroyed by postvein movement.

The croppings consist principally of white quartz sparingly spotted with copper carbonates and bunches of black-coated galena. The rich oxidized ores gave out at a depth of about 20 feet, but between that limit and the 50-foot level the ore, though spotted, is said to have averaged about $10 in gold and silver to the ton, the gold and silver being contained in galena and chalcopyrite and a few small masses of argentite.

WISCONSIN MINE.

The Wisconsin mine is 1⅛ miles northwest of Greaterville, on an iron-stained quartz vein 1 foot wide, in granite near overlying siliceous shale and dolomitic beds on the east. The vein dips 45° SW. It is opened by a number of shallow shafts and contains, from the surface down, pyrite and galena, which at a depth of about 30 feet become plentiful and carry workable quantities of silver and a little gold. Some of the surface ore is said to have run $5 to the ton in gold and silver.

OTHER PROSPECTS.

In the altered contact zone of silicified, sheared, and crumpled sedimentary rock intruded by the granite porphyry of Granite Mountain, on the south side of Hughes Gulch and ascending the ridge to the south between St. Louis and Nigger gulches, along the granite porphyry contact, there are numerous openings, nearly all of which show copper and iron sulphides. The rocks are traversed by quartz and calcite seams, some of which extend across the contact into the granite porphyry.

A mile south of Greaterville, in the flat dissected area at the head of Harshaw Gulch, on a steep southeastward-dipping fault-breccia contact of granite porphyry intruded into the red silicified shale, numerous openings show disseminated pyrite which is locally replaced by pseudomorphic hematite. Here very rich pockets of gold are said to have been found at the surface, but the metal content does not seem to persist in depth.

About a mile a little south of west from the Deering camp, in Box Canyon, at an elevation of 4,800 feet occurs a quartz vein 1 foot wide which dips to the south between granite and a 4-foot rhyolite dike. The vein is opened by a 12-foot shaft. The quartz shows comb structure, is honeycombed, pitted, and stained with limonite, and contains some galena and a little pyrite. Some of the ore when reduced in an old arrastre 200 feet to the northwest is said to have yielded considerable free gold.

The deep mines, so far as exploited in the district, are mostly on small veins, and the mineralization does not give promise of great returns. In fact, in most of the workings described the tenor of the ore at the depths reached is rather low, and the metallic minerals are widely scattered through the gangue.

PLACER DEPOSITS.

LOCATION.

The Greaterville placers, on which a preliminary report has appeared,[1] are contained in a nearly equilateral triangular area with each side about 4½ miles in length and its base on the south. (See Pl. II, in pocket.) This area includes about 10 square miles, but the deposits actually cover only about 8 square miles. Greaterville is situated a little north of the center of the area, which is the largest and richest placer area in southern Arizona.

HISTORY AND PRODUCTION.

Placer gold was first discovered in the district in 1874 by a prospector named Smith, who was soon joined by his partners from New Mexico.[2] The discovery caused a rush to the camp, and the Greaterville mining district was organized March 17, 1875, but was never recorded with the county officials.[3] The placers were worked more or less thoroughly from 1875 to 1878 by 200 or more men.[4] In 1878 76 Americans were registered as voters and the town had also a population of about 400 Mexicans.

The gravels were worked in those days by rocker and long tom, as water was very scarce. A number of Mexicans made their living by packing water in canvas or goatskin bags on burros from Gardner Canyon, 4 miles to the south. The current price of water was

[1] Hill, J. M., Notes on the placer deposits of Greaterville, Ariz.: U. S. Geol. Survey Bull. 430, pp. 11–22, 1910.

[2] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1875, pp. 389–390, 1877.

[3] Oral statement of P. J. Coyne.

[4] Hinton, R. J., Handbook of Arizona, p. 213, San Francisco and New York, 1878.

about 3 cents a gallon. Notwithstanding the difficulties of work, the output for each man was $10 or more a day. By 1881[1] the richer stream gravels had been worked over, wages were reduced, and the work became more difficult, and these conditions led a number of men to leave the camp. Many were also discouraged by the Indians, who usually attacked small parties away from the town and rendered the life of the prospector unsafe until late in the eighties.

About 1886 the placers were considered worked out. The rich gravels unquestionably had been greatly depleted, and from 1886 to 1900 the camp was practically dead. In the latter year, however, a slight revival of activity was brought about by the installation of a hydraulic plant in Kentucky Gulch, on which the Stetson Co. expended a large sum of money, but after sluicing a few months it shut down.

About 1902 considerable ground was owned and operated by the El Oro Mining Co.[2] In 1904 about 2,000 acres of ground occupied by deposits had been patented, and by 1905 the Santa Rita Water & Mining Co. had begun operations with extensive equipment, including 8 or 10 miles of ditch and pipe line. This company, under the auspices of G. B. McAvery, of San Jose, Cal., who backed and directed the work, planned and began on a substantial scale the construction of a system of dams in the canyons, notably Gardner and South canyons, at the foot of the high mountains, by which the water was to be impounded by hydraulicking. In one place water was brought to the ground and operations were conducted with profitable results. About this time, however, the death of the manager, Mr. Stetson, and of Mr. McAvery resulted in the suspension of the project, which has never been resumed.

In Kentucky Gulch at its junction with Boston Gulch the Stetson Co. tried hydraulic operations. Water was taken from the first canyon south of Gardner Canyon and carried through an 8-mile pipe line, giving a head of 125 feet. The company sluiced 1,000 feet of the creek bed for a width of 30 feet. The gravels in the overburden, however, are rather coarse, and the returns are reported to have been too low to warrant further work. The pipe line is still in good repair.

One company installed a 1-ton steam shovel, screens, and a conical concentrating tank in Empire Gulch just below Enzenberg Canyon. After an area 50 by 100 feet had been excavated to a depth of 20 feet operations were suspended, as the pay dirt was not rich enough to warrant the removal of the 16 feet or more of overburden. The machinery was left in the pit and is being buried by slumping from the sides.

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[1] Oral statement of P. J. Coyne.
[2] Report of the Governor of Arizona for 1903, p. 229.

In 1909 a few men were making a meager living from some of the gulch diggings in the camp, and one man was operating a dry-washing machine on a patch of high gravels with moderate success. From 25 to 30 cents a day at that time was considered good pay.

Recently, owing to copious rainfall in the district, there has been a partial revival of activities. A number of the properties are being acquired by outside interests and worked, and on several of them the installation of giants or dredging machinery for extracting the gold is contemplated. A new group of claims has been located near the caves beyond Boston Gulch and is being steadily developed with a small force of men. Deeper sinking on several of the leading properties has revealed workable deposits at greater depths than any hitherto known in the camp.

In October, 1914, it was reported that the Greaterville Dredge Gold Mining Co. had acquired 1,100 acres of the placer land, which during the last year it had thoroughly prospected with encouraging results and is now planning to dredge. Much of the ground is said to average about 90 cents in gold to the cubic yard, and the dredge is expected to handle 2,000 cubic yards of the gravel a day. Water for floating the dredge and washing the gravel is to be supplied from several wells now being sunk on the property to depths of 200 to 300 feet. By repeated use of the water the supply is expected to be adequate.

In 1883[1] the yearly production since the discovery of the camp was estimated to have been about $12,000, and for 1884[2] the total production was $18,000. Mr. P. J. Coyne estimates the total production of a few of the gulches as follows: Louisiana, $40,000; Graham, $100,000; and Sucker, $500,000. He further states that the total production of the camp to date probably amounts to $7,000,000. This estimate, though much higher than Burchard's, was corroborated by several old-time miners, who have been in a position to watch the production of the district. It is possible that the large figure may include the production of the deep mines as well as that of the placers. According to information gathered by the United States Geological Survey, the placer-gold production of the Greaterville district for the period from 1902 to 1908, inclusive, is estimated to be $29,500, or an average of $4,218 a year. The production in 1902 was relatively high, and it accordingly raised the annual average, which is usually about $3,000. From 1909 to 1912, inclusive, the production was approximately $2,500 a year, with a maximum of $3,557 in 1912.

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1876, p. 342.

[2] Burchard, H. C., Production of the precious metals in the United States, 1884, p. 46.

TOPOGRAPHY.

The placer area lies at the east base of the Santa Rita Mountains, its western part overlapping their lower slope. The area, as a whole, slopes to the east, the western or mountainous portion more steeply so than the eastern or bajada portion. The entire area except two prominent knobs near its center is deeply dissected by steep-sided arroyos, washes, and gulches to maximum depths of nearly 100 feet, which have produced a rough topography and converted the area, as a whole, into one of slopes, so that travel is difficult except along the drainage courses. There is but little surface water except during the rainy season in the larger gulches, so that sluicing at best is restricted to three or four months in the year. In a few gulches shallow wells supply water for local needs but not enough for rocker washing. The nearest permanent stream is in the first canyon south of Gardner Cañyon, and is fed by springs at the base of Old Baldy in the higher part of the range.

CHARACTER AND DISTRIBUTION OF GRAVEL.

The deposits consist of gold-bearing placers. They are irregularly distributed, chiefly in the bottoms of the present stream courses and gulches, where the principal diggings occur in shallow ground, and also upon the benches, slopes, and tops of the ridges, where some of them seem to represent deposits in old stream channels, examples of which occur just south of Greaterville 30 feet above the valley, on the crest of the ridge to the southeast, and on the north side of Hughes Gulch below the mouth of Nigger Gulch 15 feet above the bottom. They consist chiefly of a 2-foot bed of angular gravel which rests unconformably upon the bedrock of all the different older formations contained in the area, including the early Quaternary "cement rock." They are covered by 1 foot to 20 feet or more of overburden composed of later Quaternary and Recent gravels and wash. In places, as in Kentucky, Ophir, and Empire gulches, the upturned, irregularly eroded edges of the underlying sedimentary beds form natural riffles, behind which the gold has been concentrated.

The gravels of the gold-bearing bed are generally small, the pebbles, as a rule, being less than an inch in size, though in many places cobbles 4 to 8 inches in diameter occur. In a few places the gravels are crudely stratified and slightly cemented, generally by lime. They are sharply angular and but slightly waterworn. The sand consists chiefly of angular fragments, and many of the particles of quartz and feldspar show well-preserved crystal faces. The coarse material consists chiefly of red and yellow sandstone, shales of various colors, arkose, a little dense white rhyolite, and granite porphyry. The gravels rest in most places in a red-brown clayey matrix which is handled without difficulty by hydraulic methods.

GOLD.

The gold, which is rather uniformly distributed throughout the bed, is mostly coarse. It ranges from flakes one-tenth of an inch in longest diameter, which was the size of most of the material recovered at the time of the visit in 1909, to nuggets worth a dollar or more. The gold of the early days was all coarse,[1] nuggets ranging from $1 to $5 in value being common. Some nuggets brought into Tucson contained from $35 to $50 worth of gold, and the largest nugget reported from the camp weighed 37 ounces and had a value of about $630. The gold averaged about $17 to the ounce fine, and it was not difficult for a man to take out an ounce a day. The gold, like the containing gravels, is very angular, with many pointed projections, denoting that it is of local origin and has not traveled far. A little quartz adheres to some of it and seemingly also galena, both of which are reported to have been common in the large nuggets. The gold is mostly bright, but some of it is iron-stained and concentrates from panning contain considerable magnetic black sand.

PRODUCTIVE GULCHES.

The principal distribution of the deposits with reference to the gulches, which are shown on the map, is about as follows:

The productive gulches were Boston, Kentucky, Harshaw, Sucker, Graham, Louisiana, Hughes, Ophir below its junction with Hughes, the upper parts of Los Pozos and Colorado, Chispa on the road from Enzenberg camp to Greaterville, and Empire below its junction with Chispa.

Boston Gulch.—In Boston Gulch, which heads in the col south and west of Granite Mountain and trends a little south of east, gold was found in paying quantities from its head to a point about half a mile south of its junction with Kentucky Gulch at the Kentucky camp. In the upper 2 miles of its course the gold was found in a channel 5 feet wide on bedrock, at 2 to 4 feet below the surface. Below Harshaw Gulch the gold was still confined in a 10-foot channel in the valley bottom, 5 to 10 feet below the surface. Below the mouth of Kentucky Gulch the valley is wide, and for half a mile below this point the gold was distributed on bedrock at a depth of 10 to 16 feet for a width of approximately 50 feet.

Harshaw Gulch.—In Harshaw Gulch, a short, narrow tributary of Boston Gulch with steep bedrock sides, the pay streak, which in places was rich, was confined to the bottom of the gulch, about 4 feet wide.

Kentucky Gulch.—In Kentucky Gulch, which heads south-southeast of Granite Mountain and joins Boston Gulch at Kentucky camp,

[1] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1876, p. 342.

the gold occurs throughout its length on bedrock in a channel 6 to 10 feet in width. At the upper end of the gulch the pay streak lay at the surface, but the covering gradually thickened to 6 feet at the mouth of the gulch.

Sucker Gulch.—In Sucker Gulch, which has three small heads southeast of Granite Mountain, the gravels were productive to a point a little below its junction with Ophir Gulch. From its head to the mouth of Graham Gulch the pay channel was 6 to 9 feet wide and 3 to 12 feet below the surface. Between Graham and Louisiana gulches the pay channel averaged from 20 to 50 feet in width and the depth was from 12 feet at the former to 25 feet at the latter gulch. Below the mouth of Louisiana Gulch the gold was found distributed through the gravels on bedrock for a breadth of 100 feet. The overburden at the lower end was excessive, and therefore but little work was done.

Graham Gulch.—In the lower end of Graham Gulch, a short branch of Sucker Gulch heading southwest of the St. Louis mine, the pay gravel covered the entire bottom, about 100 feet in width, on bedrock at 12 feet below the surface. At the upper end of the gulch the pay streak was 10 feet wide and was covered by only 6 inches of soil. Some gravels 15 feet above the bottom of the gulch on the south side were also productive.

Louisiana Gulch.—At the head of Louisiana Gulch, which heads about a quarter of a mile south of Greaterville and joins Sucker Gulch a little more than a mile below, gold was found almost at the surface, but near the mouth of the gulch it lay at a depth of 10 to 12 feet. The average width of the pay streak was about 6 feet.

Hughes Gulch.—In Hughes Gulch, which heads 2 miles west of Greaterville, just south of the Yuba mine, and extends north of Granite Mountain, a narrow channel, rarely over 6 feet wide from its head to its mouth, was found productive at 2 to 6 feet below the surface.

Nigger and St. Louis gulches.—Nigger and St. Louis gulches, small tributaries of Hughes Gulch, the first named lying to the west and the second to the east of Granite Mountain, contain small gold-bearing gravel channels.

Ophir Gulch.—Ophir Gulch, which heads northeast of the Yuba mine, contains no placer deposits above its junction with Hughes Gulch. Below Greaterville, however, a channel 200 feet wide was found to contain gold as far down as the mouth of Sucker Gulch. The bedrock is rather deep here and little work has been done.

Los Pozos Gulch.—Los Pozos Gulch, which heads about a mile northeast of Greaterville, contains workable gravels in the upper 3,000 feet of its course.

Colorado Gulch.—On Colorado Gulch, a short branch of Empire Gulch, half a mile north of Los Pozos Gulch, some gold was found at shallow depths through a distance of 2,000 feet in the upper part of its course, nearly to its head.

Chispa Gulch.—In the lower three-quarters of a mile of Chispa Gulch, a small branch of Empire Gulch heading southwest of Enzenberg Gulch, a 5 to 10 foot pay streak on bedrock at about 10 feet below the surface yielded very high returns and was being worked at the time of visit in 1909. In the lower portion of an east branch of Chispa Gulch gold was also being obtained from gravels 3 feet below the surface. At the head of the western fork of Chispa Gulch, which is about a mile in length, pay dirt lay at the surface, but at the mouth of the fork the gold was contained in a 50-foot channel on bedrock with 10 feet of overburden.

Empire Gulch.—In Empire Gulch placer gold was found only along a mile and a half of its course below the mouth of Chispa Gulch. The gold occurs in a bed 2 feet thick resting on conglomerate bedrock and is covered by 16 feet of overburden. Near the mouth of Chispa Gulch the pay gravels were about 300 feet in width, but at the lower end of the pay belt they were distributed over a width of a thousand feet.

SOURCE OF THE PLACER GOLD.

Between the latitude of Greaterville, at about the middle of the placer area, and the crest of the Santa Rita Range occur, as shown in the discussion of lode deposits, numerous quartz veins, nearly all of which are gold-bearing and some of which have produced surface ores rich in gold and silver and containing nuggets of native gold. These veins have been opened at the Yuba, Quebec, and St. Louis mines and many other places in the crumpled altered sediments about the base of Granite Mountain, where many of the richest gulches head. This mountain is composed of intrusive granite porphyry, which is more or less pyritic, and the contained pyrite is thought to be probably auriferous, just as the pyrite in the Helvetia district is cupriferous. More or less gold is associated also with the rhyolite dikes.

It accordingly seems probable that the placers may have been formed by the concentration of the gold freed by long-continued weathering and erosion from the vast amount of rock that was removed from the area extending westward to and beyond the present crest of the Santa Rita Mountains. The talus and wash, at first relatively lean in gold, were originally spread out upon the side of the mountain in a vast, more or less continuous constructional sheet sloping eastward toward Cienega Creek. As the top or surface gravels were removed their gold content was mostly left behind, gradually enriching the portion of the sheet which remained. Finally, owing to climatic changes or uplift of the range, the present drainage lines were laid out and developed, whereupon gold extraction and concentration became more intense in the rapid downcutting of the stream courses and the consequent removal of the gulch gravels, and this process is still going on. In the process of concentration, where the drainage is normal, certain ledges contribute more to the gulches by which they or their resultant gravels are drained than to others.

Another view to account for the origin of the gold is that it may have been derived from veins in the Tertiary andesite and rhyolite, which contain the gold-producing veins at the Gringo mine, in the Wrightson district, at the Helena mine, in the Helvetia district, and at many other places. There can be no doubt that these rocks, whose remnants, still several thousand feet thick, form the culmination of the Santa Rita Range in Old Baldy, 4,000 feet above the placer area, and extend well into the latitude of the placer area, formerly extended much farther north and covered not only the axis of the range but most of the placer area. On the removal of these volcanic rocks by weathering and erosion their gold became concentrated in the gravels and gulches in the manner already described.

If this view is correct the volcanic rocks should be well represented in the gravels, not so much in the gravels now contained in the placers, which are mostly later than the volcanic gravels, but in those farther east in the Cienega Valley.

FUTURE OF THE CAMP.

The richer gulch gravels have been worked over to a considerable extent, but the ground that has been washed still contains some gold, as shown by the production of Mexicans who are working it at sundry localities. The gravels in the sides of the gulches and on the ridges also contain small quantities of gold, and it is quite possible that some pay channels have not yet been discovered. The general consensus of opinion of several of the best mining engineers who have examined the area is that it still contains about $50,000,000 worth of gold, and according to E. Ezekiel,[1] a mining engineer of Tucson, who is familiar with the ground and has made a very complete examination of it independently for a large company, the amount of gold present is more nearly $100,000,000. Besides the above-estimated amount of gold now mostly in sight in the area, it is inferred from geologic reasoning that similar and probably workable deposits pretty certainly occur in the deeper gravels east of the present area, which are only just beginning to be exploited.

[1] Oral communication.

Owing to the scarcity of water the means of working the gravels are limited, and as dry washing has not been a success, owing to the clayey character of the matrix, rocking has been the chief method employed. Where the overburden exceeds 3 or 4 feet in thickness small shafts are sunk to bedrock, and the pay dirt, about 2 feet in thickness at the bottom, is mined out, in some places for a radial distance of 20 feet from the shaft, hoisted by a crude windlass to the surface, and stored in heaps until a sufficient amount for a few days' rocking has been accumulated. Water is then packed in and the gold, averaging about 40 cents to the cubic yard of gravel, is rocked out, the entire operation frequently being done by one man. Although most of the gold produced was recovered in this way, it is apparent that, the richer gulch gravels being worked out and the remainder being of lower grade, the deposits can not continue to be profitably worked in this manner. They can be worked with profit only on a considerable scale by dredges or some form of hydraulic machinery which may be found best adapted to the ground.

OLD BALDY DISTRICT.

GENERAL FEATURES.

The Old Baldy district, formerly a part of the Tyndall district, lies in the west-central part of the Patagonia quadrangle, adjoining the Greaterville district on the southwest. It is about 3½ miles wide and extends from the McCleary ranch and Sawmill Canyon 6 miles southward across the Pima-Santa Cruz county line to Mount Hopkins and Old Baldy Peak, at its southeast corner. It lies on the northwest slope of the Santa Rita Mountains.

The topography is for the most part very rugged, especially on the east, where it is of the volcanic rock type (Pl. IV, *A*). The descent from Old Baldy to White House and the mouth of Madera Canyon, at the foot of the range on the northwest, is about 5,000 feet in a distance of 3¾ miles. The district is drained mainly by Madera and Stone Cabin canyons, both containing perennial streams, which head in or above the timber belt and flow northwestward to Santa Cruz River. Madera Canyon heads in two forks, one to the east and one to the west of Jack Mountain, a peak in the saddle between Old Baldy and Mount Hopkins. Jackson Canyon, which drains the north-central part of the district, joins Stone Cabin Canyon below McCleary camp.

The western fourth of the district is underlain by coarse granite, which contains northward-dipping fault planes, joints, and associated quartz veins and is cut by dikes of aplitic rock and rhyolitic porphyry. Granite occurs also on the southeast in the saddle between Old Baldy and Mount Hopkins. On the southwest the northeastern part of

Mount Hopkins is composed of a coarse dark quartz diorite that intrudes the granite and is traversed by northwest-southeast faults which are the sites of mineralization.

Old Baldy and the high ridge descending from it to the north, between Stone Cabin and Jackson canyons, are composed of dense gray Tertiary rhyolite which crops out in the saddle south of the peak at an elevation of 7,630 feet and is stained red by iron. A few knobs on the north ridge are apparently capped by red andesite. The rhyolite extends to the latitude of the McCleary camp. It occupies the upper part of Stone Cabin Canyon and forms the high, broad ridge adjoining the canyon on the east.

Between the rhyolite on the east and the granite on the west is a narrow belt of rock 3½ miles long and a quarter of a mile wide, which corresponds in the main to intrusive diorite but whose principal mineral is locally albite.

Between the southern half of the diorite belt on the east and the granite of Madera Canyon on the west is a belt one-sixth of a mile wide of dark epidotized garnetiferous micaceous quartz schist of supposed Cambrian age, in which the schistosity trends north-northwest. Quartz veins associated with monzonite porphyry strike northeast across the schistosity. On the northeast the schist passes beneath a small belt of dark-bluish limestone. In the northeastern part of the district, in Stone Cabin Canyon, the volcanic rocks give way to a belt of underlying Paleozoic limestone and shale which dips 60° SW., and in the eastern part of the district all the rocks are cut by a northeast-southwest dike of whitish rhyolite, which seems to be the continuation of a dike 5 miles to the northeast, in Box Canyon. It is conspicuous in the granite ridge west of Jackson Canyon and in Sawmill and Stone Cabin canyons, where it has a width of 20 feet. As it is younger than the rhyolite flows and all except possibly the very latest of the volcanic rocks, it is a good register of late geologic disturbance shown by offsets or lateral faulting occurring at numerous points along its course. On the northwest the granite is overlain by heavy alluvial cone deposits of Quaternary gravels discharged from Madera Canyon.

LODE DEPOSITS.

Ore was first discovered in the district in the late seventies or earlier, but there was not much production. Among the early discoveries are the Foster-Tremain prospects, in the Bob Springs Flat in Madera Canyon, and a vein on Jack Mountain.

At the time of visit in 1909 there were four inhabited and two deserted camps in the district. The principal settlement is McCleary camp, at the middle of the north end of the district, in the lower part of Stone Cabin Canyon. The other inhabited camps were Robinson camp, three-fourths of a mile east of McCleary camp; Littleshot camp, the principal one in Madera Canyon, near its head at the west base of Old Baldy, at an elevation of 6,650 feet; Curry camp, a mile west of Littleshot camp, near the Caliente Canyon divide; and the Old Madera Mining Co. camp, 1¼ miles northwest of Old Baldy at the foot of the fault scarp, at an elevation of 6,350 feet. The ranger station of the Santa Rita National Forest is at White House, at the foot of the mountains and the so-called mouth of Madera Canyon. Mail for the men working in the district is received at McCleary camp thrice a week from Helvetia, 12 miles to the north. A wagon road extends up Madera Canyon for a distance of 4 miles. The remainder of the district is reached by trails. In the upper part of the district the ground is usually covered with snow from the middle of December till March.

The district contains a few small mines and a dozen or more prospects, some of which are promising. Most of these are comprised in the following list. Some of the prospects have been held by the present owners since 1880. The metals now being developed are copper and gold. So far there are no deep workings, and few are more than 100 feet in depth.

The properties are situated principally in Madera, Jackson, and Stone Cabin canyons.

Carrie Nation.	Iron Mask (McCleary).	Old Baldy.
Central.	Iron Mask (Littleshot).	Sawmill.
Copper King.	Jackson.	Spear.
Copper Queen.	Lead.	Star Pointer.
Florida.	Lone Star.	Tucson.
Great Western.	Lucky Ledge.	Upper.
Helen Gould.	Midst.	Velvet.
Iron Cliff.	Molybdenite.	

STONE CABIN CANYON.

The principal prospects in Stone Cabin Canyon are the Robinson group or Florida mine and the Star Pointer, Helen Gould, and Sawmill prospects.

FLORIDA MINE.

The Robinson property, comprising a group of nine claims in the eastern border of the district, is located in the upper steep east side of the east fork of Stone Cabin Canyon, between elevations of 5,800 and 6,400 feet, and is reached by trail. It has been owned by Charles Robinson since 1880. The principal showing is on the Copper King and Florida, two adjoining claims at and near the so-called Florida mine. It seems to have the making of a fair copper mine, but its development is being retarded, seemingly by the high price asked for the ground. The workings are meager, consisting principally of several 50 to 100 foot tunnels and shallow shafts aggregating about 500 feet.

The deposits are on or associated with a northwest-southeast fault or shear zone traversing rhyolite, andesite, and diorite (?) porphyry. The zone is said to be mineralized for a length of about 1,500 feet, the main ledge or vein being in general 15 feet or more in width. The principal openings ascending the mountain slope to the southeast and comprised in a vertical range of about 350 feet are the Copper King and Invincible tunnels and the Florida tunnel and shaft.

The Copper King tunnel, a 64-foot northeasterly crosscut in rhyolite, is at an elevation of 6,000 feet, where the ledge, which is still 10 feet beyond the face, is said to be 10 feet wide. The Invincible tunnel, at an elevation of 6,125 feet, is essentially a 50-foot drift run south-southeastward in the mineralized shear zone in altered red andesite, which dips 80° SSW. This zone is composed of a mixture of clay, brecciated rock fragments, calcite, azurite, limonite, malachite, and a little cuprite, constituting an ore which, besides a considerable copper content, is said to contain about 60 ounces in silver to the ton.

In the Florida shaft, which also is on the fault zone at an elevation of 6,340 feet, near the top of the ridge, the ledge dips 80° NE. The hanging wall is fine-grained dark-gray diorite porphyry, consisting largely of acidic plagioclase with a considerable proportion of alteration products, chlorite and epidote, and with magnetite, a conspicuous accessory, mostly altered to hematite. Here and there the rock contains also stringers and veinlets of chalcopyrite, which seems to be primary.

The footwall is a much altered red rock with a microcrystalline groundmass of acidic plagioclase and hematite, and the first 2 to 4 feet of vein or ledge material next to it consists of fragments of rock and ganguelike clay mixed with malachite, azurite, and limonite, and is reported to average 12 per cent in copper and 25 ounces in silver to the ton. The rest of the ledge or vein, which averages about 10 feet in width, is composed of rock similar to that forming the hanging wall but crushed or intensely jointed into cuboidal fragments with faces about one-half to 1 inch square, which are filmed with azurite, malachite, and limonite. Some pyrite and chalcopyrite are also disseminated in the rock, and the whole 10 feet constitutes ore which is said to average about 3 per cent of copper and 20 ounces in silver to the ton.

In the Florida tunnel, which is 100 feet below the shaft and crosscuts the ledge at 80 feet in from the mouth but which was not enterable at the time of visit, the vein material and ore are said to be the same as in the shaft just described.

HELEN GOULD PROSPECT.

The Helen Gould prospect is on Stone Cabin Canyon below Robinson camp, at an elevation of about 4,320 feet. It is on a prominently cropping copper and iron stained ledge of quartz and silicified rhyolite which dips 60° NE. A 40-foot shaft about 20 feet above the creek shows considerable chalcopyrite and black stringers and seams of magnetite.

SAWMILL PROSPECT.

The Sawmill prospect is northeast of the Helen Gould prospect, on a tributary gulch of Sawmill Canyon, at the intersection of a northeastward-dipping siliceous reef or aplitic dike with a southeastward-dipping quartzite bed in Paleozoic limestone. It is opened by a 40-foot shaft at 60 feet above the gulch, but the shaft was not enterable at the time of visit. The dump shows considerable malachite and azurite on the joints of the crushed rock and ledge material, and small beads of native copper are said to occur in the lower part of the shaft.

STAR POINTER MINE.

The Star Pointer mine is about one-third of a mile east-southeast of McCleary camp, north of Stone Cabin Canyon, on open ground in rhyolite country rock which is agglomeratic or brecciated. It is on a 14-foot lode of silicified rhyolite and quartz which extends from the surface down and contains some chalcocite, bornite, and a little chalcopyrite and malachite in irregular bodies. Much of the ore has been formed by enrichment and replacement in the rhyolite. A 2 to 6 inch pay streak, consisting principally of chalcocite and other copper ore minerals, is reported to occur on either wall from a depth of 65 feet below the surface, or ground-water level, to the bottom of the shaft. The chalcocite, as shown by the microscope, occurs in irregular forked and reticulated bodies, following fractures and small replacement chambers and cracks in the siliceous gangue, which is composed mainly of quartz and a little orthoclase, the gangue on the whole being seemingly for the most part a replacement of the rhyolite. The quartz is mostly crystalline and occurs in fine to medium crystals and grains. In places considerable hematite is closely associated with the chalcocite. The deposit belongs to the late Tertiary period of metallization. It is opened principally by a 100-foot shaft that is inclined 85° SW. Water level in the shaft stands at 60 feet below the surface, and ground-water level here and in the vicinity of the McCleary camp is said to be about 50 feet below the surface.

JACKSON CANYON.

The deposits in Jackson Canyon extend principally from a point about a mile south of the McCleary camp, at an elevation of 4,500 feet, southward for 2 miles and lie between elevations of 3,500 and 7,600 feet. They are opened principally by the Jackson mine and the Iron Mask, Upper, and Great Western prospects. Apparently they owe their origin to iron and copper bearing thermal solutions that followed the intrusion of the diorite. Like the deposits in Stone Cabin Canyon, they are probably of Tertiary or later age.

JACKSON MINE.

The Jackson mine is located in the northern part of the district, a mile south of the McCleary camp, on Jackson Canyon, at an elevation of about 4,700 feet, the tunnel and shaft, which are the principal openings, being respectively at 4,570 and 4,775 feet. It is owned by W. B. McCleary, and since 1910 has been developed by the Old Hickory Copper Co.

The deposits are contained in a lens of dark diorite, which is intrusive into the gray granite that is exposed near by on the west. The diorite seems also to be intrusive into the rhyolite on the east. The mine is approximately on or in alignment with the Old Baldy fault scarp which delimits the rhyolite on the west, and the intrusion of the diorite probably accompanied the uplift that formed the scarp. The diorite is a dark medium-grained, moderately porphyritic rock composed chiefly of oligoclase-andesine and dark-green hornblende, and it contains considerable magnetite.

The deposit is a compound fissure vein or stockwork which has a reported extent of nearly a mile. At the shaft it is about 25 feet wide, and in the upper part of the shaft it dips 72° NNW. The gangue is largely magnetite with some quartz, and the ore is principally copper ore carrying small quantities of gold and silver. The croppings, which are not prominent, consist mainly of iron cap with weathered bands, bodies, stringers, and veins of limonite and stained magnetite, which are best developed on the hanging-wall side. They give no indications of copper, which, however, shows more and more in depth.

In the shaft, which is 100 feet deep and is one-third filled with water, some carbonate of copper occurs just below the surface. At a depth of about 20 feet a body of chalcopyrite and pyrite with a little quartz appears, and at 60 feet it enlarges to a 3½-foot lens or ore shoot of good-grade chalcopyrite ore which pitches 45° ENE. A sample collected across the shoot at this place is reported to have assayed 30.6 per cent of copper and 9 ounces of silver and a trace of gold to the ton. Run-of-mine samples averaged high in copper and assayed as high as $5 in gold to the ton.

The dip of the "vein" flattens at this place to about 45°. An additional lens of similar ore was recently struck at greater depth in the shaft, where also considerable water was encountered. The ore or chalcopyrite usually contains a little magnetite, but the chalcopyrite seems to be the later.

The tunnel, located downstream (to the north) from the shaft and 100 feet lower is driven N. 80° E. on an 8-inch vein of magnetite contained in the diorite. In the adjoining bed of the canyon at about 20 feet above the tunnel is a 10-inch vein of magnetite which strikes N. 80° W.

IRON MASK PROSPECT.

The Iron Mask prospect, also owned by Mr. McCleary, is 2¼ miles south of the McCleary camp and 1¼ miles south of the Jackson mine, in Jackson Canyon, at an elevation of 5,170 feet. It is in the same lens of dioritic rock as the Jackson mine, on a vein which dips steeply to the north. The mine is opened by a 50-foot shaft, which is all in iron-copper ore and contains some water. The vein material is about one-third magnetite, one-third chalcopyrite and pyrite in about equal amount, with a little bornite and chalcocite, and one-third gangue minerals, principally quartz and siderite in about equal amount, with a little biotite and hornblende.

The croppings are largely magnetite and other iron oxides. Pyrite, it is said, was encountered at about 25 feet below the surface and copper-bearing minerals at 35 feet. The ore on the dump, which came from the deeper part of the shaft, is slickensided and crudely, indistinctly, and irregularly banded or streaked and contains, besides magnetite, much siderite, macroscopic black tourmaline in the massive or indistinctly crystalline form, quartz, chalcopyrite, pyrite, marcasite, bornite, iridescent hematite, and a little chalcopyrite. Much of the peacock-colored mineral resembling bornite is secondary iridescent hematite, coating pyrite and chalcopyrite.

The microscope shows considerable vitreous or greasy-lustered quartz, not conspicuous megascopically, and a little hornblende and biotite. The quartz occurs in medium to fine irregular allotriomorphic interfingering grains. The chalcopyrite, pyrite, and magnetite occur in irregularly forked aggregates and veins as interstitial fillings in the quartz. In places they inclose tourmaline, and seemingly they were among the latest of the minerals to be formed. The presence of the tourmaline indicates also that pneumatolytic action may have been an important agency in the formation of the deposits and that the deposits were probably formed at considerable depth, perhaps in the deep-vein zone.

UPPER AND GREAT WESTERN GROUPS.

From a quarter to half a mile south of the Iron Mask mine, in Jackson Canyon, and on the adjoining ridges, beginning at an elevation of about 6,000 feet and lying principally between 7,200 and 7,500 feet, are a few scattered prospects on what are known as the Upper and Great Western groups, owned by Mr. McCleary. The general country rock is rhyolite, which is intruded by masses of a dark-gray dense rock, probably a diorite which is low in ferromagnesian minerals and which, though seemingly related to the rock at the Jackson and Iron Mask mines, is different. This diorite contains a large amount of disseminated magnetite and some pyrite, and nearly all the deposits are associated with it.

The rocks are traversed by east-west fractures, in the larger of which pyrite, chalcopyrite, and drusy iron-stained quartz have been deposited. Films of pyrite and chalcopyrite occur also on joint planes, of which one set trends northeasterly and another set northwesterly.

A second body of the diorite occurs on the ridge between Jackson and Birthday canyons at elevations between 6,360 and 6,600 feet. It trends north, is about 500 feet wide, and, like the larger body, contains widely disseminated pyrite and chalcopyrite and a few specks of native copper near the surface. The minerals, especially the sulphides, which begin a few feet below the surface, are mostly concentrated along north-south and northeast-southwest joint planes.

MADERA CANYON.

In Madera Canyon, the principal drainage way in the western part of the Old Baldy district, the deposits extend interruptedly from White House, about 1½ miles north of the county line, at an elevation of 4,500 feet southward for 3 miles to the head of the canyon above Littleshot camp, at an elevation of 7,000 feet.

MOLYBDENITE PROSPECTS.

The molybdenite prospects here described are located 3 miles south of McCleary camp and about half a mile south of White House, in Madera Canyon, in the foothill part of its course, where the creek and wagon road cross the Pima-Santa Cruz county line, as indicated on the accompanying map (Pl. I). They consist of a group of molybdenite prospects commonly known as the McCleary prospects, from the name of the owner. A preliminary description of them has been published.[1] They range from about 4,500 to 5,000 feet in elevation and trend nearly north along the creek, extending half a mile on

[1] Schrader, F. C., and Hill, J. M., Some occurrences of molybdenite in the Santa Rita and Patagonia mountains, Arizona: U. S. Geol. Survey Bull. 430, pp. 158–159, 1910.

each side of the county line. The deposits probably have a much wider extent in an east-west direction, for the prospects here described have only accidentally been brought to light by the erosion of the creek across a seemingly small portion of the area.

In this part of its course the creek, a fine, clear mountain stream, about 2 feet wide and 3 inches in depth, flows in a trench but 5 to 15 feet deep. The topography is gentle, and the prospects are all easily accessible.

The country rock is pre-Cambrian (?) granite. It has been fractured by dynamic disturbances, and along the more prominent of the resulting joints and fault fissures occur the quartz veins that contain the prospects. These veins range from 1 foot to 12 feet or more in width and are mostly compound veins or stockworks. They are in the main associated with intrusive aplite or allied dikes, with which, as at Helvetia, the deposits are probably genetically connected.

The most important exposures, as shown in prospect shafts and tunnels, will be described in downstream order from south to north.

The most southerly of the prospect holes is situated on the west side of the creek at an elevation of 4,990 feet. It is on a small, somewhat iron-stained quartz vein that carries pyrite, chalcopyrite, and flaky molybdenite and dips 70° N. A 20-foot dike of aplitic granite forms the hanging wall.

Just south of the road forks, in the creek bank at an elevation of 4,765 feet, in a fine-grained phase of the granite, a 4-foot vein of iron-stained honeycombed quartz dipping steeply to the north is opened by a shaft which was filled with water at the time of visit but is reported to be 40 feet deep. On the surface the vein exposes a little flaky molybdenite and a very minor amount of pyrite and chalcopyrite.

On the east side of the creek, about 200 feet from the road, at an elevation of 4,675 feet, the granite is traversed by a stockwork several feet in width, composed mainly of veins of massive iron-stained dark smoky quartz. It strikes N. 60° E. and the dip is vertical or steep to the north. The quartz is in part drusy or comby. It is concentrated along the north or hanging-wall side of the fissures, where it is from 6 inches to 2 feet in width and contains a little pyrite and a less amount of chalcopyrite. Associated in part with the pyrite and chalcopyrite and occurring also independently of these minerals, exposed at many places on the joint planes, are flakes of molybdenite that are locally concentrated in masses a quarter of an inch thick and covering an area of about 1 square inch. Flaky aggregates and small bodies of pure molybdenite also occur in the druses and otherwise inclosed in the quartz, as at Helvetia. Associated with the larger masses of the molybdenite and also with limonite on the joints near the surface is a soft yellowish earthy material which looks like clay but which on examination was found to be ferrous iron sulphate. At the mouth of the 10-foot tunnel driven on this prospect, dipping steeply to the southeast, occurs what seems to be a dike of fine-grained aplitic granite, with which the molybdenite is probably genetically connected.

The most northerly and apparently the most valuable prospect of the group is on the east side of the creek, at an elevation of 4,560 feet. Here in the granite is exposed a stockwork of quartz veinlets 3 to 7 feet wide. It dips about 60° NNW. and is traceable for a distance of 1,500 feet eastward from the opening. The granite between the veinlets is very much altered. It is soft, has a yellowish-red color, due seemingly to iron staining, and contains pyrite crystals and flakes of molybdenite. The quartz forming the veinlets of the stockwork is smoky and coated with limonite and a little molybdenite. Some walls of open fissures are coated or glazed with a black sinter-like substance, which is mostly silica but contains manganese and molybdenum. It is particularly abundant on the south or foot wall.

TUCSON PROSPECT.

The Tucson prospect is located 1¼ miles south of White House, near the middle of Madera Canyon, 100 feet east of the road, at an elevation of 5,260 feet. It is opened by a 70-foot inclined shaft sunk on a 1-foot vein of iron-stained drusy quartz containing copper carbonates and iron oxides, which also occur in the gouge on either wall. The country rock is coarse granite. The vein dips 70° NNE. On its foot-wall side there is a 3-foot parallel dike of granite porphyry, between which and the vein the granite is much shattered and iron stained and is traversed by small stringers of quartz.

LUCKY LEDGE MINE.

The Lucky Ledge Mine, owned by the Madera Copper Co., of Los Angeles, is located on the east side of the east fork of Madera Canyon 1½ miles north of Littleshot camp, on a piedmont ridge at the northwest base of Old Baldy and the foot of the Old Baldy fault scarp, at an elevation of 6,350 feet. The deposit was discovered in 1903 by W. P. Scott and has been worked more or less steadily since 1905.

The croppings consist of a north-south 10-foot lamprophyric porphyry dike in micaceous quartz schist. Both the dike and the schist seem to be parallel jointed. The joint planes are coated with limonite and malachite and the schist contains much epidote and garnet along the contact.

At the time of visit the mine was opened by a 175-foot tunnel driven southeastward about 100 feet below the croppings, principally in the dense dark iron-gray schist, which dips steeply to the west and is cut by lamprophyric dikes. One of these dikes 6 feet wide is crosscut by a lateral 100 feet in from the mouth of the tunnel.

The metal of the deposit is copper, but the workings at the time of visit showed only malachite-stained rock in a few places and some small bunches or pockets of amphibolite with dark-green epidote and a little barite, containing besides malachite a little pyrite and chalcopyrite. At 150 feet in from the mouth of the tunnel a 12-foot shear zone of soft altered material contains stringers of copper-stained calcite and quartz.

It is reported, however, that recently the mine has been developed by 3,000 feet or more of new work. The vein, supposedly the Copper Queen vein, described later, has, it is said, been cut in the upper tunnel and found to carry good ore, and it will soon be reached also by the lower tunnel, which is several hundred feet lower down and will give several hundred feet of back. The lower tunnel is now 700 feet long.

The vein is said to be very wide, being of the nature of a shear zone. The ore contains principally copper sulphide with moderate quantities of gold and silver.

OLD BALDY PROSPECT.

The Old Baldy prospect, owned by Louis Littleshot & Co., is located 1½ miles north of Littleshot camp and a quarter of a mile north of the Lucky Ledge mine, at an elevation of about 6,375 feet. It is on a 2-foot quartz vein contained in a mass or small stock of lamprophyric "spotted porphyry," which is intruded into the micaceous quartz schist. Both the porphyry and the schist are sheeted parallel with the vein. The porphyry consists of a holocrystalline groundmass of orthoclase, biotite, albite, oligoclase, and magnetite, and an earlier generation of biotite, orthoclase, oligoclase, and magnetite phenocrysts, many of which are one-eighth of an inch long. Much of the feldspar is too highly sericitized for determination. The vein dips 60° SE. and is opened by a 65-foot drift. It shows some galena and chalcopyrite, which occurs in bands 1 inch to several inches in width and in bunches, mostly in iron-stained quartz, and it is said to carry also moderate quantities of silver and gold.

A few hundred feet north of the opening above described is another good-looking prospect in the quartz schist that shows about the same minerals in a twofold banded quartz vein showing comb structure and dipping 60° ESE. Altered schist on the hanging wall contains bodies of coarsely crystalline, variously colored calcite ranging from white to black.

About 300 feet north of this prospect the schist contains an "iron ledge" consisting of 15 feet of more or less epidotized iron-bearing schist dipping 55° SE. and having on its footwall a 4 to 6 inch banded quartz vein showing comb structure and containing some chalcopyrite, malachite, and iron oxide. A little farther north is a third prospect similar to the one last described. All these prospects are associated with or near lamprophyric porphyry dikes.

COPPER QUEEN MINE.

The Copper Queen mine, owned by the Madera Mining Co., is half a mile north of Littleshot camp at an elevation of about 6,840 feet. It is associated with a fault contact of the massive garnetiferous quartz schist, which is intruded by a fine-grained reddish aplite dike. The contact has a dip of about 60°. Where it is exposed in the outer part of a 50-foot tunnel malachite and chalcopyrite, some of which is in small masses or bunches, appear near the contact, mostly favoring the schist side. In a 16-foot shaft sunk in the aplite just to the east, beyond the tunnel, the same ore minerals with more sulphide occur, principally along seams and sheeting planes. The general highly metamorphosed condition of the schist, which in places is altered to hornstone or is epidotized with a considerable development of specularite, amphibolite, and other minerals, suggests that it may have been baked by an underlying batholith and is probably much older than any of the igneous rocks in the region.

IRON CLIFF PROSPECT.

The Iron Cliff prospect consists of a 5-foot iron-stained fault or shear zone in granite. The shear zone dips 75° NNW. It is opened by a short tunnel just north of Littleshot camp at an elevation of 6,275 feet. It contains streaks of crushed rock or gouge-like material, which on the hanging-wall side carries some pyrite and chalcopyrite with a fair amount of gold. On the opposite or east side of the creek a 20-foot tunnel near by on the same ledge shows much pyrite and galena with a little pyrite and some arsenopyrite on the footwall.

VELVET MINE.

The Velvet mine is at the head of the east fork of Madera Canyon, one-eighth of a mile east of Littleshot camp at an elevation of 5,860 feet. It is in a 500-foot east-west belt of whitish rhyolite which intrudes the quartz schist country rock. On the west the schist has a width of only 150 feet to the point where it is underlain by granite, and at a short distance above the mine in an easterly direction a dark reddish-gray medium-grained quartz-mica diorite appears and seemingly becomes the country rock.

The rhyolite belt has a known length of 800 feet, some croppings of the rock appearing beyond the saddle to the southeast. The rhyolite is closely sheeted in a direction about parallel with the trend of the belt and is more or less crushed, altered, and iron stained. It contains much pyrite and considerable chalcopyrite, and both minerals frequently are in places coated with chalcocite, forming an ore that averages 3 per cent in copper and several ounces in silver and about $100 in gold to the ton. The deposit is opened by a 200-foot tunnel and a shallow shaft. About 10 tons of ore lie on the dump.

SPEAR PROSPECT.

The Spear prospect is on the east side of the west fork of Madera Canyon at an elevation of about 6,170 feet in sloping timbered ground. It is principally on a 2-foot vein or ledge in massive, partly iron and copper stained diorite and is opened by cuts and a short drift.

The ledge trends N. 75° W. and stands vertical. It consists mainly of closely sheeted or sheared diorite and quartz, about 4 inches of which is brownish iron-stained and contains some sulphide, while the remainder, which is less altered, is generally impregnated with finely disseminated pyrite, chalcopyrite, malachite, and a little cuprite, with which are associated some galena and specularite. There is also some concentration of the ore minerals with a little associated quartz in small pockets along the walls, particularly the south wall. The vein is in general frozen to the walls, which are good, but in places a film of copper-stained gouge gives a good breaking face.

The diorite here, as nearly everywhere else, is very close and tight, and no indications of dikes or fissures of any kind appear near by. On the whole, away from the contact with other rocks or formations, it does not look promising for mineral deposits.

CARRIE NATION MINE.

The Carrie Nation mine is in the southwest corner of the Old Baldy district, on the west side of the west fork of Madera Canyon near its head, at an elevation of about 6,450 feet. It is on steeply sloping ground 40 feet above the adjacent bottom of the channel and 20 feet above a side gulch on the south (Pls. I and II, in pocket). It is owned by the Tres Estados Mining Co., which is represented by C. W. Curry, of Tucson. It is on a fault shear zone in reddish-gray medium-grained quartz monzonite. (See p. 61 and analysis 1, p. 61.) The croppings of the deposit, which are not prominent, are iron-stained quartz and silicified monzonite.

The zone trends west-northwest across the sheeting structure of the rock and stands about vertical. It has good walls, each usually with about 2 inches of associated gouge. The vein filling consists principally of sheared monzonite and in places material resembling some dark dike rock or possibly quartz schist. The ore minerals, which are pyrite, chalcopyrite, and malachite with a little bornite and galena, considerable associated specularite, limonite, some molybdenite, and a little zinc blende, impregnate the monzonite and occur also in lenses, streaks, and small bodies, which are banded with quartz. The ore seems to be of low grade. Its value rests in copper, in which it is said to average nearly 3 per cent. About 12 tons of the ore lies on the dump. The property is opened by a 240-foot crosscut tunnel, 110 feet of drift, and a 30-foot shaft. The shaft contains several feet of water.

The Carrie Nation ledge and the property of the Tres Estados Co. here described are said to extend to the top of Jack Mountain on the east, where the Square Deal prospect is located on them.

LEAD PROSPECT.

The Lead prospect, which is also owned by the Tres Estados Mining Co., is located in the upper west side of the west fork of Madera Canyon 200 feet above its bottom, at an elevation of about 6,850 feet, just below the point where the pass through which the trail leads into Caliente Canyon on the west crosses the divide. A small camp, Curry camp, is also situated here. The slope is generally steep. The prospect is on a 4-foot vein of banded quartz in diorite. The croppings are mostly drusy quartz coated with limonite and psilomelane. They contain malachite, azurite, and a little cerusite, and at a foot or two below the surface chalcopyrite and galena are associated with the oxidized iron. The vein dips 80° N. and is separated from the country rock by gouge. It is opened by a 12-foot shaft and a cut terminating in a 75-foot tunnel. Where best exposed in the shaft 50 feet above the camp and tunnel, beginning on the north or hanging-wall side, it consists of (*a*) 2½ feet of crushed rock or gougelike material, lean in quartz and ore minerals; (*b*) a diorite horse which begins a few feet below the surface and gradually widens to 3 feet in the bottom of the shaft; (*c*) 2 feet of crudely banded quartz and crushed gougelike rock containing considerable galena and chalcopyrite and some zinc blende. Some of the ore farther down the slope is reported to carry 33 per cent in zinc.

A tunnel 200 feet lower, in the bottom of the canyon, is supposed to be on this same vein, but where it cuts its projection the fissure zone is occupied by sheared and altered diorite containing only a little disseminated pyrite and chalcopyrite.

It is reported that a 12-foot ore body has been opened recently south of the upper tunnel near camp and that some ore is ready to ship.

MOUNT HOPKINS.

As noted under "Geology," the diorite at the head of the west fork of Madera Canyon, which composes the northeastern portion of Mount Hopkins and is intrusive into the granite, is cut by northwest-southeast faults. These faults have been the seat of metallization, and the minerals deposited are principally galena, pyrite, and chalcopyrite. They occur in the banded quartz and locally also impregnate the diorite next to the fissures. Where the veins or gangue are siliceous the principal ore mineral is galena, but where the gangue is composed principally of sheared diorite with little or no quartz chalcopyrite is the predominant ore mineral.

PLACER DEPOSITS.

The Madera Canyon alluvial cone, heading near White House and the foot of the mountains, at an elevation of about 4,500 feet, slopes northwestward toward Santa Cruz River and has a radial length of at least 5 miles. It is composed of gravels and sands discharged from the mouth of the canyon. These gravel deposits in places are probably over 100 feet in thickness and they all carry colors of gold. Toward the head of the cone an 80-foot shaft was sunk in them without reaching their lower limit. Below the road forks, however, 1 to 2 miles northwest of White House, the deposits are deeply trenched by recent gulches from 40 to 50 feet in depth, some of which cut through the deposits to the underlying bedrock granite, and here considerable gold placer mining was done with fair returns in the early days, mostly in the late eighties, water being brought from Madera Creek by ditch and flume.

Though not connected with the subject in hand, except geographically, it may here be mentioned that in this vicinity was found the 1,400-pound circular mass of native iron known as the Irwin-Ainsa meteorite, which is now in the United States National Museum at Washington.

TYNDALL DISTRICT.

GENERAL FEATURES.

The Tyndall district, the largest and one of the most highly mineralized districts of the area, occupies the western slope of the southern half of the Santa Rita Mountains (Pl. I, in pocket). It joins the Old Baldy district on the south and west and is almost wholly in Santa Cruz County. It extends from Madera Canyon, near White House and the county line on the north, southward to Sonoita Creek, a distance of 18 miles, and from the crest of the range on the east to the foot of the mountains and Grosvenor Hills, 6 miles distant on the west. Toward the south the crest of the range follows the ridge between Squaw Gulch on the west and Temporal Gulch on the east. The district contains about 110 square miles. A small part of it south of the Salero camp is still spoken of as the Aztec district and includes the old Aztec mine and some of the surrounding country.

The topography is varied and generally rough. The surface in the northern part of the district rises to Mount Hopkins, 8,072 feet, and Old Baldy, 9,432 feet in elevation. On the west the northern part of the border declines to 3,500 feet and the southern part to 4,000 feet. In the southwestern part of the district the general regularity in the slopes is interrupted by an irregular benchlike mass of hills, the Grosvenor Hills, averaging about 5,000 feet in elevation. Most of the district is accessible only by trail, but part of it is reached without difficulty by wagon, the drainage ways forming avenues of approach. At the time of visit the northern part of the district was reached by way of Santa Cruz Valley from Tucson or Helvetia, and the southern part by a good wagon road from Patagonia to Salero and Alto. At present most of the district is most easily reached from points on the branch of the Southern Pacific Railroad recently built between Tucson and Calabasas, which by bringing the railroad facilities within 4 to 10 miles of most of the mines has led to a general revival of activities along the west slope of the range. The district, as shown on the map, contains about 20 camps, mostly located on or near the drainage courses.

The district is occupied principally by a north-south belt of quartz diorite and quartz monzonite several miles wide on the east, bordered by granite on the north and overlain and flanked by the Tertiary volcanic rocks, chiefly andesite, rhyolite, and quartz latite porphyry, on the west. In the northwestern part of the district, in the Montosa-Caliente region, there is a relatively small belt of the underlying Paleozoic shales and limestones (Pl. II, in pocket).

LODE DEPOSITS.

Mineral deposits were first discovered in the district in the later part of the seventeenth century by the Jesuit missionaries, who worked the Salero, Montosa, and other mines. As explained on page 22, American activities began in the middle and late fifties of the last century.

The deposits, broadly described, consist of two main classes—argentiferous lead ores, which occur principally in fissure veins with a siliceous quartz-barite gangue in igneous rocks, and copper-silver ores, which occur similarly in fissure veins in igneous rocks and also as contact-metamorphic and replacement deposits, principally in the limestone. Cerargyrite and copper carbonates are common in the rich vein croppings.

The district contains 40 or more mines and prospects, the most of which are given in the following list. Their general distribution is shown on Plate I.

Alto.	Hermit's Home.	Rosario.
Apache.	Ivanhoe.	Royal Blue.
Arizona-Pittsburg.	Jefferson.	Salero (Darwin).
Aztec.	Jenkins.	Santa Rita.
Blacksmith.	Jersey Girl.	Silver Sally.
Bland.	John Allen.	Tia Juana.
Bradford.	Joplin.	Three Star.
Burro.	Jumbo.	Treasure Vault.
Camp Bird.	Mary and Polatski.	Trenton.
Connecticut.	Merry Widow.	Wandering Jew.
Devil's Cash Box.	Montezuma.	Viceroy.
Elephant Head group.	Montosa.	Victor.
Eureka.	Quantrell.	Vulcan.
Helvetia.	Rhode Island.	

The properties lie mostly on or near the main drainage courses, which deeply score the district transversely and issue westward into the Santa Cruz Valley. These courses, beginning on the north, are Chino, Agua Caliente, Cottonwood, and Josephine canyons and Squaw Gulch.

ELEPHANT HEAD GROUP.

Chino Canyon drains the outer portion of the granite area in the northwest corner of the district. From the shoulder-like manner in which the granite mass abruptly terminates in Pete Mountain, where it meets the lowland plains, it is known as Elephant Head. The upper part of the canyon, at about 1¼ miles from the edge of the mountains, widens into what is known as Chino Basin, and here, at an elevation of about 5,300 feet, is the Elephant Head group of 10 claims, also known as the Tremaine-Daniels group, after the former owners. The group has been worked more or less steadily in a small way for the last five or six years, and was recently purchased and is being operated on a larger scale by the Elephant Head Mining Co., with headquarters at Tucson. The group trends east-northeast on dikes of dense greenish-white porphyritic rhyolite cutting the granite and contains a number of good-looking prospects, mostly in the sheared and altered sericitized granite and associated with the dikes. The ores are principally lead-silver ores containing some gold and copper and in places a little zinc. The sulphides impregnate the granite very near the surface.

On the Quantrell claim, at the south end of the group, a 25-foot belt of altered sericitized granite stained by iron and copper carbonate, with a 20-foot porphyry dike on the north, contains ore composed chiefly of galena, sphalerite, chalcopyrite, and pyrite, considerable portions of which are said to average 1½ per cent in copper and 11 ounces to the ton in silver.

On the Eureka claim, at the north end of the group, an 18-inch quartz vein in the granite dips 80° N., is somewhat banded, and contains sericite, malachite, azurite, and chalcopyrite, a considerable portion of it constituting ore said to average 2½ per cent in copper and 17 ounces in silver and $10 in gold to the ton. The 1,500-foot crosscut tunnel driven by the company is reported to have reached the vein, which here carries a considerable width of fair-grade ore. The ore is being shipped to the Pioneer smelter, and it is said that the installation of a dry concentrating plant is contemplated. Early in 1914 the company was reported to have installed a large concentrating plant and to be working a force of 125 men.

AGUA CALIENTE CANYON.

Agua Caliente Canyon heads in the rugged mountains next to Madera Canyon on the east, whence it extends mostly along or near the granite and diorite contact to the foot of the mountains, 4 miles distant on the west.

TREASURE VAULT MINE.

The Treasure Vault mine is located in the upper part of Agua Caliente Canyon at an elevation of about 6,650 feet. It was discovered in 1899 and is owned by the Santa Rita Mining Co., of Tucson. It is on a fault fissure which strikes N. 75° E. and stands about vertical in altered porphyritic diorite which is intruded by granite porphyry on the southeast. The diorite is fine grained and consists of andesine, hornblende, and orthoclase, with a little quartz, biotite, and magnetite. Next to the fault it contains phenocrysts of hornblende three-fourths of an inch in maximum length.

The fissure filling consists principally of about 4 feet of hard sheared and altered diorite and quartz. It is separated from the walls by a thin selvage. The ore contains mainly chalcopyrite, galena, tetrahedrite (gray copper), and sphalerite in association with quartz and some calcite. It occurs principally as pockets or stringers in the selvage and is only sparingly disseminated in the main filling. Some of it is said to average 18 per cent in copper and 100 ounces in silver and $20 in gold to the ton.

The mine is developed by two tunnels and a shaft. The tunnels are driven eastward in a ridge that separates the head forks of Agua Caliente Canyon. They are 80 feet apart vertically. The lower tunnel is 135 feet long, and from it a 30-foot crosscut has been driven to the south. It makes considerable water, which is rapidly depositing limonite on the walls and floors. The shaft, which is 100 feet deep, is located 100 feet above the upper tunnel, which is 80 feet long and considerably caved.

BLACKSMITH PROSPECT.

The Blacksmith Prospect is situated west of the lower Treasure Vault tunnel, on the northwest side of Agua Caliente Canyon. It is opened by a shaft said to be on a vein parallel to that of the Treasure Vault mine, 20 feet to the south, but it is probably on the same vein. The upper part of the vein, at least, is similar to the Treasure Vault vein. The shaft, which was filled with water, is said to be 80 feet deep. It is reported that a great deal of ore obtained from pockets and stringers during sinking was shipped from this shaft.

HERMIT'S HOME.

The Hermit's Home claim, owned by A. E. Jenkins, is located in Rattlesnake Canyon, a north branch of Agua Caliente Canyon, at an elevation of 6,300 feet. It is on a diorite and granite contact zone containing considerable epidote with small pockets of quartz containing galena, chalcopyrite, and sphalerite. A fault dipping 80° SSW. in the coarse pink country-rock granite is associated with a foot of crushed silicified granite containing much white mica and a little disseminated pyrite, chalcopyrite, and chalcocite. The deposit is opened by a 130-foot tunnel on the northwest side of the canyon.

JENKINS PROSPECT.

The Jenkins prospect is located about a quarter of a mile south of Agua Caliente Canyon, at an elevation of 5,365 feet. It is on an east-west shear fault ledge in diorite and is apparently paralleled by a dike of granite porphyry 20 feet to the north. The ledge ranges from 6 to 50 feet in width. It carries gouge and soft, crudely banded ore containing drusy quartz, galena, pyrite, chalcopyrite, specularite, hematite, and sphalerite.

SANTA RITA MINES.

The Santa Rita property lies on the north side of Agua Caliente Canyon at an elevation of about 4,600 feet. It was located in 1900. A small stamp mill, now dismantled, was operated for a short time in 1907. From 1907 to December, 1908, test runs were made with two stamps by the Santa Rita Mining Co., of Tuscon. During this period, it is said, 385 tons of ore was tested and found to average $1.50 to the ton in gold. The concentrates 1 to 20 assayed 16 per cent of lead and from $5 to $10 a ton in gold, but none of them were shipped. The gold caught on the amalgam plates was worth $12.85 an ounce. The average ore of the body, it is said, will run about 50 cents to the ton, but some of that at the surface and extending for a depth of 10 to 20 feet ran as high as $5. The pyrite continues below this depth but does not seem to contain recoverable gold.

DEVIL'S CASH BOX.

Toward the outer edge of the Montosa-Caliente belt of Paleozoic sediments there is a monoclinal north-south foothill hogback ridge capped by limestone dipping 40°–60° W. into the Santa Cruz Valley. The ridge extends from a point near Agua Caliente to Montosa Basin, being about a mile long, and is separated from the slope of the main ridge by a narrow piedmont valley. From the mineral deposits found in it at various points it is known as the Devil's Cash Box. It was not examined in this work. Among the producing properties it is said to contain are the Orosco and the Sheehy-O'Donnell. The Orosco, owned by J. M. Orosco, is said to lie at the base of a limestone formation and to have shipped some very rich silver-lead ore.

The Sheehy-O'Donnell mine, owned by Messrs. Sheehy and O'Donnell, of Tucson, is 5 miles east of Chaves station on the Tucson-Nogales line of the Southern Pacific and 10 miles from the Pioneer smelter. It has made occasional shipments during the last few years, mostly to El Paso, and has recently been operated on a larger scale. It is opened to a depth of about 100 feet. The vein or lode is said to be 20 feet wide, and the mineralized zone in which it occurs is said to extend throughout the length of several claims.

The ore is mostly lead-silver ore. The average of shipments made to the smelter is reported to be about $30 to the ton, but the ore in the deep part of the mine contains in places about 40 per cent of zinc, 22 per cent of lead, and 14 ounces in silver to the ton.

In September, 1914, the mine was bonded to a syndicate, which is working it under the name O. K. mine and producing 20 tons a day, of chiefly shipping ore. Forty men are employed under T. M. Parks, recently of the Elephant Head mine. Zinc ore as well as lead-silver ore is now produced, chiefly from a good lead-zinc showing along the limestone contact in the deep part of the mine. Some of the ore is hand sorted, and the zinc ore which is separated is shipped to Colorado and Kansas for treatment. By September 15 seven cars of the ore had been shipped.

MONTOSA CANYON.

Montosa Canyon lies 1½ miles south of Agua Caliente Canyon. It heads on the upper west slope of Mount Hopkins, and in crossing the soft shale formation, about a mile before it reaches the foot of the mountains, widens into Montosa Basin, in which are the Montosa mine and other principal openings of this drainage area. This part of the country, it is said, was worked by the Jesuit missionaries more than 300 years ago.

The first modern work in the region was done in 1876 by Clarke & Peterson on the heads of Montosa Canyon and of Josephine Canyon adjoining on the east, and much mining was done in the basin up to 1882. A number of claims are patented, among them the Pluto, on the east, and a number of others on the south, toward Josephine Canyon.

The basin is reached by wagon road ascending the lower part of the canyon from the west, and a trail leads from the basin up the canyon and across the divide to the head of Josephine Canyon.

MONTOSA MINE.

The Montosa mine is located in the southwesterly part of Montosa Basin and adjoining hills, at an elevation of about 4,900 feet and is easy of access. It is owned by Freeman & Smith, of Tucson. The property comprises a group of 14 claims known as the Montosa group. It was worked principally about 1901 and soon thereafter by Capt. John D. Burgess, of Tucson, for the Calabasas Copper Co. (Ltd.), with headquarters in New York City. The company did about 2,000 feet of underground work, mostly on the Isabella ground. It sunk to a depth of 250 feet and installed a 36-inch 30-ton water-jacket testing smelter. The smelter, however, was operated only 4½ days, but during that time \$9,600 worth of bullion was extracted and a two days' run yielded considerable ore, carrying 47 per cent of copper. The ore in general averaged 8 per cent in copper, and the bullion, which was shipped to Ledoux & Co., of New York, carried about 360 ounces of silver and 3.1 ounces of gold. Some of it contained 16 to 20 per cent of lead and 30 to 45 per cent of iron (FeO).

The ore is said to have contained principally malachite, chalcopyrite, bornite, lead carbonate, galena, magnetite, specular hematite, and in places silicified green epidote. The iron oxides occurred principally in large masses intimately mixed with the malachite.

The company gave up the mine to the owner when its bond expired, in February, 1902, and since then no work to speak of has been done on it until recently.

The deposit is a replacement body in the Paleozoic limestone, which dips to the southwest. It is in the lower part of the limestone near its contact with the underlying shale. It trends about N. 70° W. and lies in a mineralized zone which extends at least one-eighth of a mile to the southeast and beyond which the limestone soon gives way to the overlying andesite that caps the mountains. The intrusion of the andesite may be connected with the origin of the ore deposits, as is suggested by the fact that the andesite contains considerable magnetite, the deposits resembling in some respects those on Jackson Canyon, in the Old Baldy district.

A 30 by 40 foot open cut, the principal surface exposure, is about all in low-grade ore or bedded mineralized material. The entire mass is very ferruginous, containing magnetite and specular hematite, and the latter is the principal gangue mineral. The copper is represented by malachite, lead-copper oxide, and a little chrysocolla. Sulphides seem to be absent. The best part of the exposure is a 6-foot ferruginous bed that follows a slickensided footwall, dips 75° S., and seems to have been the chief source of the ore produced. It is composed principally of magnetite and specular iron and contains a little malachite, red copper oxide, and chrysocolla. About 40 tons of the ore is piled up on the ground, some of which is sorted for shipping, but it seems to contain little of value other than the iron. In the dump at the smelter the ore, which seemingly had been sorted, similarly consists mainly of malachite and azurite with a little chrysocolla and red copper oxide in a magnetite-specularite gangue. The deposit seems to contain a large amount of low-grade ore and can probably be profitably handled only if it is worked for iron as well as copper.

OTHER PROSPECTS.

About three-fourths of a mile north of the Montosa mine, seemingly on the Pluto claim, some relatively recent work has been done which includes a shaft 100 feet deep equipped with machinery. The deposit here seems to be in shale and greenish silicated limestone, and is probably associated in origin with intrusive andesite or diorite dikes which occur near by on the west.

COTTONWOOD CANYON.

Cottonwood Canyon, which lies 1¼ miles south of Montosa Canyon, heads in the upper southeast slope of Mount Hopkins. In a spur on its north side at an elevation of about 5,000 feet are several prospects and two small producing mines from which ore, mostly copper carbonate, is packed down to the wagon road on burros and shipped. The country rock seems to be principally diorite underlain by limestone, which it intrudes, and capped by andesite. These deposits lie southeast of the Montosa deposits, to which their copper-stained croppings are said to be almost continuously traceable.

One of the mines, which is owned by John Allen, of Vance, Ariz., is opened principally by a 350-foot tunnel and 60 or 70 feet of drift, with 200 feet or more of backs. The vein, which is about 3½ feet wide, dips steeply to the southwest and has from 2 to 6 inches of gouge on the hanging wall. It is in diorite capped by andesite and is associated with two intrusive rocks corresponding to granite porphyry and lamprophyre. The vein consists principally of crushed country rock diorite and quartz and carries some ore. The ore minerals are chiefly chalcopyrite and pyrite. They occur in lenses, stringers, and irregular bodies associated with the quartz and they impregnate and replace the diorite in the vein. The mine makes a small amount of water.

JOSEPHINE CANYON.

Josephine Canyon heads south of Madera Canyon in the saddles on either side of Jack Mountain, between Old Baldy and Mount Hopkins, whence it extends southward for 4 miles and then southwestward for about 7 miles, leaving the mountains at the north base of the San Cayetano Mountains.

The mineral deposits are located in the upper part of the canyon. Here the topography is rugged and the surface well timbered. The country rock is mainly diorite and quartz monzonite.

Mineral deposits were discovered here in the early sixties. In the late seventies or early eighties a dozen or more claims were patented by eastern companies, which later learned that the claims would not pay to work in those days.[1]

MARY AND POLATSKI PROSPECTS.

The Mary and Polatski claims, owned by Martin Michelske, who lives on the ground, are three-quarters of a mile north of the township line in a small west fork of Josephine Canyon, at an elevation of about 5,300 feet. The main opening on the Mary claim is a 55-foot drift on a shear zone which dips 75° N. in dacite. This zone contains stringers of quartz carrying galena and chalcopyrite with some silver. Near the face of the drift the vein is cut off by a fault which hades 30° SE., and a crosscut 50 feet to the south has not yet recovered the vein, which is thought to be a continuation of the Rhode Island vein described below.

The Polatski ground, which is north of the Mary, is opened by a short tunnel driven in the granite beside a 6-foot quartz vein that strikes N. 60° E. The quartz is iron stained, and where opened by a 60-foot drift the vein shows a little chalcopyrite coated with chalcocite.

RHODE ISLAND MINE.

The Rhode Island mine is five-eighths of a mile upstream north-northeast from the Mary and Polatski claims, on the east side of Josephine Canyon, about opposite the Tia Juana cabin, where the

[1] McGee, John E., oral communication.

trail to the Tia Juana mines leaves the canyon. It is on a 4-foot quartz vein in dacite, with about a foot of gouge on the hanging-wall side. It and the adjoining Connecticut property, owned by R. R. Richardson, were discovered in 1895, and a small adobe smelter was built to treat the ore. In recent years only assessment work has been done. It is opened by a 100-foot drift and a 60-foot shaft in which the vein for the entire length shows oxidized iron and copper stained quartz containing azurite, malachite, chalcopyrite, galena, pyrite, specular iron, a little chalcocite, and in places some zinc blende; it contains also some silver and gold. Chalcopyrite is said to be the principal ore mineral. A carload of ore shipped to the El Paso smelter in 1903 is reported to have carried 11 per cent of copper, 3 ounces in silver, and $2 in gold to the ton, and a little lead and zinc. About 50 tons of good-looking ore lies on the dump.

CONNECTICUT MINE.

The Connecticut mine, adjoining the Rhode Island, is on a fault or shear zone ledge which dips steeply to the south, in diorite. It was worked mostly in 1895–96, when about 300 feet of work was done and several tons of ore was treated in the adobe smelter built on the ground. Since the acquisition of the property by the present owner, in 1900, only the annual assessment work, which aggregates about 300 feet, has been done. In 1904 and 1905 two carloads of ore, principally from the main or upper tunnel, were shipped to the El Paso smelter and averaged 22 per cent of copper and 15 ounces in silver and $1 in gold to the ton. The ore contains no zinc or lead.

The property is opened by a 240-foot drift 110 feet above the bottom of the canyon. Along the middle 150 or 160 feet of the drift are upraises and stopes, which produced most of the ore, and here the ledge or vein, 4½ feet wide and consisting of crushed and altered mineralized rock and quartz, contains ore, mostly in bands or stringers, interruptedly all the way across and for 90 or 100 feet along its course. Also through the middle two-thirds of the drift extends a later 2 to 6 inch band or vein of ore which dips transversely to the north-northeast and is best exposed in the upper right wall and adjoining part of the roof. The ore in this vein contains chalcopyrite, malachite, and iron oxide, with a little bornite. The drift seems to be driven on the junction or horizontal intersection of this vein with the main ledge. Toward the face of the drift this vein straightens up and is represented only by a 2 or 3 inch band of gouge containing a little sparsely disseminated pyrite and chalcopyrite on the right or hanging-wall side. In a cut 40 feet above the drift it seems to be represented by stringers and a lens of ore about 6 inches in maximum width. Toward the face of the drift horizontal grooving indicates that considerable lateral movement has taken place. The drift is partly timbered and is somewhat caved.

In the lower drift, which is 110 feet below the main drift just described and but 3 feet above the bottom of the canyon and has a length of 80 feet, the ledge is composed mainly of closely sheeted, sheared, and partly altered diorite. Some slices are less than a quarter of an inch thick, and along the sheeting planes are seams or stringers of oxidized ferruginous material. In the right face of the drift is shown about 2½ feet of altered iron and copper stained rock and quartz containing some chalcopyrite and specular hematite.

During 1912 and 1913 Hogan & McCutcheon worked the mine under lease and are said to have sunk it to the depth of nearly 400 feet and shipped many carloads of fine copper ore that yielded about $1,600 each. In September, 1914, it was reported that the mine was being worked by Tate & Gartley, of Bisbee, who were taking out silver ore only and leaving the copper ore in the stopes until more settled times.

PROSPECTS NEAR CONNECTICUT MINE.

About a quarter of a mile northeast of the Connecticut mine, above the mouth of the east-side gulch, at an elevation of 5,530 feet, or 120 feet above the floor of the canyon, is a 2-foot faulted shear-zone ledge dipping steeply to the south-southeast, in diorite, which is opened by a 150-foot drift and 30 feet higher up the slope by a 45-foot cut with a 20-foot face. From both of these workings seemingly good oxidized copper ore has been taken out. The ledge, which contains but little quartz or sulphides, consists mainly of sheeted or crushed altered country-rock diorite, largely replaced by the ore minerals malachite, azurite, and oxide of iron. The ore occurs in lenses, the largest of which is about 2 feet in width. Several tons of good-grade oxidized copper ore lies on the dump. The hanging wall shows both approximately vertical and horizontal slickensiding.

As no other intrusive rocks were observed in the vicinity it seems likely that the deposits of the Rhode Island and Connecticut mines and of the neighboring prospects may owe their origin to thermal solutions that accompanied and followed the intrusion or eruption of the dacite at the locality of the Rhode Island mine.

CAMP BIRD PROSPECT.

The Camp Bird prospect is located in the main canyon about a mile above Tia Juana cabin and a mile northeast of the United States location monument. It is opened by a 10-foot shaft sunk on a tight southward-dipping fissure in granite. The walls are impregnated with disseminated pyrite and chalcopyrite in moderate amount.

TIA JUANA MINE.

The Tia Juana mine is located in the west side of Josephine Canyon three-fourths of a mile from the stream channel, between elevations of 6,100 and 6,800 feet, in the high, prominent narrow ridge which separates this canyon from Cottonwood and Montosa canyons on the west. It is but a quarter of a mile from the central head fork of Cottonwood Canyon and 1½ miles from the nearest Montosa drainage way. The topography is rugged. The mine is in a parallel gulch in the steep, cliff-like face of the ridge which the vein crosses (Pl. I), and is reached by trail from Tia Juana cabin. The country rock is diorite, in which there is a strong quartz fissure vein which stands vertical, is about 14 feet in width, and has a known length of about 2½ miles. Its course across the country is well marked by a reddish-brown belt of croppings and their resultant débris. The vein strikes N. 85° W. and extends from Josephine Canyon westward across Cottonwood Canyon and into Montosa Canyon, 1½ miles above the mine and Tia Juana ridge. The Montosa mine, though 3 miles distant, lies directly on its course, suggesting that the two deposits, though possibly not connected, may be on the same general fault or fissure.

The croppings, which in places rise boldly 20 feet above the surface, consist almost wholly of quartz, stained reddish and dark brown by limonite, manganese, and copper carbonate. The quartz occurs mostly in multiple-banded parallel reefs with a small amount of altered mineralized rock. In places the vein is crossed by a nearly vertical sheeting and slickensiding showing both vertical and horizontal movement to have taken place along the vein. On the north slices of the country-rock diorite several feet in thickness dipping to the northeast, are separated by a few inches of gouge.

The vein was discovered in the early sixties, and from openings on its end in Josephine Canyon, in the flats, pioneer prospectors chlorided considerable very rich ore, much of which averaged, it is said, more than 1,200 ounces in silver to the ton. In 1902 the ground was acquired by the present owners, who have patented three (the Santa Maria, Tia Juana, and Santa Cruz) of the five claims and are doing more than the required assessment work on the other two. Figures giving the amount of production, which was not large, are not available.

On the Tia Juana ground the vein is opened by cuts, drifts, crosscut tunnels, and shafts aggregating by estimate at least 500 feet of work, distributed at intervals throughout a distance of nearly 2,000 feet and a vertical range of about 600 feet, as shown in part in figure 19. In these openings the vein ranges from 10 to 40 feet in width and exhibits in cross section considerable variation in the filling. It is generally separated from the north wall by a 1-foot sheet of gouge, and this is succeeded by 2 to 8 feet of white, iron-stained, mostly massive quartz, which contains chalcopyrite, pyrite, and galena with some copper carbonates and chalcocite sporadically distributed, mostly in small pockets and disseminations, and a considerable part of which constitutes low-grade ore. The southern part of the vein consists chiefly of crudely banded crushed, altered,

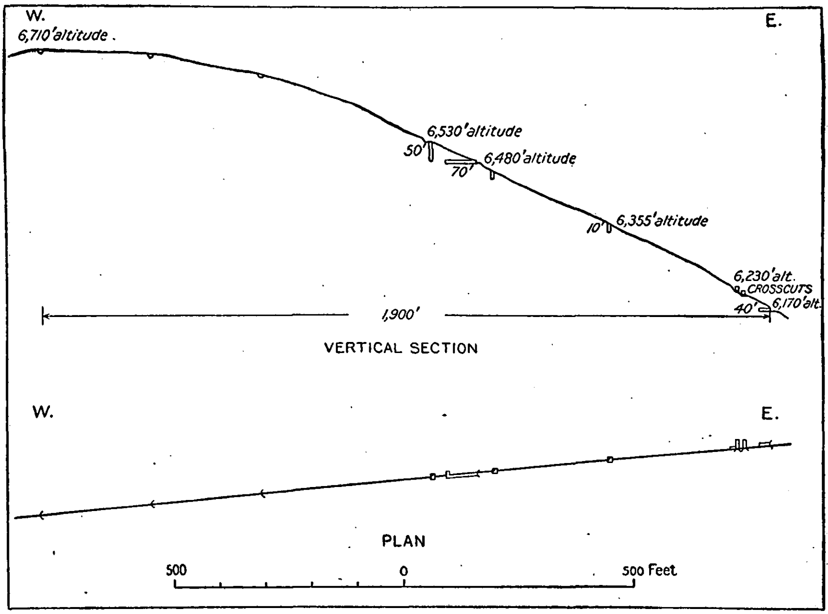


FIGURE 19.—Eastern part of Tia Juana mine.

brecciated, and mineralized diorite, locally silicified and containing veinlets, stringers, and lenses of mineral-bearing quartz, the whole being more or less impregnated with pyrite, chalcopyrite, galena, and some copper carbonates, and much of it constituting ore of concentrating grade.

On the Cottonwood Canyon side of the ground about 800 feet west of the divide and 300 feet below it, on the Tia Juana claim, the vein is said to fork or give off a strong spur which deviates obliquely from the main vein, taking a more northerly course, and at the forks the vein has a reported width of 40 feet. It has been recently opened by a 120-foot drift and crosscuts. On the north or hanging-wall side, near the surface, it contains large bodies of ore consisting mainly of carbonates of copper and lead with considerable silver and some gold, and at greater depths good bodies composed principally of chalcopyrite and galena in a quartz gangue appear.

The Tia Juana vein is large and persistent and seems to contain considerable ore, but it should be worked with due consideration to the low grade of the ore and the more or less sporadic manner in which it occurs. Where opened near the middle of the slope by a 50-foot drift and crosscut, the vein is composed mostly of crudely banded, oxidized, altered, and mineralized rock and quartz, some of which is considered low-grade ore, and it contains fine to medium grained specularite, malachite, azurite, a little pyrite, chalcopyrite, molybdenite, galena, and sphalerite. Here about 10 tons of fair-looking, mostly oxidized ore lies on the dump, and several tons of similar ore lies at each of two other openings.

SALERO AREA.

GENERAL FEATURES.

The Salero area joins the Josephine Canyon area on the south, extending in a belt about 3 miles wide southward for 6 miles to the south line of T. 21 S., R. 14 E., near the Grosvenor Hills. It lies mostly near the eastern border of this township and includes in its southern part the historic Salero camp and mine. The other principal camps, whose distribution is shown on the map (Pl. I, in pocket), beginning on the north, are the Arizona-Pittsburg, Wandering Jew, Alto, Trenton, Burro, Bland, and Hackett.

The topography of the area is mountainous in the eastern part. Elsewhere it is mostly rough and hilly, but the western middle part, centering about Wise's ranch is comparatively open. It is drained principally by an eastern branch of Josephine Canyon, known as Ash Canyon, whose head tributaries reach to the ends of the belt on the north and on the south. A narrow portion of the belt on the east drains southward through Squaw Gulch into Sonoita Creek.

The central part of the belt, about 1½ miles wide, with the north-south township line near its middle, is occupied by diorite and quartz monzonite, which on the west are overlain by Tertiary volcanic rocks—quartz latite porphyry, dacite, rhyolite, and andesite—and to the southeast, on Squaw Gulch, are succeeded by a north-south belt of intrusive granite porphyry. The mineral deposits occur in veins which strike west-northwest and are contained mostly in the quartz latite porphyry, diorite, and quartz monzonite.

The area contains half a dozen mines and a score or more of good-looking prospects, many of which are productive on a small scale.

They are mostly in or near the northeastern part of the township and are listed below.

Alto.	Helvetia.	Royal Blue.
Apache.	Jefferson.	Salero (Darwin).
Arizona-Pittsburg.	Jersey Girl.	Three Star.
Aztec.	Joplin.	Trenton.
Bland.	Jumbo.	Wandering Jew.
Bradford.	Merry Widow.	Viceroy.
Burro.	Montezuma.	Victor.
Eureka.	Rosario.	Vulcan.

A drawback of some of the ores of this area is the mixture of the metallic minerals—for example, lead, copper, zinc, silver, iron, and molybdenum—which renders treatment or final separation of the metals difficult and expensive.

SALERO MINE.

The Salero mine (also known as the Darwin and later as the Constitution mine) is located in the southern part of the area, 7 miles northwest of Patagonia. It is among the oldest mines in the region, the deposit having been discovered by the pioneer Jesuits in the seventeenth century. It was worked about 1828 to 1830 by the Tumacacori missionaries, and later by Mexicans. In 1856 or 1858 John W. Wrightson, of the Cincinnati Enquirer, and his brother became the next owners. They sunk a 75-foot shaft and opened some drifts. About 1858 the mine passed into the hands of the Salero Mining Co., of Cincinnati, Ohio. From 1858 to 1861 Tubac was the company's headquarters. Its leading men were John W. Wrightson, manager; H. C. Grosvenor, an Englishman, engineer; Gilbert, superintendent; Hopkins, mineralogist; and R. Pumpelly, geologist. All these men except Pumpelly were killed by the Indians, and in 1865 the company retired.[1]

During and after the Civil War the mine lay idle until it was relocated by John E. McGee for an English corporation, but as the mine was on the Boca Float No. 3 grant, which could not be held, it was relinquished. Early in the seventies, in the lead-silver days, it was relocated by George Clark, of the Peterson & Clark firm, who after working it to some extent bonded it to the Kranz brothers, of Sonora, Mexico. Later Clark and his partner Peterson worked it themselves, took out and shipped $10,000 worth of ore, mostly from old workings at about the 60-foot level, and, it is said, left 1,500 tons of second-grade 12-ounce silver ore on the dump.

About 1897–98 the mine was worked by John Wier, of New York City, who sunk a 300-foot (?) shaft on the property and did con-

[1] Hinton, R. J., Handbook of Arizona, p. 204, San Francisco and New York, 1878.

siderable drifting. About 1900 Peterson & Clark sold the mine for $15,000 to the Salero Mines Co., of which C. H. Ferry, of New York, and W. P. Blake, of Tucson, were the leading men. This company began to develop the mine in 1902, started the new shaft in 1904, and installed the present substantial machinery and enlarged the shaft to a two-compartment shaft in 1908. At the time of visit the company was drifting east and west on the 400-foot level and running crosscuts. Recently, since Mr. Blake died, Mr. Ferry is

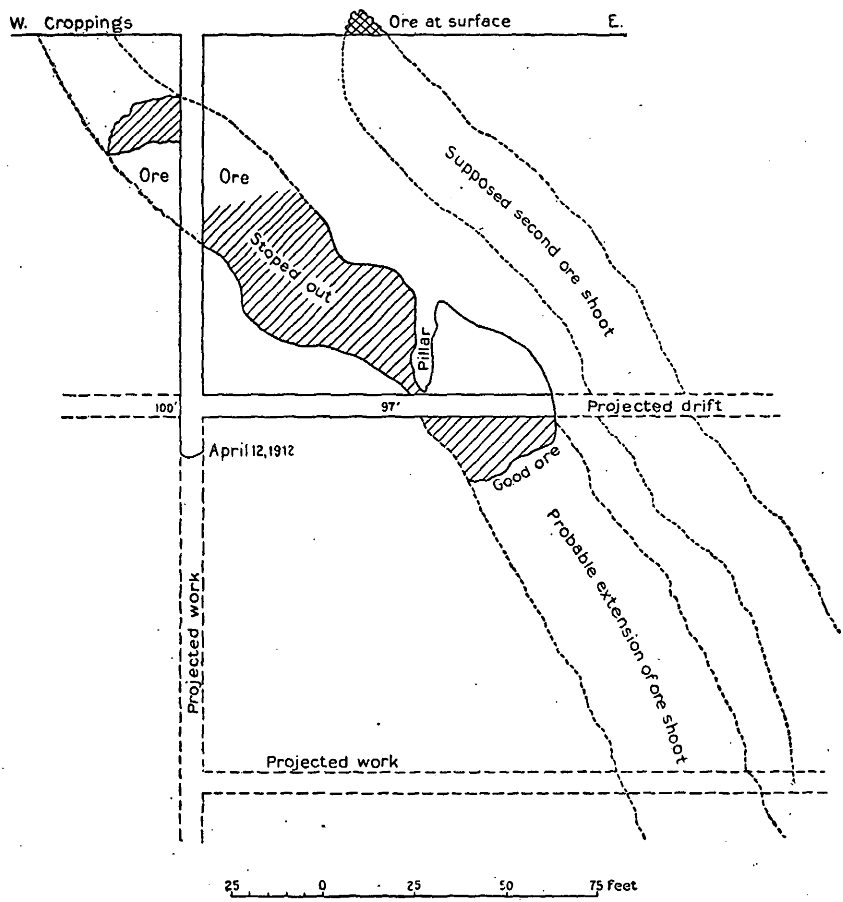


FIGURE 20.—Longitudinal section of west shaft workings, Salero mine.

said to have become the sole owner of the mine. The property comprises a group of several claims, among them the Eureka and Thunderer, both patented and said to have much ore blocked out in the ground.

The mine is opened mainly by two shafts 441 feet apart (Pl. XIV), drifts, and crosscuts aggregating about 2,000 feet of work. The east or Darwin shaft is a double-compartment shaft sunk to the

400-foot level, where drifts are run 150 feet to the east and west with crosscuts spaced 25 feet apart. The old or west shaft has 150 feet of drift on the 100-foot level and 200 feet on the 160-foot level (fig. 20).

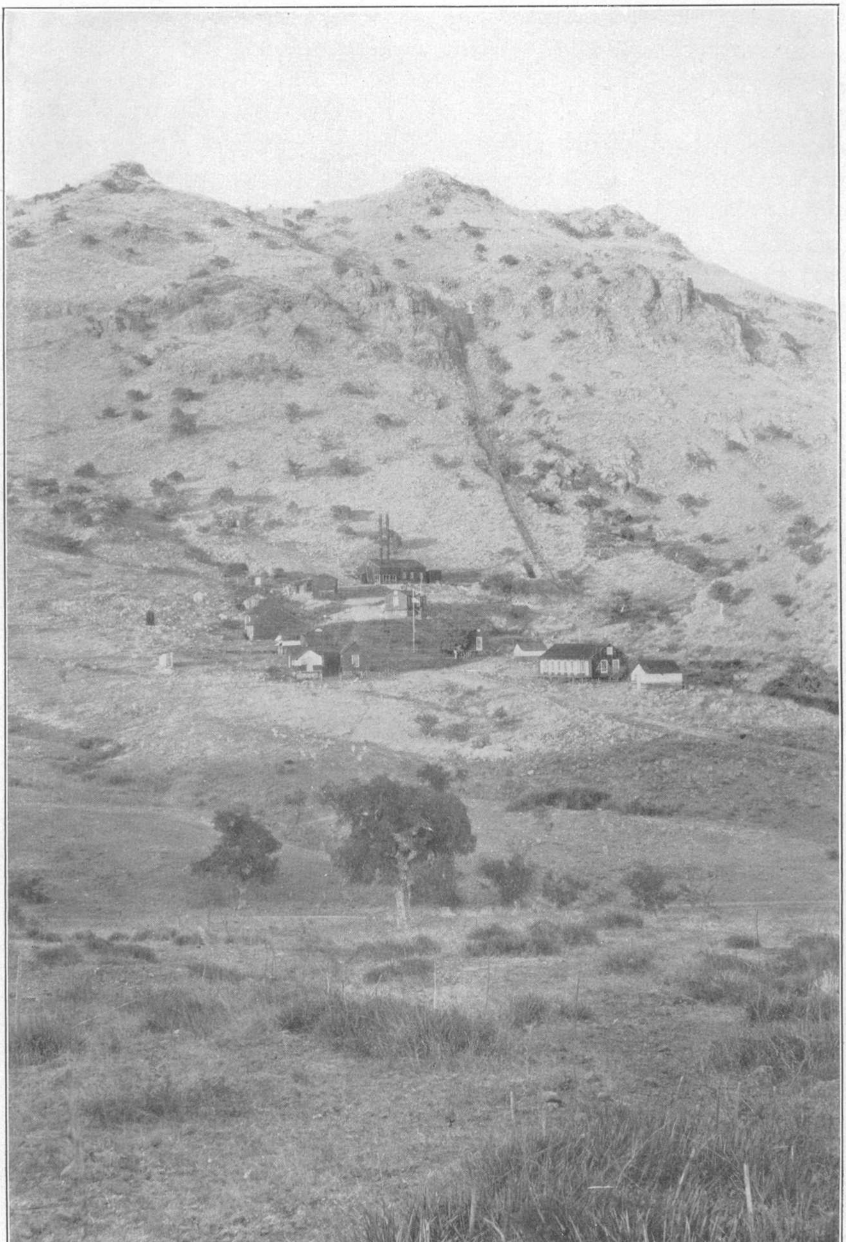
The mine is well equipped and at the time of visit the company was working 20 men.

The topography is relatively gentle. The mine is located just north of Salero camp, at an elevation of about 4,650 feet, in the southwest base of Salero Hill, which overlooks open-valley country on the south that drains northwestward into Josephine Canyon (Pl. VII, *B*).

The country rock in general is the quartz diorite, but at the mine, as seen in the footwall on the surface at both shafts and in both walls on the 400-foot level, there is a fine to medium grained acidic rock standing between aplitic granite and granite porphyry. It is intruded and overlain by fine-grained altered quartz diorite, or possibly andesite, which occurs in the hanging wall, as is well shown at the old shaft, and in places it is banded and has a tuffaceous appearance. The country is considerably faulted; one fault on the property has a reported throw of 300 feet. Water was first encountered in the mine in crosscutting the vein on the 140-foot level, and from this level down to the 400-foot level the mine makes about 20,000 gallons of excellent potable water in 24 hours. Ground water is thought by the operators to stand at depths of 120 to 130 feet, where more water was encountered than at any other depth in the mine.

The deposits are chiefly silver-copper ores contained in a quartz vein which strikes N. 65° W. and has a reported length of about 4 miles. One vein is in general well defined, the croppings in places rising boldly 20 feet above the surface. On the Salero ground it dips 75° SSW. or stands nearly vertical and ranges from 10 to 30 feet in width. The country rock, especially on the footwall, is sheeted about parallel with the vein and both the vein and the country rock are closely sheeted or cleaved by structure planes dipping 80° SE., which is obliquely across the dip of the lode.

The croppings where best exposed at the west shaft have a width of 12 feet and rise from 5 to 20 feet above the surface. They consist mainly of quartz which is more or less crushed, somewhat laminated, and drusy. The quartz is mostly whitish, but much of it is greenish, some is stained brownish or reddish and black by iron and manganese, some purple as if by fluorite, and some red speckled, perhaps by ruby silver. The last 2 or 3 feet of the quartz on the hanging-wall part of the vein is dull greenish and impure, being flinty or cherty, and is separated from the wall rock by 2 feet of



ALTO MINE, CAMP, AND HILL.

Looking N. 80° E. The tunnel is at 1.

variously streaked and iron-stained crushed rock and quartz that form a breccia-like gouge.

In the old shaft the vein is said to be 24 feet wide. The gangue is practically all quartz, and the vein carries a good ore shoot which, as shown in figure 20, pitches about 45° E. and is known to extend from a point near the surface to the 160-foot level, where the 200-foot drift extending east of the shaft, driven partly in the hanging-wall and partly in the footwall side of the vein, is continuously in good ore for 75 feet. The hanging-wall side of the vein usually carries from 1 to 2 feet of "talcose" gouge, but on the footwall side the quartz rests directly on the solid wall rock, and here most of the ore occurs.

The ore of the mine is chiefly silver-copper ore, whose value lies almost wholly in silver. It shows a tendency to be associated with the greenish quartz, which, on the 400-foot level, is more or less crushed and brecciated and in part laminated and drusy. The ore minerals are principally argentite and chalcopyrite, with also a little copper carbonate and a very little galena; pyromorphite is reported. In the surface ores occurred also considerable horn silver, or cerargyrite.

The drifts now being run on the 400-foot level are all in whitish and greenish, more or less iron stained quartz, which is as a rule barren. No ore has been encountered in the east drift, but the west drift has just passed through a so-called lens of quartz extending obliquely across the vein in an easterly direction. This lens is 10 feet or more in width and shows considerable red and brown iron stained material, some stained by malachite and azurite, and some black silver (?) sulphide. Much of the quartz has been crushed, shattered, laminated, and recemented. The country rock, on the footwall at least, is very close and tight, rendering it difficult for mineral deposits to form in it. Between the shaft and the vein, however, which are 90 feet apart, at a point about 14 feet from the shaft, occurs a fault marked by a sheet of gouge 1½ feet wide, dipping 80° S.

ALTO MINE.

Location and topography.—The Alto, formerly the Gold Tree and later the El Plomo mine, is located 2¼ miles nearly north of Salero, mostly in the SE. ¼ sec. 12, at an elevation of about 5,400 feet. It is in rough, hilly ground in Alto Hill, which, however, overlooks an open valley on the southwest (Pl. XV) that forms a natural approach to the mine and camp, the camp being at the foot and the mine mostly in the upper part of the hill, which rises 900 feet above the valley. The hill was named El Plomo by the early Spaniards, from the lead minerals occurring in it. It is merely a short truncated spurlike piedmont ridge about half a mile in diameter at the base and but a few hundred feet wide at the top.

History and production.—The deposit was discovered by the Jesuit priests of the Tumacacori mission about 1687, and they worked it pretty steadily up to 1857, when the whites were driven from the country by the Indians. About 1875 it was located as the Gold Tree by Mark Lully, of Nogales, who worked it for a few years and sold it about 1880. It was later worked occasionally, with moderate success, by Albert Steinfelt & Co., of Tucson, until about 1902, when it was purchased by the present owners, the Alto Consolidated Mines, Smelting & Transportation Co., financed by a Mr. Boynton, of New York. This company, operating in 1905 to 1907, inclusive, built roads, installed machinery, drove a long tunnel, sunk most of the shafts, including one 217 feet deep, and did most of the modern development work, principally on the Alto vein. Since 1907 some work has been done intermittently with a force of 5 to 10 men.

The property comprises a group of 21 claims, shown in figure 21. No definite statement of the early production can be made. The ores first taken out were very rich in silver, and no attention was paid to lead. In the late seventies, however, Mr. Lully shipped 12 tons of relatively pure lead-silver bullion. From February, 1906, to July, 1907, the production was $14,000, mostly in copper, lead, and silver, with a little gold. The ore was shipped[1] to the El Paso smelter and averaged about 5 per cent in copper, 32 per cent in lead, 9 per cent in zinc, and 24 ounces to the ton in silver. About 12,000 tons of low-grade ores said to range from 1 to 3 per cent in copper, 7 to 10 per cent in lead, and 4 to 6 ounces to the ton in silver lie on the dumps.

Development.—The mine is developed by tunnels, drifts, shafts, and stopes aggregating 10,000 feet or more of work. The openings are largely in the west slope and upper part of Alto Hill, most of the tunnels being spaced about 200 feet apart vertically. The longest tunnel is the Alto, which has a length of 1,632 feet. It is driven about 300 feet below the top of the hill and in alignment with a series of shafts sunk from the surface, with all of which it is designed to connect. The developments on the Alto vein alone, which constitute most of the modern work, aggregate about 6,000 feet, as follows: Shafts 1,050 feet, drifts 900 feet, tunnels 2,000 feet, stopes 2,000 feet. The company has spent several hundred thousand dollars, it is said, on the development and equipment of the property.

Geology.—The geology of Alto Hill is complicated. In the upper western part of the hill the country rock is mainly the quartz latite porphyry described on page 72, with probably a core or base of

[1] U. S. Geol. Survey Mineral Resources, 1907, pt. 1, p. 178, 1908.

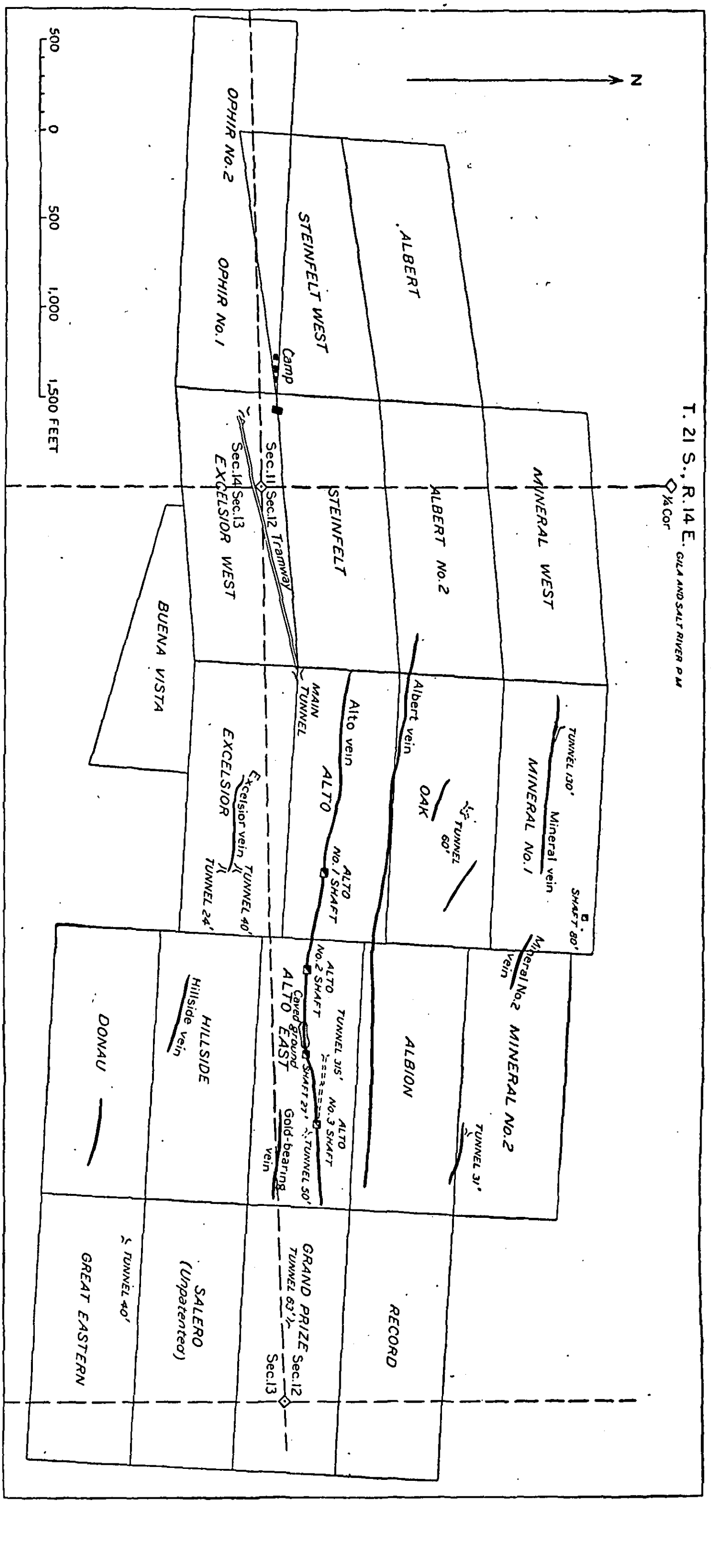


FIGURE 21.—Map showing claims and veins of Alto mine.

granite porphyry, which seems to be the dominant rock in the eastern part of the hill, and is soon succeeded by the belt of diorite and monzonite rising in the mountains on the east. The granite porphyry, and probably also the diorite, prior to the eruption of the latite apparently formed the east side of the valley or piedmont front on which the latite was deposited. Dacite and rhyolitic rocks and andesite are also present. The latite is disposed in massive sheets or flows, which at the top of the hill dip 35° E. and are agglomeratic. It seems to extend from the camp to the top of the hill and to be the principal rock in the mine, extending, with minor interruptions, from the mouth to the face of the Alto tunnel. Near station 8, about 1,200 feet in from the mouth of the tunnel, it gives way to granite porphyry, bowlders of which 2 feet or more in diameter occur as inclusions in the latite on the east near the top of the hill, toward shaft No. 1. At the face of station 6 drift, at 950 feet in from the mouth of the tunnel, the latite is intruded by dense dark reddish-brown andesite. Nearly all the shafts contain water and some are nearly filled.

Veins and ores.—The Alto property, as shown in figure 21, contains six veins, mainly in the latite and granite porphyry. They strike a little north of west and in general have a steep or vertical dip. Beginning on the north, they are the Mineral, Mineral No. 2, Albert, Alto, Excelsior, and Hillside.

The Alto vein lies in latite and granite porphyry and contains most of the development work which has been described. It extends through a length of two or more claims and is from 3 to 7 feet in width. It is opened by the 1,632-foot Alto or main tunnel with drifts, crosscuts, stopes, the Alto shafts, and also old workings. The tunnel, starting at the head of the tramway in the upper west slope of the hill, is driven eastward on or near the vein at about 300 feet below the top of the hill. The average dip of the vein for the first 300 feet in depth, as shown in shaft No. 1 (fig. 22), is about vertical, but the company now regards the steep dip to the north which prevails in the lower part of the shaft as the general dip of the vein.

At station 4, about 400 feet in from the portal of the tunnel, an auxiliary or blind vein dipping steeply to the north or vertical comes in from the west-southwest. It is opened by a back drift, known as the west drift, for 130 feet to the west and by stopes or upraises to the height of 20 or 30 feet. It shows a low-grade ore body 6 to 8 feet wide containing principally galena and a little copper, iron, silver, and zinc sulphides. It is said that some lead-silver ore and a little copper ore occur about all the way from the face of this west drift to the face of the tunnel.

For a considerable distance beyond the west drift the south wall of the tunnel is more siliceous and the country rock continues to be latite, the same as at the portal, nearly to the 1,200-foot point, where the formation is seemingly granite porphyry. Dense dark reddish-brown andesite, probably a dike, occurs in the face and adjoining part of the 200-foot drift to the southeast from the 800-foot point. Andesite is also associated with the vein in shaft No. 1 from the surface down.

Between the 600 and 800 foot points appears another small vein dipping steeply to the north and containing low-grade chalcopyrite ore. Between the 1,400 and 1,560 foot points is a large body of kaolin or gouge, and here the vein is 6 feet wide. From the 800-foot point to the face of the tunnel, 1,632 feet from the portal, the vein is in general well defined and carries a more or less continuous 18-inch ore shoot in which the ore occurs in lenses and stringers of galena 6 inches or more in maximum width, and for the last 250 feet of the course the vein dips steeply to the south. At the mouth of the south drift which connects with shaft No. 1 the ore is all galena ore with very little silver and no copper.

In the face of the tunnel the vein is about 4 feet wide and contains an ore shoot nearly a foot wide in the north or hanging-wall side, the rest of the width consisting mostly of altered rock carrying sulphide ore minerals all the way across, with some concentration and copper leaching on the south or footwall side. The middle part of the vein in this portion of the mine is said to carry generally considerable sphalerite. There is here about 6 inches of argillaceous gouge on the footwall and a little on the hanging wall.

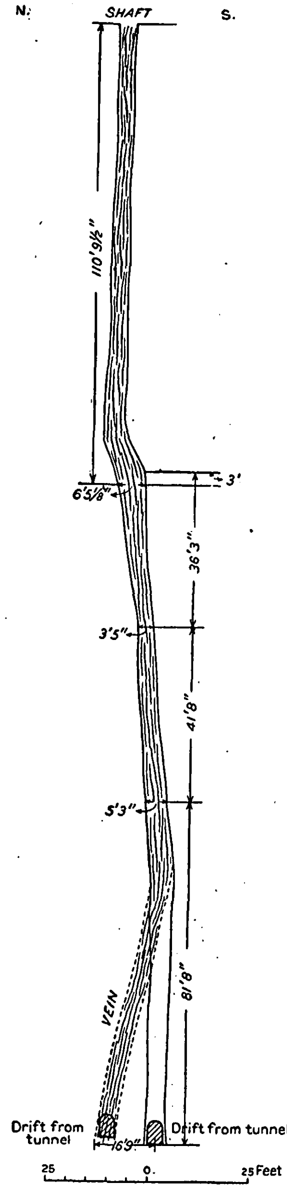


FIGURE 22.—Vertical section of Alto vein in shaft No. 1.

On the surface the ore is more or less continuously exposed on the vein for a horizontal distance of about 2,000 feet from a point 100 feet west of No. 1 shaft to the east end tunnel, which is about 800 feet east of shaft No. 3, and through about 1,200 feet of this distance, from a point west of shaft No. 1 to a point east of shaft No. 3, the ore has a known vertical extent of about 300 feet. It is regarded by the company as an established fact that 800 feet of the 950 feet of this known ore body between shafts 1 and 3 contains 170 tons of ore for each foot and that the remaining 150 feet contains 100 tons to the foot, or a total of about 151,000 tons.

At shaft No. 1, which is 290 feet deep, the vein is 3 feet wide and stands about vertical. Small dikes of andesite show at the surface and are said to be associated with the vein in the shaft.

Farther east, in shaft No. 2, which is 140 feet deep and is sunk in granite porphyry, the vein dips steeply to the north and carries much sulphide. The ore is the same galena and silver bearing sulphide ore as that in the tunnel. Some stoping is done here on the 100-foot level.

Still farther east, between shaft No. 2 and the caved ground about 350 feet distant, the surface ore changes from lead-bearing to copper-bearing ore, and from the old 140-foot shaft, just beyond the caved ground, to No. 3 shaft, 400 feet distant, the vein averages 3 feet in width. The underground workings in this area are all connected but now contain water. From the beginning of the caved ground to shaft No. 3, about 600 feet distant, the ores are all copper bearing and show marked increase in the amount of iron sulphide. Here the best ores seen, some of which are rich, contain gray copper or tetrahedrite.

Shaft No. 3, 176 feet deep, is sunk on the vein in rock that seems to be granite porphyry and is in ore all the way down. At the surface occurs a small spur vein, and some brown intrusive andesite is said to be associated with the vein in the shaft.

West of the No. 3 shaft, toward and almost under the caved ground, the vein is about 12 feet wide and carries ore all the way across, but the best ore, which is of shipping grade, comes from the middle part of the vein, from a band 4 inches to 3 feet wide, not including many rich stringers in the remainder of the vein. The lateral portions of the vein contain about 1 to 2 feet of kaolinized gouge, and the walls are altered and decomposed at the surface. The vein filling is mostly siliceous matter, largely quartz containing pyrites and calcite.

At the old workings between shafts Nos. 2 and 3 the vein is about 7 feet wide and stands vertical. It is tripartite for at least 20 feet from the surface down and consists mainly of mineralized altered rock. Here and in an old work shaft near by to the east a very large amount of work has been done. The surface part of the vein is said to be stoped out for a distance of 700 feet, and much ore has been taken out, mostly by Mr. Lully. The very large dump is composed almost wholly of sulphide material, containing iron and copper pyrite and some galena.

The ore minerals of the Alto vein are galena, argentite, chalcopyrite, pyrite, tetrahedrite (gray copper), and chalcocite. The silver is contained mainly in the argentite intimately associated with the galena and in the tetrahedrite. Where pyrite predominates in the vein the chalcopyrite is intimately associated with it and much of the pyrite seems also to be cupriferous. Where the ore becomes strongly or predominantly copper ore, tetrahedrite as well as chalcopyrite is usually present, and also some chalcocite and a little black copper oxide.

The Albert vein parallels the Alto vein about 300 feet to the north, as shown on the map (fig. 21). It has a known length of about 3,000 feet and is well defined throughout. It is about 4 feet wide and dips steeply to the south. It is opened at several points to depths of 40 to 70 feet. The ore is similar to that of the Alto vein and averages about the same in tenor, but it is said to be in places richer in chalcocite and black copper oxide and the surface ores are higher in silver. In case this vein and the Alto vein continue downward and maintain their convergent dip they should meet or intersect at a depth of about 800 feet, where it seems reasonable to expect considerable concentration in the deposits.

The Mineral vein, in the northern part of the Alto property, has a known length of about 900 feet. It seems to lie chiefly in granite porphyry and is opened by a 100-foot tunnel and several shallow shafts, each about 40 feet deep. It is about 3 feet wide, dips steeply to the south, and consists of a lode of quartz stringers in altered rock. Both the rock and the quartz contain ore, and much ore has been gouged out from the vein and a spur vein just to the east across the gulch from the east workings. The ore is argentiferous galena, with a little chalcopyrite and copper carbonates, and contains much specular hematite, which in places forms a considerable part of the gangue. Mineral vein No. 2 on the east is probably an extension of this vein or its fissure.

The Excelsior vein, which lies on the south side of the property, is known and well defined for nearly 1,000 feet. It is about 3 feet in width, and is opened by several shafts, short tunnels, and drifts. It is not of relatively great importance but contains workable ore reported to carry fair amounts of copper, gold, and silver, and a little lead.

The Hillside vein probably occupies an easterly extension of the Excelsior fissure.

WANDERING JEW MINE.

The Wandering Jew mine is located half a mile north of the Alto mine, in the upper north side of Apache Gulch, which separates Alto Hill from the mountains on the north, at an elevation of about 5,500 feet. The camp is on the opposite side of the gulch, one-third of a mile to the southwest. The property comprises a group of eight claims. It is developed to a depth of 100 feet by two shafts 300 feet apart, drifts, tunnels, and crosscuts aggregating about 2,000 feet of work, as shown in part in figure 23.

The country rock is gray diorite intruded by granite porphyry and latite. The property contains five or six veins or ledges, but the deposits are contained principally in the Wandering Jew vein, which has a reported length of about a mile. At the mine the vein varies from 6 inches to 4 feet in width and dips 50° N., into the mountains. The gangue is principally quartz. Between and adjoining the two principal shafts the vein is uncovered by a trench, and for a distance

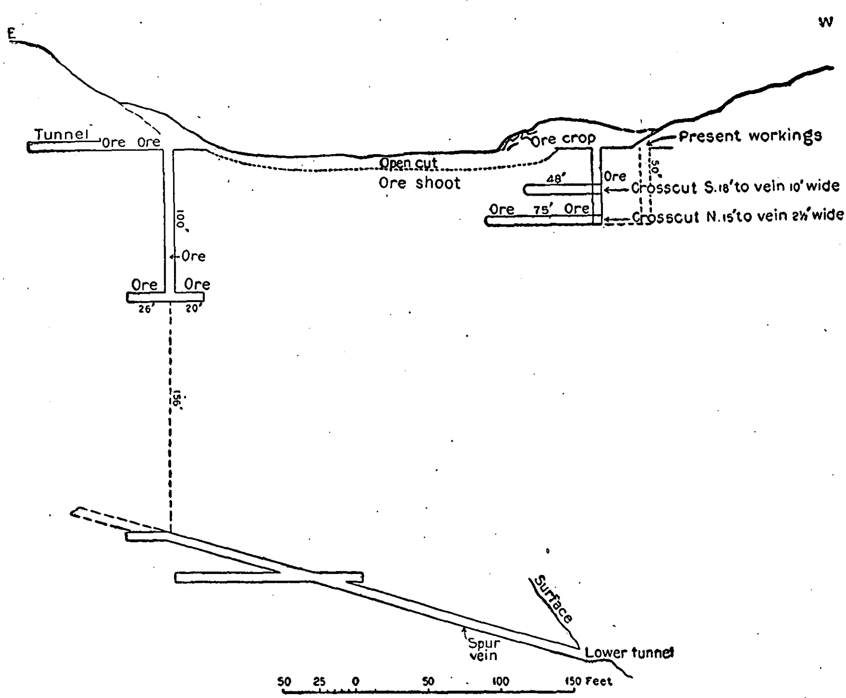


FIGURE 23.—Longitudinal section of Wandering Jew mine.

of about 400 feet it shows principally sulphide ore of the same character and grade as that found in the shafts, which are reported to contain ore all the way down and to be all in ore from the 40-foot level to the bottom.[1] From this statement the ore body, having a known horizontal extent of nearly 400 feet on the surface, seems to be a continuous sheet of argentiferous steel galena at least 100 feet in depth. Where the width of the ore body does not much exceed 1 foot the ore is said to be very pure. It is estimated that about half of the deposit is shipping ore, and the rest is good-grade concentrating ore. The ore is argentiferous lead ore and is essen-

[1] Blake, W. P., Report of the Governor of Arizona for 1903, p. 115.

tially sulphide or galena from the surface down, but in places it contains a little copper carbonates and some chalcopyrite. The quartz croppings rise boldly 8 feet or more above the surface, and toward the east the vein seems to be offset by a fault having a lateral throw of 60 feet.

The M. and S. claim, adjoining the Wandering Jew ground on the southeast and opened by a 100-foot shaft, is said to contain a large body of good-grade argentiferous zinc ore.

JOPLIN MINE.

The Joplin mine is three-fourths of a mile northeast of the Alto mine and about the same distance southeast of the Wandering Jew mine, at the head of Apache Gulch, on the south side, at an elevation of about 5,900 feet. It was owned by a Mr. Campbell about 1879, and in 1904 was bonded to Massachusetts people who soon shipped from it to the El Paso smelter 25 tons of ore that averaged about 5 per cent each in lead and copper and 35 ounces to the ton in silver. About 30 tons of sulphide ore lies on the dump. The property comprises three patented claims and is now owned by the Joplin Mining Co., of Tucson. It is developed by about 1,000 feet of work, including a 110-foot shaft, a 100-foot drift, and a 220-foot crosscut tunnel.

The topography is mountainous. The mine is in the head of a small side gulch on the steep side of Apache Gulch. The country rock is fine-grained brownish-gray quartz diorite. The vein, consisting mainly of altered diorite and quartz, dips steeply to the south and as seen in the drift seems to carry pretty continuously on the footwall an ore shoot 3 inches to 1 foot wide and in a few places reported to be 2 feet wide, containing principally pyrite, chalcopyrite, argentiferous galena, and near the surface copper carbonates. The country rock, as shown by the crosscut tunnel extending 100 feet beyond the vein, is impregnated with disseminated sulphides and in places contains also good ore.

At a depth of about 100 feet the vein, it is said,[1] encounters a nearly horizontal slip or fault, where with very flat dip it makes an abrupt offset of 15 feet to the north, below which it resumes its nearly vertical downward course. The trend of the vein at each end of the offset is almost a right angle. At the offset the ore shoot was but 3 inches in width, but the ore was rich, as it was also just below the offset, where the ore shoot resumed its normal width.

APACHE MINE.

The Apache mine is located in Apache Gulch between the Alto mine on the south and the Wandering Jew mine on the north. The

[1] Bond, Josiah, Eng. and Min. Jour., vol. 92, p. 454, 1911.

deposit, which seems to be in diorite, was discovered about 1899. About 1900 the mine was purchased by the present owner, the Santa Rita Mining Co., of El Paso, Tex., which soon worked it extensively and in 1901 shipped to El Paso two carloads of black chalcocite ore that averaged, it is said, about $250 to the ton. About 90 tons of ore was concentrated by the Arizona Gold-Copper Co. near by.

The property comprises a group of six claims, all of which are patented. It is said to be developed to a depth of 470 feet by tunnels, shafts, and crosscuts aggregating more than 2,500 feet of work. The company is reported to have expended more than $5,000 on the property.

THREE STAR PROSPECT.

The Three Star prospect is a quarter of a mile northwest of the Wandering Jew mine, on the north side of Apache Gulch, at an elevation of 4,770 feet. It is on a quartz vein which dips 85° S., in latite, and is opened by a shaft and three 10-foot holes. The quartz contains a little chalcopyrite and galena coated with earthy cerusite, argentite, and malachite.

TOLUACHI GROUP.

The Toluachi group, owned by Josiah Bond, whose camp is 1¼ miles north of Alto, comprises 19 claims lying north and east of the camp. The country rock is a somewhat tuffaceous latite of dark-green color. Along its eastern border, however, the formation contains so much granite porphyry, apparently in the form of included bowlders and pebbles, that it has been mapped as granite porphyry. The rock is cut by a large number of small fissures which trend about east, the principal strike being N. 85° W. As many as 50 small veins were noted in a distance of three-fourths of a mile north from Bond's cabin. The quartz veins are mostly rather small but range up to 4 feet in width. They are stained with iron and manganese and in places show copper carbonates at the surface. Some of the claims are said to be bonded to eastern people. Among the principal prospects are the Jersey Girl, Silver Sally, and Merry Widow.

The Jersey Girl prospect is located just east of Bond's cabin on a 5-foot lode which at the surface dips 80° S., in latite breccia, and occupies a well-defined fissure 4 to 6 feet wide, filled mostly with gouge and crushed rock. Toward its middle, however, as shown in figure 24, it contains two small veins or pay streaks from 2 to 6 inches in width, composed principally of a quartz-calcite-siderite gangue with a little rhodochrosite and rhodonite. The filling of the lode in general, not including the two quartz veins or pay streaks, is said to average $20 to the ton in copper and silver. One of the veins or pay streaks is composed chiefly of copper and lead stained quartz showing galena and seemingly a little gray copper. Some of it is banded, but postmineral movement has crushed it. The principal ore minerals are galena, proustite, tetrahedrite, horn silver, embolite, bromyrite, chalcopyrite, chalcocite, malachite, azurite, cuprite, argentite, and tennantite.

The richest ore is said to occur on the 80-foot level, where the two pay streaks join or intersect. Some of it carries 10 per cent in copper, 30 per cent in lead, and 120 ounces to the ton in silver. On the north wall the ore contains much white mica. Between the two pay streaks sericitic mica still remains, but the filling is mostly quartz, and it is stained with manganese and iron. On the 90-foot level chlorite is associated with the sericite. On the south wall, where also the material is much iron stained, it apparently runs higher in silver.

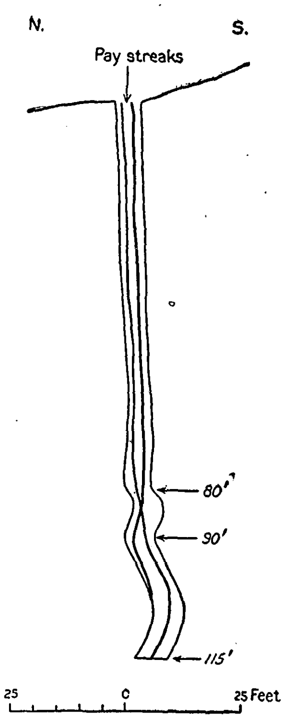


FIGURE 24.—Cross section of Jersey Girl shaft and veins.

The Silver Sally prospect is on a vein which strikes N. 60° W. and is opened by a 280-foot shaft and a 100-foot drift to the east on the 220-foot level. The vein is 15 feet or more in width. It consists principally of iron-stained silicified diorite, which, however, contains a 4-foot band of iron and lead stained quartz that carries galena and sphalerite. Some of the ore, which probably contained horn silver or cerargyrite, is said to have averaged 50 ounces in silver to the ton.

The Merry Widow prospect is located in Bond Canyon at an elevation of 4,970 feet, on the Merry Widow-Badger vein, which dips steeply to the south in andesite breccia and is opened by a 100-foot shaft, from the bottom of which a 45-foot drift has been run to the west, with a 20-foot winze sunk at the face. The vein contains ore, of which a shipment of 5 tons is said to have averaged 8 per cent of lead and 72 ounces to the ton in silver. The ore also contains some copper and zinc, and for the latter mineral the shipment was penalized. The ore minerals are principally galena, sphalerite, and chalcopyrite, contained in a quartz-calcite gangue.

ARIZONA-PITTSBURG MINE.

The Arizona-Pittsburg mine is located $3\frac{1}{2}$ miles north of Salero and about a mile northeast of the Jersey Girl prospect, on the south fork of Bond Canyon, at an elevation of 5,550 feet. The vein on which it is located has been known for many years and is said to have been worked in the nineties. In 1905 J. M. Orosco relocated the property and sold it to Frank Reichert, who called the two principal claims the Black Hills Nos. 1 and 2. In 1908 the present owners, the Arizona-Pittsburg Mining & Smelting Co., of Pittsburgh, Pa., bought the property.

The property comprises a group of five claims. It is developed by a 185-foot shaft and 25 feet of drift to the west on the 125-foot level.

The topography is rough (Pl. I, in pocket). The country rock is diorite, and the deposits are contained in a 9-foot quartz vein which dips 87° N. This vein extends a mile or more to the east and is thought to be the vein on which the Augusta or Hosey and American Boy mines are located, respectively about 1 mile and 2 miles to the east, on the opposite side of the divide in the Wrightson district.

The quartz in general is stained with iron and manganese and a little azurite and malachite. The ore minerals it contains are galenite, pyrite, and chalcopyrite. Some galenite occurs in the surface ore, but sulphides are not abundant above the 70-foot level. From that level down, to judge from the material seen on the dump, the ore consists largely of galenite in a silicified brecciated diorite gangue, and there is a marked increase in pyrite and chalcopyrite in the lower part of the mine, where the ore seems to contain also some tetrahedrite.

ROYAL BLUE MINE.

The Royal Blue mine is located just west of the United States location monument No. 11, which is between the Alto and Bland camps. It is owned by the Apache Mining Co., of Cincinnati, Ohio, and is said to be developed by a 60-foot drift tunnel and a 40-foot shaft sunk from this level, which is 16 to 18 feet below the surface. There are also two lower openings, one a crosscut and the other a drift. The mine is on a vein which is supposed to be an offshoot from the Bland vein and which carries copper and silver, principally in chalcopyrite and galena. A streak of good ore of shipping grade, it is said, is now being worked in it by Thomas Frazer, of Tucson, and a tunnel is being driven to undercut the shaft.

TRENTON MINE.

The Trenton mine is a quarter of a mile south of the Alto mine, in the bottom of Trenton Gulch, at an elevation of about 4,800 feet. It is on a vertical or steeply southward-dipping vein in granite porphyry, but the footwall in the lower part of the mine is reported to be diorite.

The mine was first worked in 1891 by Clark & Peterson, from whom it was purchased in 1901 by the Arizona Copper Co., which sunk the main shaft and built a mill at a point 1 mile to the west. The Trenton Mining Co., with headquarters in New York, acquired the property in 1906, and recently Frank Reichert became the owner. There is a small mill which is not in good repair.

The mine is opened by a 120-foot shaft containing about 80 feet of drift on the 50-foot level, 230 feet on the 80-foot level, and 300 feet on the 110-foot level. The vein is said to be the northwestward extension of the Old Jefferson vein. It is 12 feet in width and consists largely of a stockwork in brecciated diorite with a quartz-barite gangue. The ore is lead-silver and is contained in shoots about 8 inches in width, which extend along the vein, and pitch to the east. The principal mineral is argentiferous galena.

It is said that in 1904, from one ore shoot in the lower east level, were shipped 150 tons of ore which averaged 58 per cent in lead, 41 ounces to the ton in silver, and a little copper. Zinc is said to occur in a streak of barite near the footwall.

JEFFERSON TUNNEL.

The Jefferson tunnel is located on the south side of Trenton Gulch, southeast of United States location monument No. 11, at an elevation of 4,985 feet. The property is owned by Curtis & Steinfelt, of Tucson. The tunnel runs S. 40° E. for 110 feet but could not be examined for more than 75 feet from the mouth on account of water. The country rock is diorite. It is said that at 90 feet from the mouth the tunnel cuts a siliceous vein carrying ore that contains principally chalcopyrite and galena. Apparently the same ledge is cut in a tunnel about half a mile to the east on the Georgia claim.

BLAND MINE.

The Bland mine is located in Alto Gulch about a mile southeast of the Alto mine, at an elevation of about 5,400 feet. It was discovered in 1885 and worked until 1889. The mine is now owned by William Powers, R. Crew, T. M. Heck, and F. Reichert, who report that they have sold from it $1,200 worth of ore and that the total production from the mine up to 1909 was about $4,000. Two carloads of ore taken out near the divide and sold to the El Paso smelter in 1890 are said to have averaged 64 per cent in lead, 24 per cent in copper, and 35 ounces to the ton in silver. Recently it was reported that in driving 535 feet of drift good concentrating ore was taken out for a distance of 200 feet.

The property comprises a group of five claims extending eastward into Squaw Gulch. As indicated in figure 25, it is developed by a tunnel and drift aggregating about 1,500 feet of work.

The deposits are principally contained in a main vein which occupies a fault fissure in diorite and stands about vertical or dips steeply to the north. The vein is opened at numerous points over a horizontal distance of about half a mile and a vertical distance of 540 feet. It is supposed to extend westward to the Alto ground. It is from 3 to 6 feet wide and consists principally of gouge and crushed diorite in which the ore minerals chalcopyrite and pyrite are generally disseminated. The better-grade ore consists largely of

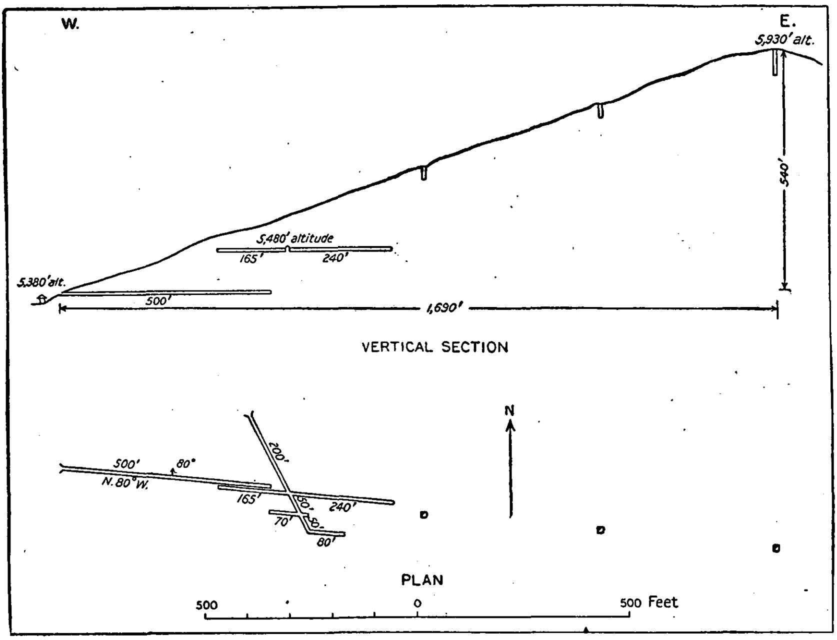


FIGURE 25.—Vertical and horizontal projections of Bland mine.

lenses of almost pure massive chalcopyrite which pitch to the east. Separating the ore-bearing portion of the vein from the wall rock on each side is a sheet of later gouge. The wall rock, however, for 5 or 6 feet from the vein is impregnated with disseminated pyrite and chalcopyrite. The slickensided walls indicate greater lateral than vertical movement. Along the footwall in the lower tunnel is a small seam of banded quartz and sulphides which widens out into two fair-sized lenses of ore in the 500 feet of drifting. One of these lenses or ore shoots starts at a point about 25 feet in from the mouth of the tunnel and extends for 100 feet toward the face. It ranges from 2 to 4 feet in width and contains massive pyrite and chalcopyrite with some bornite; a little cuprite and malachite are also seen on some of the joints. Ore of this class is said to run 25 per cent in copper and 50 ounces in silver and $4 in gold to the ton. The last 100 feet of the drift is in the second lens, which fills the entire fissure, 4 feet wide. This lens is composed of massive pyrite and chalcopyrite crudely banded with quartz and is said to run 16 per cent in copper and 8 ounces in silver and $2.80 in gold to the ton. There is about 300 tons of ore on the dump of this tunnel which is reported to assay 8 to 12 per cent in copper and 6 to 15 ounces in silver and $3 to $12 in gold to the ton.

The vein is opened at 100 feet above the lower tunnel by a cross-cut tunnel with a 165-foot drift to the west and a 240-foot drift to the east. It is said that in the west drift, which is near the surface, the vein is 3 feet wide and contains a larger proportion of lead than in the east drift, where the backs are much heavier and the vein is 9 feet wide and carries from 2 to 4 feet of siliceous copper sulphide ore.

A parallel vein along which a 70-foot drift has been run, 50 feet south of the Bland vein, is said to show 3½ feet of galena-chalcopyrite ore. On a second parallel vein 100 feet south of the Bland, is an 80-foot drift to the east. It is reported that this drift shows 4 feet of massive pyrite and chalcopyrite ore, which runs 10 per cent in copper with considerable silver and a little gold. There is about 500 tons of ore on the dump, which is said to average 6 per cent in copper, 13 per cent in lead, and $2 in gold and 17½ ounces in silver to the ton.

In the 60-foot shaft on the divide at an elevation of 5,930 feet the ore is largely galena with a very little pyrite and chalcopyrite contained in a quartz gangue. It is stained with limonite, azurite, and malachite and is reported to average about 40 per cent in lead, 6 per cent in copper, and 23 ounces to the ton in silver. It is said that all the ore here was argentiferous galena to a depth of 60 feet, where copper sulphides began to appear, a feature which seems to be general in this property.

EUREKA MINE.

About a mile north of Salero, extending from a point east of the township line along the south line of sec. 12 in the northeast slope of Salero Hill and adjoining ground, are several mines which have been productive, among them the Eureka, Thunderer, and Highside. Some of them are reported to have been prospected by Humboldt in very early days. The topography is mountainous. The deposits are contained principally in a 5-foot east-west, about vertical, quartz vein in fine-grained iron-gray quartz diorite.

The Eureka, better known as the Old Mexican mine, was discovered in 1850 or before. After the Civil War it was relocated, and late in the eighties it was acquired by a New York company and considerable high-grade copper-silver ore was mined. About 1898 it passed into the hands of Clark & Peterson, from whom in 1902 it was purchased by the present owner, C. H. Ferry, of New York, who already owned the Marble and Thunderer, adjoining patented claims, and at the time of visit was patenting the remainder of the group of six claims. Mr. Ferry soon did nearly 2,000 feet of work, mostly in tunnels and shafts on the Eureka and Marble claims and in crosscuts on the Highside, and from the Eureka he took out and shipped considerable ore.

The general run of mine ore, of which several hundred tons now lie on the dump, averages, it is said, about 18 per cent in lead, 2 per cent in copper, and 40 ounces to the ton in silver, but some rich bodies or pockets show about 2,000 ounces in silver to the ton. A shipment of four carloads of the hand-sorted ore in 1904 is said to have averaged more than 100 ounces in silver to the ton. The ore minerals are principally argentite, tetrahedrite, galena, and chalcopyrite. Other metalliferous minerals are chrysocolla, azurite, malachite, covellite (?), a little specularite, and sphalerite. Much of the quartz gangue is greenish, crushed, and recemented by seams of iron oxide and silica.

MONTEZUMA MINE.

The Montezuma mine is 1¼ miles south of Salero, on the Salero-Patagonia road and the township line at the northeast base of the Grosvenor Hills, at an elevation of about 4,350 feet. It was worked in the early part of the nineteenth century by the Jesuit priests and in 1857 and 1858 by the Wrightson brothers, who worked only surface ore in an 8-inch vein.

About 1860 it was worked by the Aztec Mining Syndicate, which is said to have sunk a shaft to a depth of about 300 feet. In the upper levels the vein, for the most part, did not much exceed a few inches in width and did not pay to work, but at the bottom of the shaft the vein gradually widened to 34 inches and contained reticulating lenses of silver and copper glance ore, some of which averaged $2,250 or more to the ton, the copper content being about 15 per cent. But the ore was not sufficient in quantity or high enough in grade to be workable at that time, although about 15 tons of it was shipped.

Later in the sixties the mine was acquired by the McCormick Harvester Co., of New York, and was examined for that company by J. H. Hammond, who made an unfavorable report. About 1900 it was leased by Clark & Peterson, who took out about 30 tons of silver and copper glance ore. This ore, after hand sorting, averaged about 125 ounces in silver to the ton, no allowance being made for copper, which in general runs about 5 per cent.

The mine is developed to a depth of only 80 feet, principally by shallow shafts and drifts. The property as commonly known comprises three claims, the Montezuma and the east and west extension claims, known, respectively, as the Empress of India and the Queen of Sheba. The Montezuma claim, which contains the mine, and the west extension are now owned by the Red Cloud Mining Co., and the east extension is owned by C. H. Ferry, who is said to have made in recent years a thorough test of his claim by putting down six diamond-drill holes to a depth of 300 feet, finding the lode to continue at this depth with about the same characteristics as near the surface. The ore minerals occurred in stringers varying from some that were very thin to those about 8 inches in width, but they gave no indications of workable deposits.

The mine is on open, hilly ground. The country rock is medium-grained iron-gray quartz-bearing diorite. The deposits are contained in a silicified and partly sheared and crushed zone or lode of this rock and associated quartz, which dips 65° N. The lode in the vicinity of the mine is 175 feet in width. It is plainly traceable for nearly a mile east of the mine and is said to extend very much farther. On the west it passes beneath the covering of the younger volcanic rocks.

The lode contains also considerable quartz and iron or ferruginous material in rough-surfaced irregular stringers, veins, and bodies, ranging from half an inch to nearly 18 inches in width and mostly lying about parallel with the dip or main structure of the lode. Also in the wall rock for 10 feet or more back from the lode is developed a stockwork of reticulated quartz veins or stringers, most of which lie at about right angles to the lode.

The croppings, which are mostly prominent, are heavily stained with iron and manganese and in places with copper carbonates and oxidized minerals of silver. A distinctive feature of the ledge is an 8-foot vein of quartz or siliceous ore on the north or hanging-wall side, containing considerable chalcocite or copper glance.

The deposits occur in numerous quartz stringers from 1 inch to 4 inches in width, which carry malachite, azurite, chrysocolla, limonite, cuprite, and seemingly argentite. The work on the claim is very irregular; it follows the small mineralized stringers in a chloriding manner. Most of the work, comprising four shafts, is on a quartz stringer about 40 feet north of the south edge of the siliceous zone. The eastern shaft is 30 feet deep and connects with another 50 feet to the west by a drift 10 feet below the collar. This shaft is about 75 or 80 feet deep, and in it a 30-foot level extends to the west. At 40 feet west of this shaft there is a 20-foot shaft, and the westernmost shaft is 40 feet deep.

VULCAN MINE.

The Vulcan mine is 3½ miles north of Wise's ranch, 5 miles north-northwest of Salero, and a mile west of Josephine Canyon, in the foothills. It is on a prominent 40-foot silicified iron-bearing or ferruginous ledge, in intrusive diorite or andesite "porphyry," on or near its contact with the Paleozoic limestone, which dips to the south-southwest. The deposit contains, besides iron, some chalcopyrite and copper carbonates.

SQUAW GULCH AREA.

The principal mines in the Squaw Gulch area, in the eastern border of the district, some of which have been productive, are the Burro, Viceroy, Victor, Rosario group, and Ivanhoe.

BURRO MINE.

The Burro mine is located in the upper part of Squaw Gulch, half a mile east of the Bland mine, at an elevation of about 5,740 feet. It is on two heavily iron-stained quartz veins where they cross the contact of granite porphyry intruded into the country-rock diorite. The veins strike about N. 75° W., and the formational contact approximately follows Squaw Gulch in a north-south direction. The veins are opened by shallow shafts, which are filled with water, but the dumps show fair-looking ore consisting mainly of galena, pyrite, chalcopyrite, and a little chalcocite, contained in a quartz gangue.

VICEROY MINE.

The Viceroy mine is three-fourths of a mile southeast of the Burro mine, at an elevation of about 5,455 feet, on the east slope about 500 feet above the gulch. It is opened by a tunnel, which is somewhat caved, but is said to be 300 feet long and to connect with a 70-foot shaft near the face. The tunnel follows a vertical fissure trending N. 75° W. in granite porphyry. Owing to timbering but little of the vein is exposed in its first 150 feet. Water from the vein is depositing alum. On the dump is a few tons of quartz ore carrying principally chalcopyrite, galena, malachite, and some chalcocite.

The vein is traceable westward into Squaw Gulch, where it cuts through diorite, crossing the bed of the gulch on the 5,550-foot contour, and it apparently continues westward as the main Bland vein.

VICTOR MINE.

The Victor mine is a quarter of a mile southeast of the Viceroy mine, in an east fork of Squaw Gulch, at an elevation of 5,580 feet. It was located about 1895. The present owners, Bacon & Koon, of Tucson, relocated it in 1904.

The mine is opened by a 330-foot tunnel, a 90-foot upraise, and an 80-foot drift (fig. 26). The country rock is granite porphyry, and it is cut by a system of east-west faults. Some of the fault fissures contain mineral-bearing quartz veins, in one of which most of the deposits occur. This vein, which is followed by the tunnel in an irregular easterly course, is 4 to 6 inches wide and is contained between good walls with gouge on either side. At 200 feet in from the mouth of the tunnel occurs an ore shoot which the upraise follows to the surface. At 130 feet beyond the upraise, where the vein is cut obliquely by a N. 70° E. fault, is a second ore shoot that pitches to the west and has a width of 15 feet on the strike of the vein, and the 80-foot drift extending eastward on the fault shows about 6 inches of quartz, carrying some mineral. The ore contains principally galena and chalcopyrite in a quartz gangue.

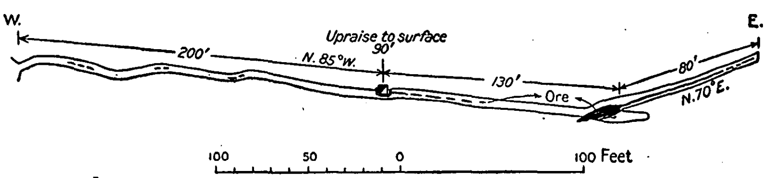


FIGURE 26.—Plan of Victor tunnel.

ROSARIO GROUP.

The Rosario group, which has produced some ore,[1] is located about 1½ miles northeast of Salero, on the divide between Josephine Canyon and Squaw Gulch, at an elevation of about 5,400 feet. The property comprises nine claims. They were located in 1904, but the work on the Rosario No. 1 claim is very old, probably Mexican.

The deposits are contained in several quartz fissure veins in altered diorite. The veins mostly strike west-northwest and are linked, forming a stockwork. They are opened by tunnels and shallow shafts aggregating several hundred feet of work. The vein followed by the 150-foot tunnel and 60-foot upraise near the camp, on the Rosario claim, carries a stringer of quartzose ore containing principally a little earthy cerusite and galena, which is said to average very high in silver. Just north of this vein and the camp is a larger and more distinct vein which throughout seems to be a stockwork of quartz veinlets in altered diorite, carrying limonite, psilomelane, cerusite, and galena.

The vein on the Rosario No. 2 claim dips steeply to the south or stands vertical. It ranges from 8 inches to 2 feet in width, and in some places has good walls. The filling is apparently brecciated

[1] U. S. Geol. Survey Mineral Resources, 1907, pt. 1, p. 178, 1908.

diorite and quartz, the whole being very much stained with iron and manganese oxides and lead carbonate. It shows a little galena coated with earthy carbonate and is said to carry horn silver, silver bromide (bromyrite), and native silver. The ore is reported to average about $25 to the ton, mostly in silver with minor amounts of copper. The vein is opened by two shafts and cut. The main shaft is 110 feet deep, with a 20-foot drift to the east on the 70-foot level and two drifts on the 100-foot level. The shaft to the northwest of the main shaft is 25 feet deep and is said to have been sunk on a pocket from which were taken 3 tons of silver ore that netted $240 to the ton and contained about 3 per cent in copper. Though some galena is mixed with the oxidized ore found at a depth of 110 feet in the main shaft, the sulphide zone has not been reached.

Two parallel veins on the United States No. 2 claim are about 90 feet apart and dip steeply to the south. The northern vein, opened by an 80-foot shaft that is half filled with water, contains principally lead ore, which averages about 40 per cent in lead and from 3 to 4 ounces to the ton in silver. The minerals observed are galena and sphalerite contained in a gangue of white quartz and altered crushed diorite. The southern vein is about 2 feet in width. Its value lies principally in copper and silver.

IVANHOE MINE.

The Ivanhoe mine is 3 miles northwest of Patagonia and 3 miles east of the Montezuma mine, on the east side of an eastern tributary of Squaw Gulch, in the upper part of the ridge which separates this gulch from Smith Gulch, an adjoining tributary to Temporal Gulch on the east. It is at an elevation of about 4,600 feet and is reached by wagon road. Some of the openings are on the Smith Gulch side of the ridge, where they descend to the 4,300-foot contour.

To judge from an old 300-foot cut thought to have been made by the pioneer Mexicans, mineral deposits were probably discovered here early in the fifties, but modern activities date from the rediscovery and location of the ground in 1905. A year later the mine was acquired by the present owner, the Ivanhoe Mining Co., of Minneapolis, Minn.[1]

The property comprises a group of 22 claims. At the time of visit it had produced and shipped some ore,[2] amounting, it is said, to $700 more than the cost of development work and expenses. About 1,700 tons of fair-grade milling ore lay on the dump. The property has since been steadily developing and producing on a moderate scale. Toward the close of 1911 it was reported that ore shipments

[1] U. S. Geol. Survey Mineral Resources, 1906, p. 170, 1907.
[2] Idem, 1907, pt. 1, p. 178, 1908.

netting over $10,000 had been made and that several thousand tons of ore was in sight in the mine and on the dumps. At the time of visit the mine was developed by about 300 feet each of tunnel, drift, and shafts to a depth of about 250 feet, which with subsequent development probably aggregates about 2,000 feet of modern work, as the company had then planned to sink to the depth of 400 feet.

The topography is mountainous but not rugged. The country rock is red granite, locally called "quartz porphyry" from the strong contrast of its greasy-lustered quartz with the red feldspars. Some of the feldspars are altered to the pale-greenish or whitish kaolinized and sericitized stage. The rock is a medium-grained granitic rock composed almost wholly of orthoclase and quartz. Some of the orthoclase is microperthitic. Biotite or hornblende seems to have been present in small amount, but in the slide examined is altered beyond determination. In the vicinity of the mine the granite is considerably leached.

On the east the granite is overlain by gray andesite, which ascends the slope to a point about 150 feet above Smith Gulch and the Commercial tunnel, and in the tunnel at this place diorite seemingly intermediate in age between the granite and the andesite is also present. A portion of the ridge is capped by reddish, partly silicified andesite tuff or "burnt rock," which near by and in the mine seems to be intrusive into the granite and is said to contain generally fair amounts of silver. Both the granite and the andesite are sliced by a north-northwest sheeting with steep easterly dip.

The mine seems to be in part on the easterly extension of the Montezuma vein, which here dips 80° SE. and with a vertical range of 600 feet trends across the ridge into the head of Smith Gulch, and at an elevation of about 4,300 feet is opened by the 200-foot Commercial tunnel or drift. The drift is mainly in andesite, but upfaulted greenish diorite forms the hanging wall of the drift and fissure on the south. The vein as shown in this drift is about 4½ feet wide and consists mainly of irregularly, coarsely, and crudely banded brownish iron-stained and whitish silicified and kaolinized altered and mineralized rock breccia and quartz. It is more or less porous or honeycombed, and in places, particularly in the face of the drift, which is in ore at about 200 feet below the surface, it contains small pockets or bodies of galena, some cerusite, and a little lead molybdate. Associated with the ore minerals are also some epidote and manganese and iron oxides. In this drift sulphides first appear at a point about 100 feet from the portal and 100 feet below the surface. About 150 tons of concentrating ore piled on the dump is said to average about $3 in gold and $6 in silver and lead to the ton.

To the southwest up the slope, about 400 feet above the drift or tunnel, at the Commercial No. 1 shaft, which is but little more than a 10-foot incline, the vein or ledge, which here lies in the granite, is about 40 feet in width and has yielded some ore said to average 90 ounces in silver and $6.50 in gold to the ton.

On the westerly slope of the ridge to the south of the Montezuma vein occur two veins or lodes which trend in a northerly direction, about parallel with the ridge and the sheeting structure in the rock, and obliquely to the transverse Montezuma vein. The western vein is known as the sulphide vein and the eastern one as the horn silver vein. The sulphide vein, as shown in the bottom of the 100-foot vertical shaft and its crosscut to the east, is about 10 feet in width and has fairly good footwalls, and the mineralized zone containing it is about 28 feet wide. It is a blind vein, without croppings other than a little brecciated granite. It was first encountered in the shaft about 50 feet below the surface, where the entire shaft for some distance is in ore. In the upraise from the south drift at the bottom of the shaft the vein contains a 4-foot ore shoot, which consists mainly of crushed granite intruded by dark andesite, all more or less ferruginated and silicified, in part carries chalcopyrite and argentite, and is said to average 12 per cent in copper and 140 ounces in silver and $2 in gold to the ton. In the north drift from the bottom of the shaft or adjoining part of the crosscut a 16-inch ore shoot on the east or hanging-wall side of the vein, which is banded, is richer than the corresponding part of the vein in the south drift. It contains considerable chalcocite and is said to average about 21 per cent in copper and 300 ounces in silver and $9 in gold to the ton. Much of this ore readily air slacks on exposure.

The horn silver vein lies about 100 feet east of the sulphide vein, in altered granite, and is seemingly associated with an andesite dike. It is opened by a 90-foot crosscut tunnel connecting with a 120-foot inclined winze, with about 150 feet of drift on the tunnel level and as much more at the bottom of the winze. It is several feet in width and at about 140 feet below the surface changes from a steep westerly dip to a steep easterly dip. It is composed mainly of crudely banded silicified iron and manganese stained crushed rock and quartz. The ore occurs in stringers or streaks from 1 inch to several inches in width and carries good values. It contains mainly silver chloride, or horn silver, and silver chlorobromide, or embolite.

The dumps at the western shafts and tunnels contain about 1,500 tons of ore, said to average 1½ per cent in copper and 17 ounces to the ton in silver.

ELLEN DELLA AND VANSUELLA PROSPECTS.

East of the Ivanhoe mine, on the Smith Gulch side of the ridge, are several prospects, of which the Vansuella, on Smith Gulch, opened by several short tunnels and a 40-foot shaft, is on the Old

Republican vein, as is probably also the Ellen Della, near by. At the Vansuella prospect the vein is associated with the contact of the younger dark andesite intruded into the older andesite and seemingly also into the diorite, and the ore is similar to that of the Commercial tunnel, on the Ivanhoe, described on pages 216–218.

The Ellen Della prospect, owned by James Cochran, of Bradford, Pa., is located at a point intermediate between the Vansuella and the Ivanhoe, about 50 feet above the gulch, at an elevation of 4,440 feet. Here the vein is in coarse granite, strikes N. 55° E., and is heavily stained with hematite and malachite. It is opened by a 60-foot shaft.

BRADFORD MINE.

The Bradford mine is located in the southern border of the Tyndall district, 5 miles southwest of Patagonia, at an elevation of about 4,000 feet, in a side gulch of Sonoita Creek, from which it is about one-third of a mile distant. Bloxton, the nearest railroad station, is 1 mile to the east.

The mine is now owned by C. H. Ferry, of New York. The deposit was discovered in the late seventies and has been worked at intervals, at first for gold and later for copper. It is reported that recently the Copper Queen Co., of Bisbee, has taken over the mine and will develop it on a large scale.

The property comprises a group of five patented claims. It is developed to a depth of about 200 feet, mainly by shafts and drifts aggregating about 1,000 feet of work distributed on three levels but mainly on the 60 and 120 foot levels.

The mine is in hilly ground, but it is reached by a wagon road of fair grade and more directly by trail. The country rock is fine-grained diorite, and at the mine the diorite is seemingly cut by an east-west agglomeratic rhyolite dike or possibly is in contact with a sunken fault block of this rock about 240 feet in width. The deposits are associated with the contact. The dike contains inclusions of the diorite and is traversed by a north-south sheeting. On the east the rhyolite overlies the diorite and covers Sanford Hill, where it is rather thick. Along the subordinate divide about 500 feet north of the mine it is highly silicified and replaced by quartz which is heavily iron stained, resembling vein croppings.

The deposits are contained in the dike, which near its middle is traversed longitudinally by silicified parallel croppings, and the openings follow the gulch across it from north to south, the main shaft being located within 600 feet of its south edge. The ore contains principally malachite, azurite, chrysocolla, and a little chalcocite. It occurs mainly in the altered rhyolite and diorite, which it impregnates and replaces, and locally it is accompanied by iron oxide and quartz. The main shaft is said to have encountered, at about the 50-foot level, a large body of rich ore of this class which continued downward for 18 or 20 feet and had a considerable lateral extent, especially in a northeasterly direction—a feature which, considered in connection with drill tests, indicates that the ore probably occurs in a nearly horizontal bedlike body. At about 40 feet from the shaft, near the south contact of the dike, the drill between depths of 60 and 78 feet passed through an 18-foot body of ore that seems to be similar to that encountered in the mine at about the same level. Between depths of 78 and 297 feet the rhyolite, as shown by the drill core, contains very finely disseminated pyrite but no other indications of ore, and from 297 to 347 feet the drill encountered only barren diorite. The run of mine ore is said to average about 4 per cent in copper and a few ounces to the ton in silver, with a small quantity of gold.

PLACER DEPOSITS.

Placer gold occurs in the Tyndall district, and some was produced in early days 2¼ miles southwest of Salero and 1 mile south of Mount Allen, at the southwest base of the Grosvenor Hills, on each side of the township line, in the SW. ¼ sec. 35 and adjoining ground, in the open basin-headed canyon which is tributary to Ash Canyon.

WRIGHTSON DISTRICT.

GENERAL FEATURES.

The Wrightson district adjoins the Tyndall district on the east, lying on the opposite or east slope of the southern part of the Santa Rita Mountains, as shown on Plate I (in pocket). It extends from the latitude of Old Baldy Peak on the north and Adobe Canyon on the northeast to Patagonia, 12 miles distant, on the south, and from the crest of the range between the Arizona-Pittsburg and Augusta mines to Sonoita Creek at the Pennsylvania ranch, 8 miles distant, on the east. Its southeast boundary follows Sonoita Creek to a point 2¼ miles below Patagonia, where it meets the west boundary, which follows the ridge between Temporal Gulch on the east and Squaw Gulch on the west. It is in Santa Cruz County. Patagonia is the post office and supply point for the district.

The topography is generally rough, of the eroded volcanic rock type, the surface being scored by many approximately parallel gulches or canyons, through which the drainage issues southeastward into Sonoita Creek and which render transportation transversely to their courses difficult. The largest of these canyons is Temporal Gulch, which heads on the south slope of Old Baldy a mile and a half from the peak, extends southward for 12 miles, and joins Sonoita Creek ¾ of a mile below Patagonia.

Across the west-central part of the district, in which most of the mines are located, the surface declines from an elevation of 6,500 to 4,500 feet in the distance of 6 miles, or about 333 feet to the mile.

The country rock, as shown on Plate II (in pocket), is mainly andesite, which occupies a north-south belt about 2½ miles wide in the west-central part of the district. In the northwest corner the andesite gives way to a belt of the underlying rhyolite three-fourths of a mile wide, which extends 4 miles southward into the district and which on the south, along the middle of the west boundary, is succeeded by a similarly narrow belt of the quartz diorite and monzonite of the adjoining Tyndall district. This in turn, along the southern part of the boundary, is similarly succeeded by the granite porphyry of Squaw Gulch, which also underlies the andesite on the east. Almost the whole of the eastern part of the district is covered by Quaternary gravels, through which, however, a small area of the Mesozoic shale protrudes on the north. The general relations of the rock formations are indicated in section *C–D*, Plate III (in pocket).

The andesite belt shown on the map and represented in the section locally, as at the Gringo and Anaconda mines, contains small areas of an older or pre-rhyolite (?) andesite that could not be differentiated in this work. The belt also contains areas of the Mesozoic intrusives, for example, monzonite at the Mansfield and Augusta mines, aplite at the Happy Jack, and granite at the Ivanhoe.

ORE DEPOSITS.

Compared with the west slope of the range and especially with the Tyndall district, the Wrightson district is for the most part relatively young in mining activities, though mineral deposits were first discovered here in the late seventies. The deposits contain principally copper and lead. They occur in quartz fissure veins and replacements in the igneous rocks, chiefly in the monzonite and older andesite, largely in association with intrusives. A small group of the deposits, however, of which that opened by the Gringo mine is an example, carry gold only and occur in veins, principally in the older andesite, being similar to the gold-bearing Tertiary veins occurring in the volcanic rocks of the West in general.

The district contains six or eight camps and 20 or more small mines and prospects, most of which are comprised in the subjoined list.

As shown on Plate I, they are mostly located in the west-central or more rugged portion of the district.

American Boy.
Automobile Chute (Anaconda).
Black Cap (Mansfield).
Castle Butte.
Copper Mountain (Anaconda).
Double Header (Anaconda).
Gringo.
Happy Jack.
Hosey (Augusta).
Ivanhoe.
Little Joker (Anaconda).
New Era.
Philadelphia (Anaconda).
Silver Cave (Anaconda).
Star.
St. Louis (Anaconda).
Sweet (Mansfield).
Ultimo (Anaconda).
Walker.
Wasp (Anaconda).
Wild Cat.

GRINGO MINE.

The Gringo mine, which is a gold mine, is located in the southern part of the district about 3 miles north-northwest of Patagonia in Gringo Gulch, a northeast tributary of Temporal Gulch, at an elevation of about 4,250 feet. It is about a quarter of a mile above the mouth of Gringo Gulch and is reached by a wagon road.

The deposit was discovered about 1893, but little development work was done until 1906, when the present owner, the Arizona Gold Mines & Milling Co., of Tombstone, Ariz., acquired it. This company installed a 5-stamp mill, which was soon enlarged to 10 stamps, and at the time of visit an increase to 20 stamps was being planned.

The property comprises a group of nine claims and extends for 4,500 feet on the vein. It is developed to a depth of 180 feet or more by drifts and shafts aggregating about 3,000 feet of work, the general plan of which is shown in figure 27.

The mine lies in the lower foothills of the range. The topography is hilly to mountainous. The country rock is andesite, a more or less propylitically altered, epidotized gray fine-grained, moderately porphyritic rock. It is somewhat banded with flow structure and weathers reddish brown. Calcite films coat the joint planes and some calcite occurs in the rock. The rock is composed principally of long and short laths of oligoclase-andesine, hornblende, and biotite resting in a glassy base having parallel fluidal structure, with a few larger feldspar phenocrysts some of which are nearly 0.2 inch long. There is also considerable magnetite and a little augite and calcite. The rock is apparently correlative with the early andesite occurring elsewhere, as at the Anaconda group, 5 miles to the north, and with the cerusite-bearing andesite at the Sonoita prospect, west of Patagonia.

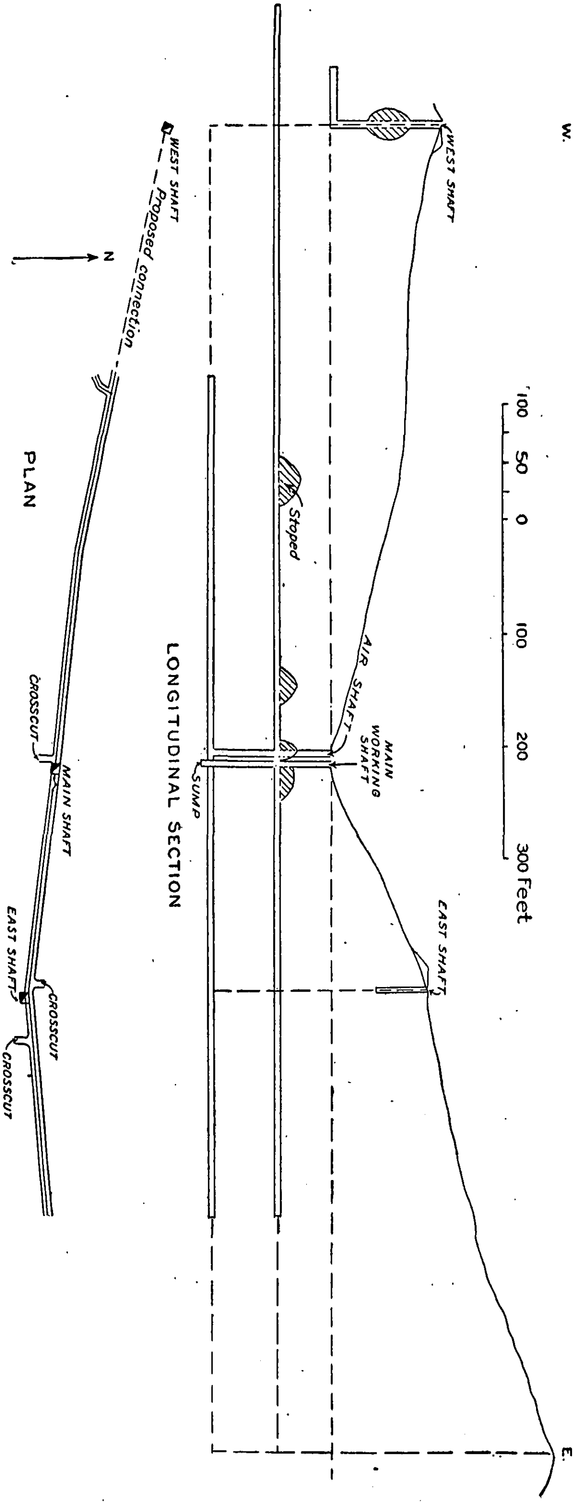


FIGURE 27.—Longitudinal section and plan of Gringo mine and vein.

The andesite is cut by a steeply southward-dipping sheeting, about parallel with the lode, and also by two other sheeting structures, one trending northeast and the other northwest. Water stands about 70 feet below the surface in the main shaft, which is sunk in the bottom of the gulch. This water is near the lower limit of the oxidized zone and is regarded as representing approximately ground-water level.

The deposits are contained mainly in two veins, the Gringo and the Independent, which traverse the andesite and are said to extend for several miles. The more extensively developed is the Gringo vein, on which the mine is chiefly located. It dips 80° S. or stands about vertical and is from 5 to 20 feet in width. It consists principally of coarsely and crudely banded quartz and crushed and altered andesite, with a little calcite or spar. The rock portion occurs in various stages of alteration, but it is in the main highly altered, some to the slacked whitish clayey gouge stage, and some has a talcose feel. Large portions of the vein, however, are wholly or almost wholly quartz, as shown, for instance, by the large dump from the west shaft. The quartz is more or less crushed and is stained reddish and brown by iron and manganese and in some places green by malachite or reddish and purple banded by fluorite, as at the west shaft. Some of the quartz is glass-greenish and some is rose-red. Locally it exhibits a laminated structure, seemingly pseudomorphic after calcite, which, considered in connection with the fact that a short distance to the southeast, in the East Fork of Temporal Gulch, some veins belonging to this same east-west fissure system consist almost wholly of calcite, indicates that the original gangue of the Gringo and its fellow veins was probably calcite, which has been replaced by quartz, as in Mohave County and elsewhere in the West.[1]

The first or 60-foot level contains 1,100 feet of drift, 700 feet to the west of the main shaft and 400 feet to the east. The face of the west drift, which shows ore all the way across for a width of 5 feet, is 118 feet below the surface, and the vein is mostly good stoping ground from this level all the way up to the croppings, which are 15 feet wide. The ore is a roughly banded, partly iron-stained quartz with some altered andesite and kaolin. Just west of the air shaft the vein is 15 feet wide and is said to be all good milling ore. Here the footwall is well defined, but the hanging wall is rough, suggesting that the true wall may not have yet been reached.

[1] Schrader, F. C., The mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: U. S. Geol. Survey Bull. 397, p. 88, 1909; A reconnaissance of the Jarbidge, Contact, and Elk Mountain mining districts, Elko County, Nev.: U. S. Geol. Survey Bull. 497, pp. 54–56, 1912. Lindgren, Waldemar, The gold and silver veins of Silver City, De Lamar, and other mining districts in Idaho: U. S. Geol. Survey Twentieth Ann. Rept., pt. 3, p. 170, 1900.

East of the shaft the vein is 20 feet or more wide and nearly all milling ore, and back of the vein on the footwall side is a 7-foot dike of silicified porphyritic andesite, which carries about the same amount of gold as the vein and which seems to be a metasomatic replacement deposit in the wall rock. The face of the east drift is 180 feet below the surface.

The value of the deposits lies in their gold content. The gold is fine and is somewhat uniformly distributed in the vein except that it generally favors the footwall, rarely the hanging wall, and that the tenor is higher in the whitish altered, more or less porous kaolinized and silicified andesite or so-called sparry quartz and also in association with the glass-greenish, the laminated, and the purple or fluorite varieties of the quartz.

The ore is free-milling gold ore. It averages about $10 in gold to the ton and contains also a little silver, copper, and lead. The lead occurs in the form of yellowish molybdate, which here and there forms dark smooth adherent spots on the plate that interfere with amalgamation of the gold. The gold plates about $5 to the ton, and the concentrates containing the rest of the gold together with the other metals are smelted

The oxidized zone extends to about 75 feet below the surface, measured from the bottom of the gulch, but the ore from the lower level in the sulphide zone, which is about 40 feet below the water line, stamps and mills about the same and is of the same tenor as that from the oxidized zone.

The Independent vein, which is approximately parallel to and about 600 feet north of the Gringo vein, is in general from 15 to 20 feet in width but where joined by spur veins widens to about 40 feet. The portion in the vicinity of the mine is said to be nearly all ore averaging about $9 in gold to the ton. It is in nearly all respects similar to the Gringo vein except that the ore is more ferruginous.

There are on the property also several diagonal or cross veins, one of which extends from the Independent vein near the east end of the ground to the Gringo vein beyond the shaft, near the west end. To judge from the character of the croppings they may be almost as good as either of the main veins.

The veins of the Gringo mine and vicinity belong to the late metallogenetic epoch. Their origin seems to be due to hydrothermal gold-bearing siliceous solutions that circulated through the fissures after the intrusion or eruption of the igneous rocks, probably rhyolite or later andesite, though these rocks were not observed on the Gringo ground. The gulch gravels include also pebbles of a rock which apparently stands between aplite and diorite. This rock, which could not be examined in place, seems to occur in considerable volume in the mountains to the north, at the head of the gulch, and it may be intrusive into the andesite. The solutions must have been strong to judge from the manner in which they have dissolved out the former vein filling and metasomatically altered and replaced the minerals in the andesite.

STAR MINE.

In the Star mine, which is located by the roadside just below the Gringo mine, apparently in the same country rock, the andesite as well as the vein is said to carry fair amounts of gold. As at the Gringo mine, the vein trends east and has a considerable horizontal extent, but it is only a few inches wide. A considerable portion of it is said to average $37 in gold to the ton.

MANSFIELD MINES.

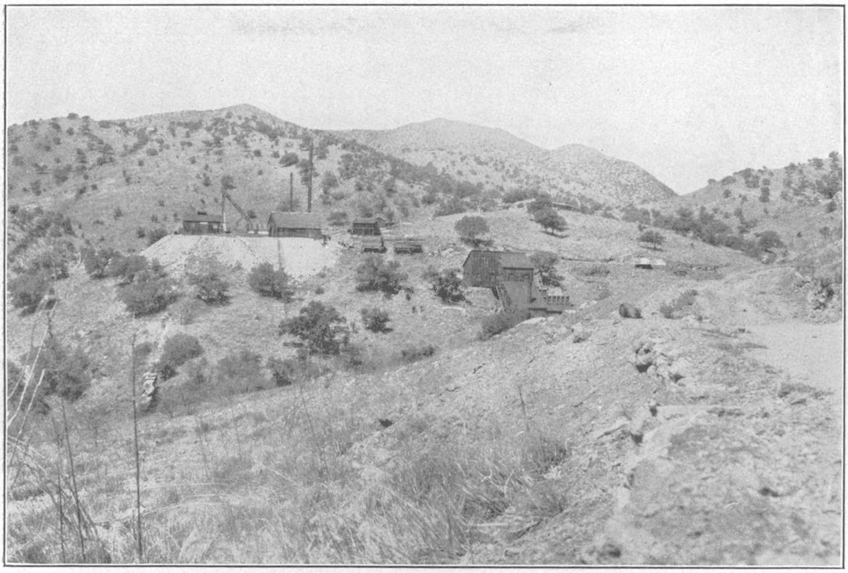
LOCATION AND GENERAL FEATURES.

The Mansfield mines are located near the center of the district, on Temporal Gulch 3½ miles north of the Gringo mine and about 6 miles north of Patagonia. The Mansfield mine, which formed the nucleus of the present property, comprised three original adjoining claims. The deposit was discovered in 1879 by Jack Mansfield and Con Ryan, who sunk a 50-foot shaft on the Mansfield claim and in 1881 took out some ore. In 1883 the Gunsight Mining Co. bonded the property for $50,000, paying $8,000 down. In 1884 after shipping 30 tons of ore which, it is said, averaged 30 per cent in lead and 15 ounces to the ton in silver, this company relinquished the bond. In 1903 A. B. Richmond became the owner. Meantime William Powers had in 1890 shipped from the Contention ground, just to the southeast of the Sweet shaft, 10 tons of ore said to have averaged 40 per cent in lead and 40 ounces to the ton in silver; and $25,000 in silver is reported to have been taken out in the early days from the Dog Day claim, just southeast of the camp.

In 1906 the property was acquired by the present owner, the Mansfield Mining & Smelting Co., of Kansas City, Mo. Most of the development work was done by this company between 1906 and 1908, principally on the Sweet and Black Cap ground.[1] Late in 1907 the company shipped to the El Paso and Douglas smelters, mostly from the Black Cap and Ruby claims, 100 tons of hand-sorted ore that averaged $50 to the ton in copper, gold, and silver.

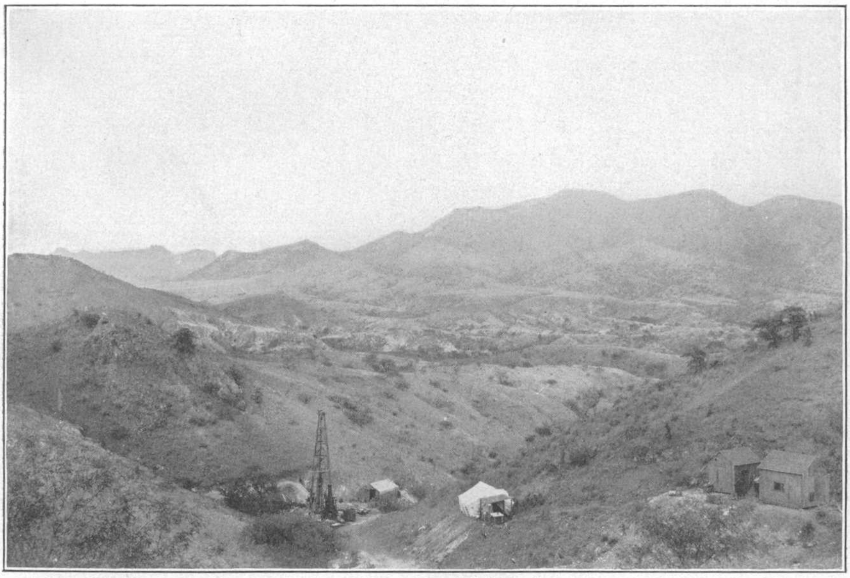
The property now comprises a group of about 40 claims, of which 25 are patented, and extends through a distance of more than 3 miles.

[1] U. S. Geol. Survey Mineral Resources, 1907, p. 178, 1908.



A. SWEET MINE AND SMELTER PLANT OF MANSFIELD GROUP.

Vein croppings in right and left foreground. Looking S. 80° W.



B. CASTLE BUTTE MINE, SONOITA VALLEY.

Red Mountain at right. Looking S. 65° E.

The camp is located in the east end on Temporal Gulch, and the principal claims and mines lie on a tributary known as Mansfield Gulch and are reached by wagon road. Since 1908 the property has been worked each year by a small force of men. It is developed by over 4,000 feet of work, principally in shafts, drifts, and tunnels at the Sweet and Black Cap mines. The smelter is located at the Sweet mine (Pl. XVI, *A*). Late in 1912 the company was reported to be working with a force of 20 men, mostly at the Black Cap mine, and early in 1914 it cut a large shoot of copper-gold ore at a depth of 400 feet.

The topography is hilly and becomes mountainous in the western part of the property (Pl. II, in pocket, and XVI, *A*). The country rock containing the deposits is the medium to fine grained quartz monzonite described on page 178 as occurring at the Carrie Nation mine, but it could not be differentiated from the overlying andesite on the accompanying map. It is composed principally of oligoclase-andesine, orthoclase, hornblende, biotite, and quartz. The quartz monzonite is intruded by rhyolite, which also, like the andesite, overlies and caps it in the surrounding hills.

SWEET MINE.

The Sweet mine (Pl. XVI, *A*) is located in the east end of the Mansfield property, on the Sweet claim, on Mansfield Gulch at an elevation of about 4,700 feet, the collar of the shaft being 80 feet above the bottom of the adjoining canyon. It is on the south vein of a large lode or mineralized zone, which strikes N. 70° E. and dips 80° S. in the reddish medium-grained quartz monzonite. The dominant structure in the monzonite dips 35° E. Rhyolite is intruded near by on the north, and is in general light gray and vitrophyric, but in part pale grayish and reddish brown. It is tuffaceous and contains fragments of a coarse altered granitoid rock. It is traversed by a coarse sheeting which dips 60° W.

The vein is about 6 feet wide and consists mostly of quartz, which is iron stained near the surface. It is opened by a 360-foot shaft, the Sweet shaft, the latest large piece of work done by the company, with levels spaced 100 feet apart, beginning at a depth of 150 feet. The showings of ore in the bottom of the shaft are said to be good, but considerable water is encountered. At or just beyond the north-south gulch, a few hundred feet beyond the shaft, the vein is faulted off laterally 60 or 80 feet. On the first and second levels drifts extend 200 feet west on the vein. On the first level a drift extends 100 feet east, and on the second level a crosscut extending to the north cuts a second vein, which, as shown in the right foreground of Plate XVI, *A*, parallels the Sweet vein at about 80 feet to the north.

The vein in the mine contains some ferruginous copper ore, which carries principally pyrite, chalcopyrite, and a little galena in a white quartz gangue, but it has not produced any ore to speak of, and the company states that it was not expected to produce within the limits of the present workings. Northwest of the shaft, across the road, on the Gone Gosling claim, occurs a good-looking siliceous ledge bearing galena-silver ore, which dips steeply to the south and whose croppings rise boldly 12 feet above the surface.

BLACK CAP MINE.

The Black Cap mine is about 4,400 feet west of the Sweet mine, on the Black Cap claim. It is at an elevation of 5,020 feet on the south slope of Mansfield Gulch, the collar of the shaft being 110 feet above the gulch floor. The mine was worked principally in 1907 and produced about 250 tons of copper-gold-silver ore, that was shipped to El Paso and Douglas. About 70 tons of $30 ore now lies on the dump.

The mine is developed by a 140-foot shaft and a 200-foot tunnel with laterals on three levels and stopes, aggregating nearly 2,000 feet of work. The tunnel and first level are 30 feet below the collar of the shaft and the second and third levels at 90 and 130 feet, respectively.

The country rock is close-grained dark-gray monzonite or diorite allied to that of the Sweet mine and is considerably altered. As at the Sweet mine, it is intruded and overlain by rhyolite on the south. In fact the mine seems to be on an east-west contact of these two rocks.

The deposits occur mainly in a 10-foot siliceous vein or lode which dips 70° SE. In this vein the principal value lies in an ore shoot or pay streak said to be about 3 feet in width. The ore contains mainly chalcopyrite and pyrite in the fine-grained massive form, little tetrahedrite and galena, considerable manganese, and in places bornite. The metals are chiefly copper, with some silver and a little gold. A moderate-sized portion of the ore shoot is said to have contained principally bornite and averaged 35 per cent in copper and 4 ounces to the ton in gold.

Along the road between the Sweet and Black Cap mines the ground in general is mineralized, and openings show good indications of copper and lead sulphide ores; above the Black Cap claim, near the bottom of the canyon, the Sulphide tunnel, 200 feet in length, cuts one of the Black Cap ledges or a branch of it and shows a width of 4 feet of sulphide ore, which, however, is mostly pyrite. Farther up the canyon the country rock is largely rhyolite in which openings show the iron and copper sulphides to be widely disseminated, and the workings, including stopes on the Ruby ground, reveal good ore containing principally chalcopyrite and chalcocite.

In September, 1914, it was reported that the Lee shaft on the Ruby ground had attained a depth of 500 feet and that a body of copper-silver ore 4 feet wide, averaging about 8 per cent in copper, had been opened on the 450-foot level, where also a 50-foot crosscut had been driven, chiefly in ore averaging 2 per cent copper.

AMERICAN BOY MINE.

The American Boy mine is two-thirds of a mile northwest of the Black Cap mine, on Piper Gulch, a northern tributary entering Mansfield Gulch about 1,500 feet above the Sweet mine. It is on the north slope at an elevation of about 5,400 feet, or 20 feet above the gulch.

The deposit was discovered in 1906 by George Clark and since 1907 has been worked steadily on a small scale and has yielded occasional shipments of rich ore.

The property comprises a group of six claims. It is opened by a 350-foot tunnel and accompanying drifts, crosscuts, and stopes to a depth of about 150 feet. The country rock is fine-grained quartz monzonite, which weathers reddish and dark and is sheeted in directions trending N. 20° W. and N. 40° E. The mine produces 30 gallons of good potable water a minute. The water was first encountered near the surface. In the lode and its vicinity the ground is soft and requires good timber and lagging.

The deposits are contained mainly in a 25-foot lode which dips 80° N. into the hill. Clark & Peterson report having traced the lode for about 5 miles westward into the Salero and Josephine Canyon country. The Augusta, Arizona-Pittsburg, and other properties seem to be on it. On the American Boy ground the lode has several spur veins or feeders.

The lode consists mainly of crushed and altered country rock, some of it altered to the gouge or kaolin stage. The croppings, which are not prominent, consist of quartz and silicified, altered, and weathered country rock containing and stained with yellowish-brown and whitish cerusite, a little green malachite, and reddish-brown and black iron and manganese. The lead-carbonate croppings almost invariably indicate the presence of copper underneath. The stringers and shoots, which in the surface ore contain principally lead carbonates and galena, in the unoxidized zone become mainly copper sulphides carrying silver and gold.

In the lode the ore occurs in seams, stringers, and shoots, some of which are several feet in width. A 40-foot upraise or stope in the hanging-wall side of the lode from the west drift is on an ore shoot nearly 3 feet wide, from which there was shipped to Douglas 15 tons of sorted ore that averaged 18 per cent in copper with fair quantities of gold and silver, also 150 tons of second-grade ore.

The ore in general contains principally chalcopyrite, pyrite, tetrahedrite, chalcocite, bornite, some galena, and a little sphalerite. In places the tetrahedrite occurs in crystalline form. The footwall side of the vein carries about 2 feet of pyrite and chalcopyrite with some black copper sulphide and in places 5 to 6 inches of bornite ore containing considerable silver and gold. According to report, good ore has recently been encountered on the lower level.

AUGUSTA MINE.

The Augusta mine, also called the Hosey and the Presidential, is about a mile northwest of the American Boy Mine, near the head of a north-side head tributary of Mansfield Gulch, at an elevation of about 5,500 feet. It is reached by a wagon road ascending the gulch.

Copper was known to be present here as early as 1880, but it was discovered in workable amount in 1905 by John Leek, who, with his partners, soon took out $1,100 worth of black and gray copper sulphide ore from a 40-foot shaft. This ore, with shipments made a little later, aggregated five carloads.[1] At the time of visit there was about 300 tons of good-looking ore on the dump.

In 1909 the mine was bonded to William Kemp, of Tucson, and the Calumet Arizona Co., who soon began operations, and during the later part of 1909 and the early part of 1910 steadily shipped considerable ore, sometimes from 20 tons to a carload a day, it is said, to Globe.[2] Much of this ore, however, came from dumps of earlier work. During the summer of 1912 the mine was also reported to be shipping ore to the Pioneer smelter.

The property comprises a group of seven claims. It is said to have been purchased recently by Col. O. P. Posey.

The mine is developed to a depth of 215 feet by shafts, drifts, crosscuts, and stopes aggregating about 1,000 feet of work. The levels are about 100 and 200 feet below the surface.

The topography is mountainous. The country rock is quartz monzonite cut by rhyolitic dikes, with which the deposits are associated. It is a fine-grained, very dark iron-gray rock that weathers reddish and is moderately porphyritic. Besides the usual minerals it contains much magnetite and hematite, also chlorite derived from the hornblende and biotite. It is traversed by a sheeting which dips steeply to the south, about parallel with the veins, and by a more pronounced sheeting that strikes a little west of north and dips

[1] U. S. Geol. Survey Mineral Resources, 1907, pt. 1, p. 178, 1908.
[2] Eng. and Min. Jour., October, 1909.

steeply to the east or stands vertical. Water level stands about 50 feet below the surface.

The property contains three veins which lie about parallel and dip 75° S. Each vein is associated with the footwall side of a rhyolite dike. From the south or main vein the middle vein lies 30 feet distant and the north vein 140 feet.

The south vein, on which nearly all the development work has been done, is from 8 to 15 feet in width, and just west of the shaft is marked by croppings of brecciated and honeycombed hematite and limonite stained quartz, rising boldly 8 feet above the surface. The vein is opened by a 215-foot double-compartment shaft inclined 75° and a few hundred feet of drifts extending each way, with crosscuts and stopes on the 100-foot and 200-foot levels. It is said to carry a 4-foot ore shoot which averages about 12½ per cent in copper and contains some silver and a little gold and which is the main source of the ore thus far produced.

The ore is siliceous and occurs in part as metasomatic replacement deposits in the rock. It contains mainly fine-grained chalcopyrite and pyrite, tetrahedrite, and a little chalcocite and argentite. It is usually sold under contract for large amounts to the Globe smelter, where it is in demand as flux for other ores. A microscopic section of the ore, which, however, seems to be from ore contained in the intrusive rhyolite, is highly altered and sericitized and may not be wholly representative, but consists mostly of a cryptocrystalline to glassy or isotropic base with irregular flow structure containing disseminated chalcopyrite, pyrite, hematite, and tetrahedrite.

The middle vein is opened by an 80-foot shaft, said to be all in ore, as is also a crosscut near the surface. The north vein, which is 6 feet wide, seems to form the footwall side of a 20-foot rhyolite dike. Only a little surface work has been done on it, but it makes a good showing and seemingly carries good ore containing principally pyrite and chalcopyrite, with some bornite and chalcocite.

HAPPY JACK MINE.

The Happy Jack mine is about half a mile south of the Black Cap mine (Pl. I, in pocket), near the head of a western tributary of Temporal Gulch, at an elevation of about 5,300 feet.

The deposit was discovered in 1881 by Jim Lewis, who sunk a 30-foot shaft and took out a few tons of good lead ore. In 1894 it was worked by W. H. Barnett and Frank Powers, who soon encountered more good ore, which resulted in the incorporation of the Happy Jack Mining Co. The mine has been worked intermittently ever since. In 1908 the company was reorganized as the Happy Jack

Mining & Reduction Co., which is still the owner, with offices in Philadelphia and Patagonia. By June, 1908, the mine had shipped to El Paso six carloads of high-grade ore that averaged 41.8 per cent in lead, 2½ per cent in copper, and 21 ounces in silver and $2 in gold to the ton.[1] Several hundred tons of good concentrating ore lies on the dump, and the amount of concentrating ore in the mine is large. By reason of its desirable smelting properties the ore received from the smelter a lead credit of $1.84 to the ton.

The property comprises a group of nine claims. The mine is developed by drifts or so-called tunnels, winzes, and stopes, aggregating 4,000 feet of work. The main or lower drift is 950 feet in length and reaches a depth of 400 feet at the face.

The mine is near the top of the ridge between Temporal and Squaw gulches. The topography is mountainous, as is shown in Plate I. The country rock is light-gray, medium-grained, altered and highly sericitized granitic aplite, or perhaps granite porphyry, and in the mine it is seemingly intruded by a dense olive-green to brown altered andesite. Both rocks contain a little disseminated pyrite and galena. Water stands in the winze and there is some in the lower tunnel.

Several veins occur on this property. As at the Augusta mine, they lie about parallel and dip steeply to the south. The most valuable of the veins, beginning on the south, are the Clipper, Mountain View, and Eclipse. The developments are nearly all on the Mountain View, which is the middle or main vein. It is known from croppings to have an extent of 3,100 feet, ranges from 3 to 6 feet in width, and usually has a foot of soft clayey gouge on each wall. The filling is mostly highly altered rock, with a moderate amount of quartz. The ore occurs mostly in the hanging-wall side of the vein.

The vein is opened by a 950-foot main or lower tunnel and an upper one 200 feet higher, connected with the lower tunnel at about 600 feet from the portal by an upraise, west of which, at about midway between the two tunnels, considerable intermediate work, including several drifts and some stopes, has been done. This work, which supplied most of the production, is said to lie in a continuous ore body or shoot having a known extent of 175 feet and ranging from 6 to 30 inches in width. The ore shoot is also almost continuous throughout the length of the lower tunnel. The ore is lead-silver with some copper, and it carries a few dollars in gold to the ton. It contains principally galena, tetrahedrite, and argentite and is reported to carry locally a little uranium, which probably occurs in the form of uraninite or pitchblende.

[1] U. S. Geol. Survey Mineral Resources, 1906, p. 171, 1907.

A 60-foot winze about 600 feet in from the portal of the tunnel is said to contain good ore, and at 700 feet in a 195-foot crosscut to the south is mostly in pyritic ground, in which some of the pyrite seems to be cupriferous. The face of this crosscut, which has a depth of about 300 feet, is said to be within 30 feet of the Clipper vein. At 750 feet in from the portal the vein splits or gives off a spur which extends obliquely to the southwest, while the main vein curves slightly to the northwest. The tunnel in the last 200 feet of its course follows the spur vein, which probably joins or intersects the Clipper vein.

The Clipper vein is from 5 to 6 feet in width and has strong iron-stained quartz croppings which in places are very much wider. The vein filling is principally quartz, as is also that of the Eclipse vein, several hundred feet to the north.

The Happy Jack ground in general seems capable of being advantageously worked through the main tunnel, which when extended will soon attain a depth of 1,000 feet on the vein. The mine seems to contain considerable ore, the larger part of which could be most economically handled by concentration on the ground.

ANACONDA GROUP.

LOCATION AND GENERAL FEATURES.

The Anaconda group consists of 54 claims occupying a mineralized belt three-fourths of a mile wide, which extends from the Mansfield camp northward on each side of Temporal Gulch for about 2 miles. The Anaconda camp is near the center of the belt, about 7 miles north of Patagonia. A wagon road ascends the gulch.

Some of the veins occurring in this belt were worked as early as 1873. The group is now owned by the Anaconda-Arizona Mining Co., of Kansas City, Mo., which began operations here in 1905, did considerable development work, and in 1910 was erecting buildings and installing machinery[1] that was later reported to be in successful operation.

The topography is mostly rough, of the type produced by eroded and decomposed volcanic rocks, but in most of its course through the belt Temporal Gulch widens into an open valley or basin. The country rock is highly altered whitish older andesite. It is in part tuffaceous and is intruded by dikes and masses of a younger black andesite. Ground water in general stands about 20 feet below the surface.

The country rock is also cut by a system of quartz veins which strike about N. 60° W. and usually dip steeply either to the north

[1] Eng. and Min. Jour., Jan. 15, 1910.

or to the south. The veins, as plainly shown by their mineralized croppings, are numerous. They are spaced from about 200 to 300 feet apart. Many of them are small, but about 40 by estimate are of workable size. They range from 6 inches to 6 feet in width. As shown by the croppings and the exposures in the workings, the continuity of any one vein is interrupted to an unusual degree, so that along the course and depth of its fissure the vein may consist of a series of tabular sheets or relatively flat lenses.

The veins differ from one another in their economic content. Most of them carry chiefly copper minerals, commonly chalcocite containing silver. In some, however, as the Double Header vein, the principal ore mineral is argentiferous galena. The main openings, none of which exceed 100 feet in depth, occur on the Double Header, Ultimo, Copper Mountain, Philadelphia, and Little Joker claims.

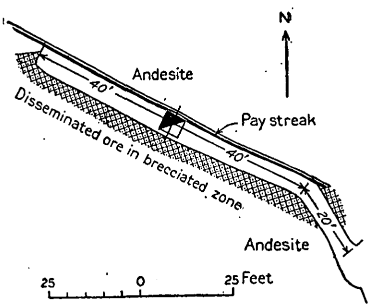


FIGURE 28.—Plan of Ultimo drift and vein.

ULTIMO PROSPECT.

The Ultimo prospect, on the claim of the same name, is opened just opposite the Anaconda camp by a 20-foot crosscut tunnel containing 65 feet of drift (fig. 28) and a 30-foot shaft on the vein, which strikes N. 62° W. in crushed tuffaceous andesite. The tunnel and drift do not attain a depth of more than 28 feet. The drift contains a 6-foot winze which is filled with water. Sulphides begin at a depth of about 17 feet, and as shown by the tunnel the wall rock on the south side of the vein consists of 16 feet of crushed and brecciated andesite, mineralized with pyrite and chalcopyrite, and constitutes a body of low-grade milling ore said to average about 2½ per cent in copper. In the vein along the north wall of the drift mineralized seams open into small ore lenses about 2½ inches wide composed of quartz, barite, chalcopyrite, tetrahedrite, galena, and pyrite, some of which is said to average about $40 to the ton. In the shaft, at a depth of 17 feet, the vein is about a foot in width and contains principally banded ore, consisting of chalcopyrite, galena, and tetrahedrite in a quartz-barite gangue.

DOUBLE HEADER PROSPECT.

The Double Header prospect is one-eighth of a mile south of the Ultimo prospect, on open ground. It is developed by a 100-foot inclined shaft on an east-west vein in white silicified rock which seems to be rhyolitic tuff and is probably intrusive into the andesite. This rock contains a little disseminated pyrite. The dip of the vein flattens from about 60° near the surface to 30° in the lower part of the shaft (fig. 29). A thin black clayey gouge separates the vein from the wall rock, especially on the hanging-wall side. Water stands about 15 feet below the surface. The vein is composed mainly of the brecciated siliceous rock in which the ore occurs in lenses that are generally connected by seams of barite. The lenses contain mainly quartz, barite, galena, gray copper, and sphalerite. They are usually banded, with the sulphides mostly in the outer portion and barite in the inner or middle portion. Quartz is sparingly present and is well crystallized in comb structure at right angles to the wall.

On the dump is a small amount of ore which is said to run 47 per cent in lead and $8 in gold and 44 ounces in silver to the ton. From some of this ore as high as $60 a ton was reported.

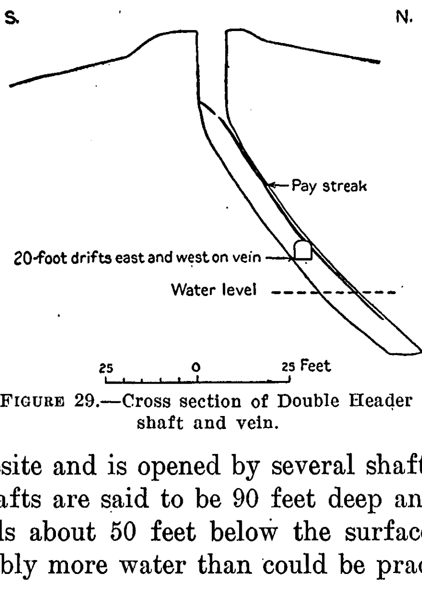


FIGURE 29.—Cross section of Double Header shaft and vein.

PHILADELPHIA PROSPECT.

The Philadelphia prospect is north of the Anaconda camp, on open ground. It was first worked in 1873, and John Parks is said to have shipped from it in 1882 to the smelter at Socorro, N. Mex., two carloads of ore that averaged 300 ounces in silver to the ton. It is on a strong vein which dips 70° SSW. in red tuffaceous andesite and is opened by several shafts and drifts. The two deepest shafts are said to be 90 feet deep and the other 60 feet. Water stands about 50 feet below the surface. The main shaft makes considerably more water than could be practically handled with a horse whim.

The croppings of the vein, which are not prominent, consist of iron-stained quartz and barite and in some places show considerable malachite and azurite. The vein is about 2½ feet in width. It is banded and in the oxidized zone is composed mainly of a barite-quartz gangue and the ore minerals, galena and gray copper. The surface ore is all oxidized and carries lead and copper carbonates in a mixture of limonite-stained quartz and barite. Its value was principally in copper and silver, the latter being probably carried in the chloride or bromide form. The deeper ores were composed of argentiferous galena and gray copper.

ST. LOUIS PROSPECT.

The claim of the St. Louis prospect adjoins that of the Philadelphia prospect on the north. The principal openings, consisting of short tunnels and shafts, are in the side and bottom of a canyon-like gulch, on a 4-foot vein which dips 80° S. It is said that John Parks in 1882 shipped from the prospect 20 sacks of silver-copper ore which netted $300 to the ton. The vein is composed mostly of crushed or brecciated reddish andesite cemented by quartz. On the hanging or south wall it carries a 9-inch pay streak of ore which consists mainly of quartz, barite, limonite, galena, gray copper, chalcopyrite, pyrite, and sphalerite, the whole being more or less stained with malachite, azurite, and cerusite. It is said that 2 tons of this ore shipped to the Copper Queen smelter, at Douglas, Ariz., gave returns of 5.75 per cent in copper and 96 ounces to the ton in silver.

LITTLE JOKER PROSPECT.

The Little Joker claim lies north of the St. Louis, on a parallel 4-foot east-west vein. It is opened by three shafts, the deepest 60 feet deep. The croppings of the vein are prominent, standing in places, as west of the shafts, from 4 to 10 feet above the surface.

The vein as exposed in the main shaft and tunnel is composed principally of quartz and barite. It is crushed and iron stained and contains pockets and stringers of galena, and the joints are coated with copper carbonates and apparently with silver bromide. The sorted ore is said to average 5.2 per cent in copper and 22.3 ounces in silver and about $1 in gold to the ton.

COPPER MOUNTAIN PROSPECT.

The Copper Mountain prospect, located about half a mile south of the Anaconda camp, is on a 10-foot east-west vertical mineralized shear zone in andesite. It is opened by a 45-foot shaft and a 90-foot tunnel. The shaft contains about 15 feet of water. The croppings are stained with and contain copper carbonates and limonite. The carbonate is principally azurite, some of which is beautifully crystallized. Iron and copper sulphides are said to begin at the bottom of the shaft. The sorted ore is said to average 5.5 per cent in copper, 1.25 ounces to the ton in silver, and a trace of gold.

SILVER CAVE PROSPECT.

The Silver Cave prospect, just southeast of the Copper Mountain prospect, is on a silicified east-west 12-foot shear zone or lode which dips 70° S. in andesite. The deepest opening is a 40-foot shaft in which no sulphides were found. The only macroscopic minerals are the gangue minerals limonite and quartz, but the deposit is said to carry as high as 4 ounces in gold to the ton.

WALKER MINE.

The Walker mine is about 10 miles north-northwest of Patagonia and 2½ miles north of the Anaconda camp, near the head of the south fork of Casa Blanca (formerly Josephine) Canyon, at an elevation of 5,750 feet. It was first worked in 1894 and is now owned by H. C. Hale, of Patagonia. The deposits are contained in a 5-foot siliceous iron-stained vein which dips 80° NW. in crudely bedded andesitic agglomerate and tuff which dip 40° SE. The vein consists mainly of crushed tuffaceous andesite cemented by quartz, and the ore seen on the dump contains principally this gangue coated with azurite, malachite, and seemingly silver bromide. Samples of the ore are said to assay as high as 1,000 ounces in silver to the ton.

WILD CAT GROUP.

The Wild Cat group of claims is about a mile south-southwest of Josephine Peak and 1½ miles west of the Walker mine, in the head of Temporal Gulch, at an elevation of about 6,500 feet. The camp is located just east of the crest of the range. The deposit was discovered in 1880 and was relocated in 1907 by the present owners, F. B. Sayer, R. T. Stump, and others. It is opened by two tunnels, each about 200 feet in length, spaced about 130 feet apart vertically and 1,000 feet horizontally.

The topography is mountainous. The country rock is coarse-grained diorite, some of which is nearly black, representing a very basic segregation, and apparently stands near anorthosite.

The deposits occur principally in a rhyolite dike or ledge 200 feet wide which cuts the diorite. In the lower tunnel, where it makes the best showing, the dike contains numerous east-west seams, stringers, or parallel veins, the largest about an inch wide, which are composed of massive crystalline pyrite with some chalcopyrite and parts of which are said to assay 0.5 per cent of copper and $18.60 in gold and 6 ounces in silver to the ton. The ledge extends for half a mile east of the prospect and for a considerable distance to the west across the divide into Josephine Canyon. Some sulphur and alum are leached out on its surface, and the diorite on the north contains a small deposit of specular hematite.

CASTLE BUTTE MINE.

The Castle Butte mine is in the south end of the Wrightson district, 2 miles west of Patagonia, on a small western tributary of Temporal Gulch, at an elevation of about 4,200 feet (Pl. I). It was located in 1879 and is reported to have produced in 1880 some ore which carried gold and copper. Later it was relocated by A. J. Stockton, who named the property Castle Butte. Shipments of carbonate ores in 1886 to 1888 gave returns of 13½ per cent in copper and 7 ounces in silver and $6 in gold to the ton. Mr. Stockton states that from a large pocket of silver glance in the main shaft 8 feet below the surface a ton of high-grade ore was taken. In 1908 the Castle Butte Mining Co. took over the mine, and in 1909 it was under bond to the present operator, the American Oil & Mining Co., of Los Angeles, Cal. This company at the time of visit was prospecting the ground with a churn drill, which had attained the depth of 397 feet, all in rhyolite. The property is opened by a 120-foot tunnel and several shafts, of which the deepest is about 80 feet deep.

The topography, as shown in Plate XVI, *B*, is rough. The country rock is principally light-colored rhyolite, in general overlain and intruded by dark andesite, with which the deposits are associated.

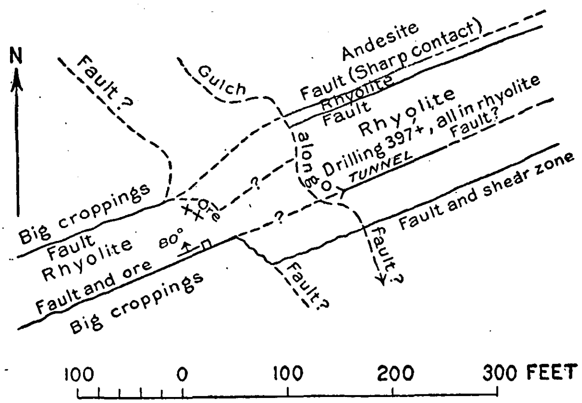


FIGURE 30.—Geologic ground plan at Castle Butte mine.

The deposits are distributed in a fault or shear zone about 120 feet in width, which, as shown in figure 30, trends N. 68° E. and dips steeply to the north-northwest. The middle part of the zone is occupied by a rhyolite fault block from 50 to 80 feet in width, which is flanked on each side by a thinner slice of the same rock with strong croppings. The deposits are contained mainly in the vein which bounds the main fault block on its south side, and of which the block forms the hanging wall. The vein dips 80°–85° NNW. Besides the gangue minerals, which are principally crushed rock, quartz, and gypsum, it contains considerable malachite, chrysocolla, azurite, limonite, and epidote, all more or less crushed.

The main shaft is 40 feet deep, and from the bottom extends to the drifts east and west on the vein. Open cuts west of the shaft and

30 feet higher show the sheared zone to be split, with about 50 feet of tuffaceous rhyolite between the two parts. A tunnel in the bottom of the gulch to the east of the main shaft is 120 feet long, running N. 75° E. on an iron and manganese streak about 1 inch in average width, which is said to carry copper. This streak is an offshoot of the main fault, which lies north of the tunnel.

The vein is traceable to a point about half a mile to the east, where it is opened on the east side of Temporal Gulch. Here it is represented at the surface by a 1½-inch veinlet of heavily manganiferous gypsum and quartz, which contains stringers of malachite and chrysocolla dipping 80° S. It is opened by an 80-foot shaft. The prevalent gangue mineral is quartz in the deeper workings and gypsum in the surface ores.

SONOITA PROSPECT.

The Sonoita prospect, owned by W. T. Powers, of Patagonia, is about a mile west of that place and half a mile northwest of Sonoita Creek. It is in andesite and is opened by a 15-foot shaft. The deposit consists mainly of a 2-foot fault or shear zone of the crushed, altered, and mineralized andesite that dips steeply to the north and contains principally cerusite, with which are associated wulfenite, pyrolusite, psilomelane, and reported silver and gold. The wulfenite occurs in reddish-yellow columnar crystals with truncated faces, and the manganese in both massive and crystalline forms.

REDROCK DISTRICT.

GENERAL FEATURES.

The Redrock district adjoins the Wrightson district on the southeast. It is 6 miles wide and extends from Sonoita Creek between Patagonia and the Pennsylvania ranch 11 miles southeastward to Meadow Valley Flat and Canelo Pass. Harshaw Creek forms the southwest boundary, and the northeast boundary approximately coincides with the axis of the Canelo Hills. (See Pl. I, in pocket.)

Three camps, the Hale, Jensen, and La Plata, are now active in the district and one is abandoned. Crittenden, on Sonoita Creek, where an adobe smelter was located in the early days, was at one time the principal town of the region, but Patagonia has superseded it. The Hale camp is on Harshaw Creek, 4 miles southeast of Patagonia, and the Jensen camp is in Redrock Canyon, 7½ miles in an air line southeast of Patagonia.

The topography is mountainous and in part rugged. The district drains into Sonoita Creek, the principal stream being that in Redrock Canyon, which rises in the Canelo Hills, flows westward, and joins Sonoita Creek at Patagonia.

The district contains four kinds of rock, which are disposed in parallel northwest-southeast belts. (Pl. II, in pocket.) Beginning on the northeast they are limestone, conglomerate, andesite, and rhyolite. The general relations of the rocks are shown in section *E–F*, Plate III (in pocket). The limestone belt, as shown on the map, is but a part of a much broader belt of undifferentiated Paleozoic limestones that lie outside of the district. Within the district the belt has a width of about a mile. It includes the crest of the Canelo Hills and their upper southwest slope. The general structure is that of a monocline dipping to the southwest, with a fault plane somewhere along the northeastern flank of the hills. The belt is composed of relatively thick-bedded cherty limestones of usually light-gray color, which strike parallel to the ridge; about N. 35° W., and dip 15°–30° SW. These beds flatten to the east, near the crest of the range, on the eastern flank of which thin-bedded limestones dip to the southwest at medium angles.

Overlying the limestone on the southwest side is a belt of coarse reddish conglomerate composed of pebbles and cobbles of red sandstone, limestone, chert, red rhyolite, and dark andesite cemented by sand, whose estimated thickness is between 300 and 500 feet. It dips 30° SW. and is probably of Tertiary age.

The valley of Redrock Canyon is underlain by flows of dark-gray porphyritic andesite which overlie the sedimentary rocks of the Canelo Hills, usually overlapping the red conglomerate above described, and toward the south, near Meadow Valley Flat, andesite also overlaps the older limestones.

The peculiar flat-topped hill a mile north-northwest of the Jensen ranch is composed of reddish rhyolite similar to that of Red Mountain, south of Patagonia, described on page 247. The mountain which lies between Harshaw and Redrock canyons and reaches an altitude of 5,700 feet is also rhyolite, as is the spur running northeastward toward the flat-topped hill just mentioned.

The andesite flows of Redrock Canyon cover this rhyolite and have a rather even upper limit at elevations of about 4,900 to 5,100 feet. The andesite weathers into rounded forms of a dull-gray to chocolate-brown color. It is cut by an approximately east-west system of faults whose fissures are occupied by dikes of a black porphyritic olivine-bearing basalt, also by dikes of a seemingly younger light-colored acidic intrusive rock that trend in both east-west and north-south directions. Both of these intrusive rocks crop out boldly above the surface of the older mass.

The dome-shaped hill just northwest of Canelo Pass is composed of a rather coarse granite porphyry which is exposed on its west flank and is overlain by andesite. The andesite flow, however, is apparently thin, as it is reported that at a depth of 70 feet in the

Meadow Valley shaft the "quartz porphyry" was encountered under andesite, the contact between the two dipping about 30° N.

HISTORY AND PRODUCTION.

The first mining in the district was done by a party of Frenchmen who came into the country in the late seventies. M. Carré, one of the party, located the La Plata mine in 1881 and with his partners worked it until 1883, during that time, according to rumor, obtaining $10,000 from oxidized silver ores. At about the same time Salá & Michelato located a claim about a mile north of the La Plata and did a little work there on an east-west copper-gold vein. Both of these properties were in 1886 relocated by Peter Jensen and partners, who still hold the New York mine, located by Salá & Michelato. In 1899 Mr. Jensen shipped a carload of ore from the New York, which, he states, averaged about 10 per cent in copper and 45 ounces in silver and $5 in gold to the ton.

The only other mine worked in the early days is the Meadow Valley mine, about 1½ miles south of the La Plata. In 1881 Frank Olsen and his partner sunk several shallow shafts here on an east-west vein, which at the surface contained some rich pockets of horn silver. These did not continue in depth, however, and owing to difficulties with water and lack of funds work was discontinued.

There are also numerous small prospects in the district on which but little development work has been done. Of the larger properties all but one are located in the southeastern part of the district, in an area about 2 miles square on the southwest slope of the Canelo Hills, between elevations of 4,700 and 5,500 feet.

LA PLATA MINE.

The La Plata mine is in the southeastern part of the district, about 10 miles east of Patagonia, in the upper Redrock Canyon. It is reached by a wagon road which extends to the Jensen ranch and a trail for the last 2 miles.

The deposits occur in the La Plata vein, which crosses a low hill and is opened by about 2,500 feet of work, consisting of about 600 feet of tunnels or drifts on the vein, distributed on each slope at about 75 feet below the crest, 350 feet or more of shafts located at intervals across the top of the hill, several winzes sunk from the tunnel levels to a reported depth of 115 feet below the crown of the hill, and upraises and stopes. The workings, which followed the ore exclusively, are narrow and badly caved.

The vein occupies a fault fissure which traverses the red conglomerate on the southwest base of the Canelo Hills and dips 85° SSW. At the northwestern portal of the tunnels is exposed a dike of black augite andesite, or basalt, that apparently came up along the fault plane. This dike is similar to the later eruptive rocks of the Redrock district in that it is fresh and weathers to angular blocks of small dimensions. It is in the joints thus formed and particularly along the hanging or southeast wall of the vein that the valuable metals were found.

The ore, which is said to have been very rich in argentite and horn silver, occurred in small stringers and pockets in the altered basalt dike rock. From the position of the workings and the few parts of them still visible it appears that postintrusive movement has broken the igneous rock into angular blocks. Subsequently solutions (?) altered the basalt along the fractures to a considerable extent, forming a greenish-white soft, crumbly mass. This result is particularly noticeable at the mouth of the northern tunnel. Along the joints malachite, azurite, limonite, hematite, psilomelane, and calcite are visible, with a little soft yellow lead carbonate. The black psilomelane contains some carbonate of zinc. The carbonates and oxides, it is said, particularly those showing copper carbonates, carried the most silver.

At first the rich ores were amalgamated in an arrastre situated in the bottom of Redrock Canyon, at a small water hole, about 1½ miles west of the mine. Afterward shipments were made to the smelters at Benson and Tombstone.

NEW YORK (JENSEN) MINE.

The main workings of the New York or Jensen mine are situated a mile west of the La Plata mine, on the low hills in the upper Redrock drainage basin, about three-fourths of a mile east of Redrock Wash and 8½ miles east-southeast of Patagonia. The Jensen camp or ranch (Pls. I and II) is in the main wash where the trail to the mine turns out of the Patagonia-Canelo road.

About 850 feet of development work has been done, most of it on the East claim, which has a 160-foot shaft sunk at the top of the hill with 200 feet of drifting. A 50-foot crosscut and a 250-foot drift are located about 200 feet west and 50 feet below the shaft. There are also a few shallow pits on the croppings. Water stands in the deeper workings.

The topography is rough. The country rock is a dark chocolate-brown altered andesite cut by two dikes. The older dike is a reddish banded rhyolite which breaks into plates along what appear to be flow lines. It is about 10 feet wide, dips 55° NE., and is traceable by scattered outcrops for about 1½ miles to the southeast. So far as could be seen it was mineralized at only a few points. The ore body is a quartzose dike or ledge ranging from about 40 to 60 feet in width. It strikes N. 70° E., dips 80° S., and offsets the older dike about 2 feet. This ledge contains throughout widely disseminated iron and copper pyrites, which on weathering have stained the croppings yellowish with small patches of green and blue. At the main workings there is near the center of the ledge about 8 feet of very siliceous material in which the metallic minerals are apparently much more concentrated. The croppings here are stained red by iron. They are only slightly colored by copper carbonates but show some lead and manganese minerals of the oxidized zone. It is a peculiarity of the deposit, however, that sulphides show immediately at the surface mixed with the oxidized ores. Mr. Jensen states that on the East claim there were at the surface some native silver and considerable lead associated with iron, but at water level, at a depth of 30 feet, the lead gave way to copper and zinc began to appear. The ore at present is estimated to average $7 to $8 a ton in copper, lead, silver, and gold.

MEADOW VALLEY MINE.

The Meadow Valley mine is about 2 miles south-southeast of the New York mine, in the upper part of Meadow Valley Flat, at an elevation of about 4,800 feet.

The developments consist mainly of a 70-foot vertical shaft with a 30-foot incline at the bottom. Two other shallow shafts were sunk near by when water barred work in the first shaft.

The country rock is a coarsely porphyritic andesite flow whose weathered surfaces are chocolate-brown. The flow is cut by two systems of joints or faults, one striking N. 80° E. and the other N. 65° W. Along some of these, especially the larger ones, are belts of siliceous material which in places are stained with copper carbonates and oxides and, it is reported, carry considerable quantities of silver chlorides and bromides.

The mine is on one of the larger east-west quartz veins, which is about 4 feet wide and at the surface stands vertical. At the time of visit water stood in the shafts within 30 feet of the surface. Mr. Olsen reports that the vein continues vertical to a depth of 70 feet, where it dips 30° N. The footwall of the lower part of the vein is "quartz porphyry" or granite porphyry similar to that seen on the surface about half a mile east of the workings. The vein, it is said, was continuous along the contact of the porphyry and andesite but contained no metallic minerals. Above the 70-foot level the white vein quartz was broken by small joints and seams, some of which, especially next to the hanging or north wall, were coated with a green mineral, horn silver or cerargyrite, from which some very high assays were obtained. The only other ore mineral is argentite, which was found in sinking the shaft in a very small pocket at a depth of 55 feet. The highest assay received was from ore taken 4 feet below the surface, which gave 42 ounces in silver to the ton.

HALE PROSPECT NO. 2.

Along what appears to be a southeasterly continuation of the dike which runs through the New York mine, at a point about 1½ miles distant from that property, Frank Hale, of Patagonia, has put down some 10-foot holes, which show a little copper carbonate in a soft claylike material between the dike and the andesite wallrock.

HOMESTAKE PROSPECT.

About a quarter of a mile south of the Hale prospect No. 2 occurs a small circular patch of garnetiferous, slightly copper-stained limestone croppings, in which a shallow pit was sunk, and at 100 feet to the southwest a shaft has been sunk 160 feet through white crystalline limestone. At the bottom of this shaft a 40-foot crosscut was driven in the hope of intersecting what was expected would prove to be an ore body, but no indications of ore were found.

SULPHIDE PROSPECT.

About a mile south-southwest of the La Plata mine, on the low divide between Meadow Valley Flat and Redrock Canyon, there is a 2-foot vein striking N. 65° E. and dipping 75° S. in granite porphyry, which along the vein is more or less impregnated with iron and copper sulphides and is rather siliceous. The vein is composed of barite slightly stained with malachite and azurite.

HALE PROSPECT.

Frank Hale, of Patagonia, holds a group of claims in Meadow Valley Flat, east of the Meadow Valley mine. Here the country rock is andesite, cut by small vertical joints and fissures striking N. 80° E. and N. 65° W. Some of these fissures, which have been opened by shallow pits, show films and narrow bands of gray copper associated with malachite, azurite, and cuprite. Hale reports that a few sacks of the ore picked from the surface material average well in silver. The small seams and veinlets, however, appear to pinch out at depths of about 12 feet. From similar occurrences at the Meadow Valley mine it seems very probable that the veins have but slight vertical continuity.

HALE PROSPECT NO. 3.

Another prospect owned by Frank Hale is half a mile north of the Meadow Valley mine, on the divide between Redrock Canyon and Meadow Valley Flat. It is on a siliceous dike or ledge about 40 feet wide that strikes N. 80° E. and stands almost vertical. It is opened by a 65-foot shaft and several shallow pits sunk on the vein. Disseminated through the whole mass are small crystals of pyrite and chalcopyrite, which are locally concentrated in veinlets. The croppings are much iron stained and here and there show small patches of malachite, azurite, and cuprite.

POWERS (COPPER MOUNTAIN) PROSPECT.

The Powers or Copper Mountain claims are about 3 miles east of Patagonia, on the south side of Redrock Canyon, at an elevation of about 4,400 feet. They were located by William Powers in 1885, but since then little work has been done. It is said that 500 tons of iron float derived from the weathering down of the ledge was picked up on the surface of this ground and used as flux at the Patagonia smelter. The croppings form a reef about 150 feet in height and 70 feet wide of red ferruginous silicified leached rhyolite that strikes N. 60° W. The rhyolite is pitted with casts of pyrite and some of it is so heavily impregnated with iron oxides that it constitutes a good low-grade iron ore, and the adjoining gravels in which the development tunnel is driven are firmly cemented by hematite and limonite leached from it. The croppings just above and 200 feet southeast of the tunnel contain besides the iron a small amount of malachite and azurite stain, which probably suggested the name Copper Mountain.

CONCLUSION.

The Redrock district as a whole is not favorable for prospecting, for the prevailing rock, the late Tertiary andesite, is in general undisturbed either by movement or by later intrusion. The only ground that seems to warrant prospecting is the portion which lies between Redrock Wash and the southwestern flank of the Canelo Hills, along which there appears to have been some postandesite movement and intrusion. The more promising veins are those associated with the acidic intrusions, as at the New York and Meadow Valley mines.

HARSHAW DISTRICT.

LOCATION AND GENERAL FEATURES.

The Harshaw district adjoins the Wrightson and Redrock districts on the south. It is about 5 miles wide and extends from Sonoita Creek at Patagonia 9 miles southeastward to a point 3 miles beyond Harshaw. Harshaw Creek marks the northeast boundary;

Meadow Valley Flat the east boundary; an east-west line passing just south of the American mine the south boundary, separating it from the Patagonia district; and the main ridge of the Patagonia Mountains to the west of Alum and Flux gulches the west boundary, separating it from the Palmetto district (Pl. I, in pocket).

The principal settlement is Patagonia, which is on the railroad and is a flourishing mining center with about 200 residents. It is the chief distributing and supply point for the district as well as for a much larger surrounding region. Two daily passenger and mail trains stop here.

Harshaw, in the south-central part of the district, was also once a prosperous village and camp and has mostly stone buildings, but in 1909 only a few families were living there. The other principal camps, as shown on the map, are the Hardshell, World's Fair, Wieland, Elevation, Standard, and Thunder. A daily stage and mail service is maintained between Patagonia, Harshaw, Mowry, Washington, and Duquesne. The roads and trails in the district are good and the mines and prospects as a rule are easy of access.

The topography is rough and much of it in the western part, which lies in the Patagonia Mountains and rises to elevations of more than 6,000 feet, is rugged, of the type produced by erosion of volcanic rocks in an arid climate. Red Mountain, a castle-shaped mass in the north-central part of the district just south of Patagonia (Pl. XVI, *B*), reaches an elevation of 6,350 feet, whence the surface declines to 4,500 feet in a radius of 2½ miles. South of Red Mountain and east of the Patagonia Mountains the elevations rise to about 5,000 feet. The drainage is principally northwestward into Sonoita Creek by way of Harshaw Creek on the east and Alum Gulch on the west. Both streams flow through canyons in the middle parts of their courses.

The bedrock of the district comprises five or more formations, which, named in ascending order, are the Paleozoic limestones, quartz diorite, granite porphyry, rhyolite, and andesite (Pl. II, in pocket). They are described under "Geology" (p. 44), and their general relations are indicated in section *E–F* on Plate III (in pocket). The most important of the formations with reference to the mineral deposits are the diorite, granite porphyry, and rhyolite.

The Paleozoic limestones occupy only a small east-west belt along the middle part of the southern border of the district, but this belt is a part of the limestone area around Mowry on the south, described on page 294.

The quartz diorite and granite porphyry belong with the group of Mesozoic intrusive rocks and the rhyolite and andesite with the Tertiary volcanic rocks.

The quartz diorite occupies an irregular belt about three-fourths of a mile wide and nearly 3 miles long, extending from a point about a mile southeast of Harshaw northwestward to the World's Fair mine and Alum Canyon.

The granite porphyry occupies a belt about half a mile wide along the western border of the district, where it seems to underlie the rhyolite. This belt is but the eastern part of the much larger area in the Palmetto district, on the west.

The most extensive formation is the rhyolite, which, besides occurring in a north-south belt near the west border of the district, occupies a belt 2 miles wide extending across the north-central part and includes practically the whole of Red Mountain. It is a coarsely porphyritic, tridymite-bearing rock profusely impregnated with pyrite, chalcopyrite, and chalcocite disseminated in crystals and grains and at a number of places contains promising copper prospects. The oxidation of the iron content of these minerals colors the entire mountain a brilliant red. In Alum Canyon, on the southwest, the weathered surface of the rock and the alluvial gravels derived from it are coated with efflorescences and incrustations of alum, some of whose constituents seem to be derived from the pyritic contents of the rock by oxidation.

The next most abundant rock is the andesite, which occurs in flows and tuffs filling chiefly the valleys and low places. It overlies the rhyolite and other older rocks. Besides occupying an irregular circular area about 2½ miles in diameter in the south-central part of the district, north of Harshaw, it also occurs in a belt about a mile wide extending thence northward along the Patagonia road for about 3 miles.

In the western part of Alum Canyon occur also locally some syenitic rocks, described on page 68.

Occupying two belts, each about 1½ miles in width, across the northeast and southwest ends of the district, the Quaternary gravels shown in Plate II more or less deeply cover the bedrock formations above described.

LODE DEPOSITS.

DISCOVERY AND MODE OF OCCURRENCE.

The Patagonia Mountains are well mineralized and contain many attractive prospects, chiefly in copper ore of concentrating grade. Mineral deposits were discovered here in the early days. Among the first producing properties in the Harshaw district are the Old Trench, January or Pádrez, Hermosa, Hardshell, Alta, Flux, World's Fair, and other mines, most of which are opened to depths of 300 to 500 feet and have produced large quantities of high-grade lead-silver ore.

The deposits occur principally in veins in the diorite, granite porphyry, and rhyolite, generally in association with younger intrusive rocks. They consist chiefly of lead-silver ores carrying some gold and are in general very similar to the ores of this class occurring in the Tyndall and Wrightson districts, on the northwest. Some of the mines, however, contain principally copper minerals. The veins are mostly large and the ores are in general easily reduced.

The district contains about 40 mines and prospects, most of which are given in the subjoined list. Some of them, as the Hardshell, Hermosa, Alta, World's Fair, and Flux, are opened to depths of several hundred feet and have produced many thousand dollars' worth of rich ore. They occur mostly in the canyons or deep drainage ways, where the veins and deposits have been exposed by erosion.

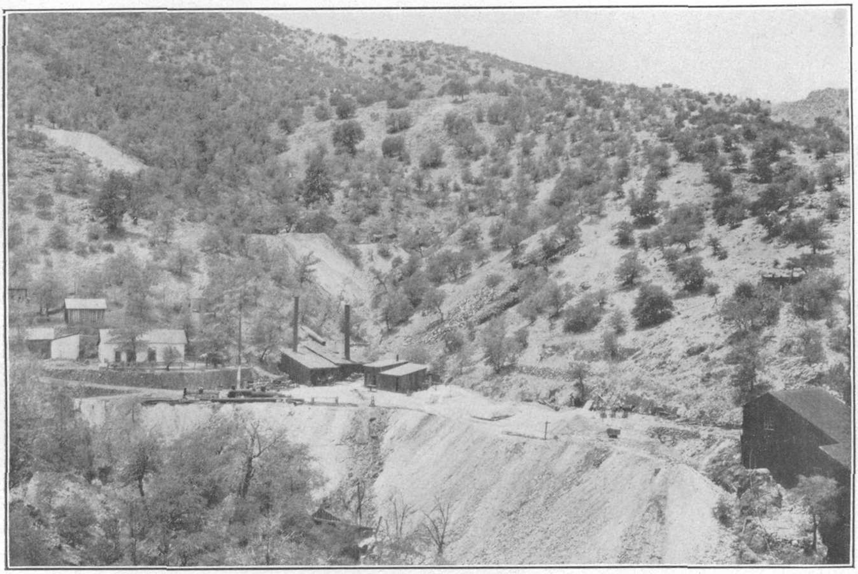
Alta.	Flux.	Red Bird.
American.	Garfield.	Red Rock.
Aztec.	Great Silver.	Santa Cruz.
Basin.	Hampson.	Sonoita.
Blue Nose (Abe Lincoln).	Hardshell.	Standard.
Blue Eagle.	Hermosa.	Sunnyside.
Brown.	Humboldt.	Thunder.
Buffalo.	Invincible.	Trench.
Christmas Gift.	January.	Volcano.
Cotton Tail.	Josephine.	Wieland.
Dewey.	Lead Queen.	World's Fair.
Elevation.	Morning Glory.	

WORLD'S FAIR MINE.

The World's Fair mine is near the center of the western part of the district, 2 miles west of Harshaw, on Alum Gulch, at an elevation of about 4,680 feet. (See Pls. I and II, in pocket.)

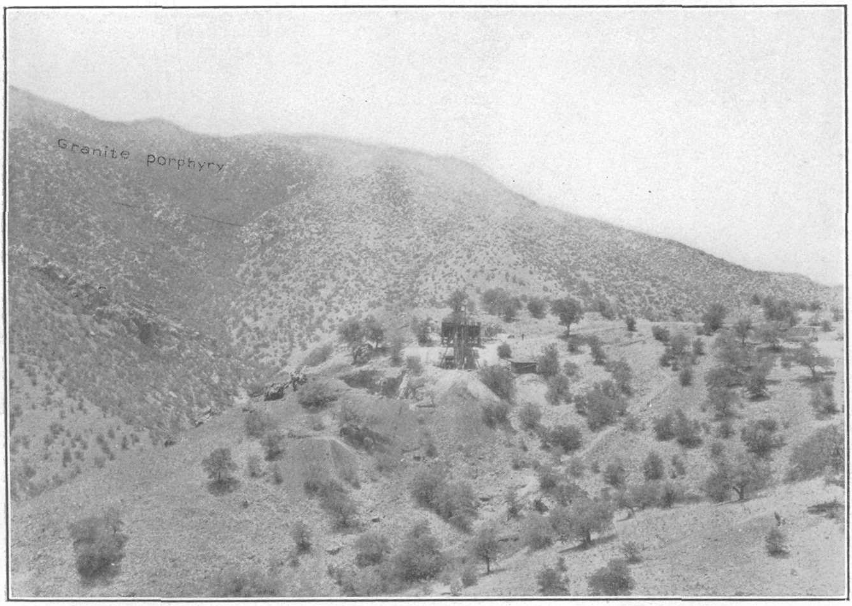
It was located in 1879 by a Mr. McNamee, who shipped a considerable quantity of ore from it and is said to have abandoned it in 1881. In 1883 William Moran relocated the property and in 1884 sold it to Frank Powers, the present owner, for $100. Mr. Powers is reported to have soon shipped a few carloads of ore of 25 tons each, which brought from $8,000 to $25,000 a car, and by 1903 it was said that $600,000 worth of ore had been blocked out in the mine ready to ship. Since its acquisition by Mr. Powers it has been worked at intervals only[1] but has always produced considerable rich ore, which was mined or milled and shipped as desired. In 1907, for instance, the production was $74,210 worth of ore, in lead, copper, gold, and silver.[2] During the year 1910 the production was $42,730.82.[3] In 1912 a shipment of a few carloads, mostly very rich

[1] U. S. Geol. Survey Mineral Resources, 1905, p. 155, 1906; idem, 1906, p. 170, 1907.
[2] Idem, 1907, pt. 1, p. 178, 1908.
[3] Mines and Mining, Aug. 1, 1911.



A. WORLD'S FAIR MINE.

Mill at lower right. Looking S. 70° W.



B. FLUX MINE.

Three R Mountain of granite porphyry in left background. Contact fault scarp of granite porphyry and rhyolite crosses left field. Looking S. 55° W.

ore, is reported to have been made to the Selby smelter. Early in August, 1914, the mine was said to be shipping two carloads of rich ore a week to Douglas.

The property comprises a group of eight claims and is reported to have produced more than $1,000,000, of which over $500,000 was in high-grade ore. Several hundred thousand dollars' worth of medium-grade ore, it is said, now lies on the dumps. It is reported that the owner has received several offers for the mine, ranging as high as $500,000 to $600,000,[1] but that the price asked has been $1,000,000, of which 10 per cent was to be paid down before anyone would be allowed to enter the mine to make an examination. In 1913 the mine was reported to have been sold or bonded to the Copper Queen Co. for $800,000. Early in 1914 the tax commission of the State of Arizona was reported to have valued the mine at $155,000 and to have collected $7,000 in taxes based on this valuation. More recently it has been reported that Charles E. Knox, president of the Montana-Tonopah Mining Co., of Tonopah, Nev., and A. Y. Smith, formerly manager of the Prince Consolidated, of Pioche, Nev., have taken over the mine, and are shipping about 50 tons of ore daily.

The mine is said to be developed to a depth of 600 feet and is the deepest mine in the district. It contains about 15,000 feet of drifts, tunnels, stopes, shafts, and winzes. The owner was absent at the time of visit and the mine was closed. The main entrance to the mine is a crosscut tunnel at an elevation of 4,680 feet, from which, it is reported, a winze has been sunk to a depth of 600 feet with drifting 1,000 feet each way from the winze on the vein at levels spaced 100 feet apart.

The principal equipments are a 10-stamp mill supplied with concentrators, etc., which made an apparently unsuccessful run of three months in 1897 and has been idle ever since. There is also a steam hoist within the tunnel and power drills.

The topography is rough, as shown in Plate XVII, *A*, and the canyon on the north below the property is impassable, so that the mine is reached by 1½ miles of wagon road of easy grade descending the canyon on the south from the county highway at a point a mile west of Harshaw.

The country rock, as shown in figure 31, is a small area of diorite which forms the northward continuation of the Harshaw belt, but which at the mine is almost surrounded, overlain, and intruded by rhyolite and is more or less pyritic and mineralized. The rhyolite, which is also considerably mineralized and altered, seems to be similar to that at Red Mountain, with which it is apparently connected.

[1] Curtis, J. N., Report of the Governor of Arizona, 1902, p. 47.

Just across the canyon east of the mine the surface is underlain by a purple altered andesitic volcanic rock composed almost wholly of oligoclase-andesine and a little biotite or altered hornblende.

The deposits, to judge from the location of the workings, are about all on or associated with the contact of the rhyolite intruded into the diorite. The workings trend north-northwest and the deposits seem to dip about 80° WSW. into the mountain, but in the mine the dip is said to be about 45°. From the main entrance, which is located about 40 feet above the floor of the canyon, the openings and croppings extend for one-eighth of a mile or more southward and through a vertical range of about 400 feet, which together with the 600 feet of depth the vein is said to have in the mine gives for the deposits a known vertical range of about 1,000 feet. The croppings are irregular, however, and in places difficult to identify and follow.

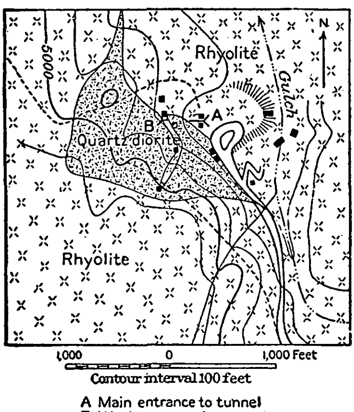


FIGURE 31.—Geologic map of the vicinity of the World's Fair mine.

The croppings range from 10 to 14 feet in width, and the average width of the vein in the mine is said to be about 6 feet, nearly all of which is good workable ore. The metalliferous minerals are said to occur mostly in the rhyolite or hanging-wall side of the contact. A considerable portion of the openings to the south of the mine are on the north-south rhyolite dike cutting the diorite. The croppings of the dike are 15 to 25 feet wide and consist of a reddish-yellow siliceous rhyolite. The valuable metals in the ore are silver, gold, lead, and copper, silver predominating. The gangue of the vein is commonly said to be quartz, but in most of the ore seen on the dump barite seems to equal the quartz in amount, and in some run of mine specimens it is the chief or only gangue mineral, quartz being inconspicuous or absent. The barite gives to much of the ore a sparry aspect and is particularly prominent as seams, blades, and plates filling fractures and cavities, denoting that much of it is of late or postvein age.

In the upper workings the ores, it is said, were mostly rich lead-silver sulphides, but below water level, in the unoxidized zone, where they maintain or exceed their surface tenor, they carry besides galena considerable copper, mostly in the form of tetrahedrite or gray copper, with some chalcocite and antimonial silver, in places rich in gold. In fact, a considerable part of the ore seems to be antimonial silver. There is also a sprinkling of finely disseminated chalcopyrite and pyrite. The ores from the deeper part of the mine are reported to average about 20 per cent in copper and 500 ounces in silver and $15 in gold to the ton. Judging from about 500 tons or more seen on the dump the ore is mostly hand-sorted and well graded, seemingly by screens, into sizes ranging from that of a walnut up to that of a 10-inch bowlder. It is then shipped direct to the smelter at Selby, Cal.

CHIEF GROUP.

The Chief group of copper prospects consists of 12 claims adjoining the World's Fair property on the southwest and near the Three R group on the northwest. It is owned by E. E. Bethel, of Patagonia. It is opened by shallow shafts to depths of 50 feet or more, aggregating about 500 feet of work. It is said that recently the group was leased to the Calumet & Arizona Copper Co. for $75,000 for a period of two years and that it is being developed at a substantial rate.

HUMBOLDT MINE.

Near the head of Alum Gulch, about a mile south of the World's Fair mine and 1½ miles west of Harshaw, are several small mines—the Humboldt, Red Bird, and January—which have been productive and whose geologic and mineralogic features are similar to those of the World's Fair mine, the deposits being associated with the rhyolite intruded into the country-rock diorite.

The Humboldt deposit, on the ridge between the two forks of the canyon, was discovered in 1885 by William Harrington and James Gillespie, who soon worked it and took out lead-silver ore. It was worked mostly in 1887 to 1889 and has produced about $10,000 worth of ore. On the dumps there are about 5 tons of ore which shows dark fine-grained galena, sphalerite, and seemingly a little tetrahedrite in a quartz gangue. On November 30, 1912, this mine, together with its group of claims, is said to have been purchased for $10,000 by the Phelps-Dodge Co., which planned to operate it and ship the ore to the Copper Queen smelter at Douglas.

The mine is developed by about 700 feet of work, which includes a 160-foot shaft inclined 80° S., located at an elevation of 3,950 feet on the point of the ridge. It is in rhyolite intrusive into diorite, 15 feet south of a contact which dips 85° S. Water stands within about 15 feet of the collar of the shaft.

The ore is lead-silver ore in the shaft and upper tunnel and lead, silver, and copper ore, all sulphide, in the lower workings. It contains considerable pyrite, with which atmospheric action heavily incrusts the surface of the ore on the dumps, the cement presumably being the resulting iron oxide.

About a quarter of a mile southwest of the shaft, on the east side of the gulch, at an elevation of 5,000 feet, is a tunnel in rhyolite, about 30 feet south of the rhyolite-diorite contact, which here strikes N. 45° E. The tunnel is on a slip in the rhyolite that is parallel to the contact and dips 83° NW. At 40 feet from the mouth is a fault striking N. 50° E. and dipping 87° SE. The rock north of this fault is dark and very much altered and seems to be diorite. It contains disseminated pyrite. Along this fault there is 2 feet of crushed material, of which the 2 to 3 inches on the hanging-wall side is very siliceous and shows galena and a little gray copper.

Below this tunnel, at an elevation of 4,910 feet, is a lower tunnel which starts in altered sheared rhyolite and runs N. 55° E. At 20 feet from the entrance a 13-foot crosscut to the south exposes a very siliceous zone 9 feet wide which dips 70° NE. This zone shows disseminated pyrite and chalcopyrite, and in the crosscut the walls are coated with copper and iron sulphates.

On the west side of the gulch 200 feet southwest of the lower tunnel and 10 feet above it is the mouth of a new tunnel, which runs N. 75° W. for about 55 feet in altered silicified rhyolite. It seems to be on a shear zone that dips 80° N. Some ore from the dump shows pyrite, chalcopyrite, and galena disseminated through the siliceous material and concentrated in joint or shear planes. At 30 feet above the mouth of the tunnel is a shaft, the dump of which shows pyrite and chalcopyrite in dark quartz.

In all the Humboldt workings the ore deposits occur principally in rhyolite, 15 to 30 feet from its contact with diorite, in a fault or shear zone that is parallel to that contact. Sulphides occur at the surface and water stands in the lower tunnels and in the old shaft at a depth of 150 feet.

RED BIRD MINE.

The Red Bird mine and the January mine, described below, are on patented claims. They are owned by the Blue Flag Mining Co., of Summit County, Colo., and have produced considerable ore but have since been idle for some time.

The Red Bird, also known as the Uncle George or Norton mine, is just east of the Harshaw and World's Fair road, at an elevation of 4,900 feet. It is opened along a dike of rhyolite that dips 78° NE. in the diorite and extends from the mine for about a quarter of a mile down the road and stream to the northwest. The dike is 15 to 20 feet wide, and the diorite for 4 feet from the contact on the northeast or hanging-wall side contains considerable manganese. Alum and sulphur are being leached from the rhyolite and the dump, which is large, indicating that the work is extensive. Owing to a cave-in underground examination could not be made. The mine is said to have produced a fair amount of ore, some of which was very rich.

JANUARY MINE.

The January mine is about one-third of a mile north of the Red Bird, on the northeast side of the canyon and the World's Fair road. It is said to have been worked in the early seventies under the name of Pádrez, but has been held since 1882 by the Blue Flag Mining Co. The total production is estimated to be about $12,000. A pocket of argentite found near the surface on the northeast corner of the claim is said to have produced 10,000 ounces of silver.

Two old shafts are located on a continuation of the Red Bird dike or vein, and where opened the vein is 6 to 7 feet in width. It strikes N. 30° W. and dips 75° NE. About 50 feet east of the vein is a vertical timbered shaft, but it contains no ladders. Water stands about 80 feet below the surface. The material on the dump at this shaft consists mostly of diorite, but the dike or vein has been cut either by this shaft or in a crosscut from it. Considerable good-looking ore was noted on the dump. It contains mostly galena, sphalerite, pyrite, and argentite in a quartz gangue stained with limonite and a little lead carbonate. It is said that ore of this class averaged 35 per cent in lead and 60 ounces to the ton in silver.

TRENCH MINE.

The Trench mine is about 1¼ miles northwest of Harshaw and a quarter of a mile southeast of the Red Bird mine on an eastern tributary of Alum Gulch just below the 5,000-foot contour. It is on or near the World's Fair road one-third of a mile off the stage road. The deposit was discovered in the fifties or earlier and was worked in 1859 by Col. Titus.[1] It was patented by J. B. Hagan prior to 1872. In the middle and late seventies it was extensively worked by Señor Pádrez.[2] In 1880 the present owner, the Hearst estate, of California, purchased the mine and sunk a 400-foot shaft, which is the most extensive piece of work on the property, and in the middle eighties Hagan & Tevis took out a great deal of rich ore. In 1889 Powers and partners took out and sold to the Crittenden smelter two carloads of ore which averaged 40 per cent lead and 60 ounces to the ton in silver and netted $4,400. At present writing it is said that W. A. Clark has a bond on the property and is operating it with a force of 20 men.

The mine is said to have produced a large amount of high-grade lead-silver ore, much of which has been treated in the old plant now on the ground. The tailings show that a large amount of work has been done, and about 2,000 tons of good-looking ore lies on the dump.

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[1] Blake, W. P., Report of the Governor of Arizona, 1899, p. 11.

[2] Hinton, R. J., Handbook of Arizona, p. 126, San Francisco and New York, 1878. Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains for 1875, p. 389, 1877.

The deposits are contained in a fissure vein which dips 60° NNE. in diorite that is intruded by rhyolite near by. The vein ranges from 1 foot to 5 feet in width, and is worked interruptedly throughout the length of the claim, the pioneer work having been done on the west part, it is said, to procure lead for the manufacture of bullets. The vein contains chiefly cerusite, pyromorphite, and silver-bearing galena in a gangue composed mainly of quartz, rhodochrosite, and specular iridescent hematite derived from pyrite. The ore is similar in some respects to the Hardshell ore. The vein and ore are banded, porous, and drusy.

JOSEPHINE MINE.

The Josephine mine is about a quarter of a mile northwest of the Trench mine, at about the same elevation, near the World's Fair mine road. The deposit was discovered in the middle seventies but was not worked until about 1885. Operations then continued until 1890. In 1899 it was relocated by the present owners, Messrs. Farrell, Powers, and Morrison, who have done considerable work on it. It has produced $750,000 worth of ore, of which $375,000 was taken out during the period from 1893 to 1897, when about three carloads a month were shipped.

The mine is developed by about 3,500 feet of work, extending to a depth of 500 feet on the dip of the vein. Most of the work was done in 1893 to 1897.

The mine is on the northwesterly continuation of the Trench vein, which is opened at intervals between the two mines and dips about 45° N. in the same diorite country rock, with intrusive rhyolite near by. The vein is said to widen in the lower part of the Josephine mine.

The ore here is about all sulphide. Most of that which has been produced is said to average 60 per cent in lead and 45 ounces to the ton in silver, and on the lower levels the ore contains also about $2.50 in gold. Some very rich ore running 1,800 ounces or more in silver to the ton, it is said, was taken out on the west toward the rhyolite butte. The mine is reported to contain in sight 80,000 tons of ore that averages 5 per cent in lead and 5 ounces to the ton in silver.

SUNNYSIDE MINE.

The Sunnyside mine is 1¼ miles southwest of the January mine and 2½ miles west of Harshaw, on the upper part of Alum Gulch, at an elevation of about 5,800 feet. The property comprises a group of eight claims (fig. 32). It was located in 1897 by R. Farrell, the owner. During the first half year of his ownership, with a force of 16 men working in the shafts, he shipped five carloads of copper carbonate ore that brought returns of $5,000 in copper and silver. Early in 1912 the property was reported to be bonded to L. D. Ricketts, of Cananea.

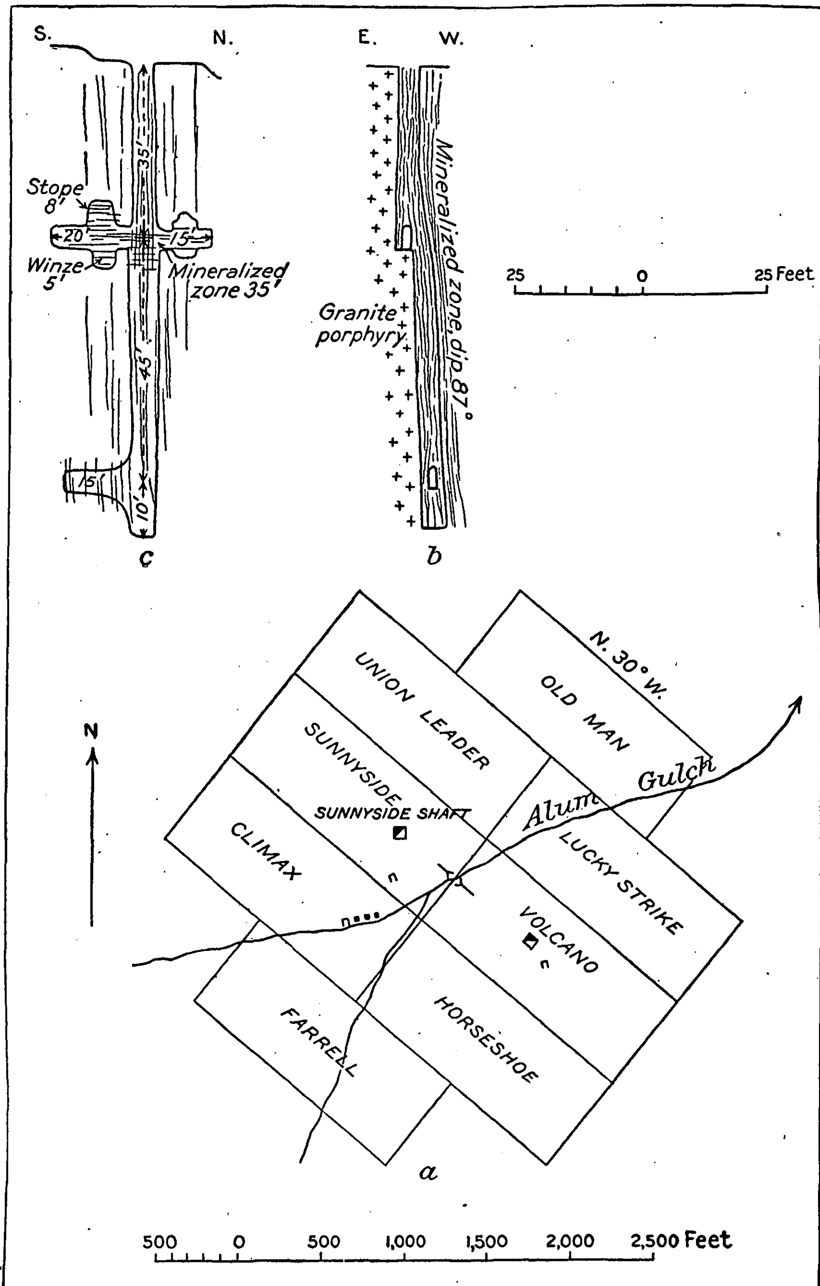


FIGURE 32.—Map and sections of Sunnyside mine. *a*, Claim map of group; *b*, cross section of shaft and ore zone; *c*, longitudinal section of shaft and ore zone.

The deposits are contained mainly in a mineralized zone about 200 feet wide in granite porphyry, which trends N. 50° W. across the claims. This zone consists of belts of sheared and silicified country rock which in places shows copper carbonate ores associated with limonite and quartz. The belts are opened principally by several shafts to depths of about 90 feet. From the Volcano shaft, sunk to a depth of 30 feet on a siliceous belt which dips 70° SW. and carries copper carbonates, were shipped two carloads of ore that averaged 9 per cent in copper and 2 ounces to the ton in silver.

In the Sunnyside shaft, which is 90 feet deep, an 8-foot stope in a drift to the south yielded 22 tons of malachite ore that averaged 20 per cent in copper and carried a little native gold and some silver. The malachite is well crystallized, individuals as much as one-eighth of an inch in length being noted on drusy surfaces, and in the more massive parts of the ore fibrous rosette forms are prevalent. In the same drift just under the stope is a 5-foot winze from which has been taken about 15 tons of oxidized ore that is said to average 14 per cent in copper and 5 ounces to the ton in silver. This ore is very fine, soft, dark greenish-gray earthy material and is apparently a mixture of iron oxides with copper carbonates.

To a depth of 40 feet the mineralized zone is composed largely of quartz carrying considerable copper carbonates, but below this depth the shaft passes through soft earthy material containing a few small masses of siliceous rock and a larger amount of iron oxide than is seen at the surface. At a depth of 80 feet in a small south drift another small pocket of the black oxidized copper ore was uncovered. The soft material, through which the shaft extends, is said to average about 2 per cent in copper carbonates. On the dump there are 500 tons of reported 3 per cent copper ore and 15 tons of 14 per cent ore.

STANDARD AND THUNDER PROSPECTS.

Two-thirds of a mile south of the Sunnyside mine and 1½ miles west of American Peak in the extreme head of Alum Gulch are two prospects, the Standard and the Thunder, whose deposits are similar to those of the Sunnyside mine. They occur in shear or sheeting zones in the granite porphyry country rock and contain principally copper minerals. The Standard group consists of 14 claims. Here some chalcocite is reported to have been found at a depth of 20 feet, associated with pyrite and chalcopyrite, in a 40-foot shaft.

On the Thunder group of eight claims the granite porphyry, which in general is silicified and altered and contains widely disseminated pyrite and chalcopyrite, includes northwest-southeast bands or shear zones and also an east-northeast system of faults and joints with flat southerly dip, along both of which the sulphide ore minerals are concentrated. Here all but the first 20 feet of an 82-foot tunnel driven westward in one of these zones is in mineralized soft rock regarded as low-grade ore and said to average about 0.6 per cent in copper and 2 ounces in silver and 40 cents in gold to the ton. The metallic minerals are pyrite and chalcopyrite, with a little tetrahedrite and molybdenite.

INVINCIBLE PROSPECT.

Beginning at the north foot of the mountains, in the mouth of Alum Canyon,[1] a series of a dozen or more prospects, some of which are on patented ground, extend southward along the course of the canyon and gulch for about 2 miles to a point within three-fourths of a mile of the World's Fair mine. These prospects are accessible by wagon road ascending the canyon and gulch from the north. The topography is rough. The country rock containing the deposits is mostly the rhyolite of Red Mountain, already described.

The Invincible prospect is 2½ miles south of Patagonia, in the north foot of the mountains, at an elevation of 4,200 feet in Alum Canyon. It belongs to the Ivanhoe Mining Co., of Minneapolis, Minn. It is opened by a tunnel 60 feet in length, running N. 25° E. into the base of Red Mountain.

The country rock is a nearly massive porphyritic rhyolite carrying a great deal of disseminated cupriferous pyrite and a little chalcopyrite. It is typical of the Red Mountain mass and is said to contain in general from 1 to 3 per cent of copper and about $1 in gold to the ton. It is cut by a series of joints dipping 25°–30° NNW., in which there is a concentration of nearly pure iron sulphides in veinlets or bands, the widest 1½ inches in width. The tunnel is headed to intersect a 20-foot quartz vein several hundred feet above and 500 feet from the mouth, the iron and copper sulphides in which are said to carry from $5 to $19 in gold to the ton. In the tunnel a good deal of alum and sulphur is being deposited on the walls and a few patches of blue copper sulphate were noted. The surface of the rhyolite is stained a deep red by iron. It is stated that the rock at this place has been tested for the manufacture of sulphuric acid and that the concentrates averaged 33 per cent of iron and 35 to 36 per cent of sulphur.

BLUE EAGLE MINE.

The Blue Eagle mine, belonging to James Hale, of Harshaw, is in Alum Gulch half a mile south of the Invincible prospect, at an elevation of 4,375 feet. The deposit was discovered about 1897 and was acquired in 1901 by the present owner, who in the next year or two worked it and shipped from it to the Douglas smelter about 60

[1] The term "canyon," as here used, refers only to the steep, high, and more or less box-sided portion of the Alum Gulch drainage way, about a mile in extent, lying near the north end of the Patagonia Mountains. The rest of this drainage way, though portions of it are canyon-like, is by priority of usage designated by the term Alum Gulch.

tons of hand-sorted ore that is said to have averaged 18½ per cent in copper and 17 ounces in silver and $1.50 in gold to the ton. Considerable ore is in sight in the mine, which is now producing.

The mine is developed by a 240-foot tunnel on the vein, 20 feet each of upraise and crosscut, and a 50-foot winze. Haulage rates from the mine to the railroad are $1.50 a ton.

The country rock is rhyolite porphyry in which the deposits are contained in a well-banded quartz vein that strikes east and stands vertical. The croppings are coated with alum, sulphur, and some blue copper sulphate. The vein is about 2½ feet in width and carries good-looking copper ore but branches somewhat in feathery form. There is said to be present also an associated 8-inch vein or shoot, rich in black copper ore. The metallic minerals are well-banded bornite, pyrite, chalcopyrite, and argentite, contained in a quartz gangue. Some oxidized ores are associated with sulphides at the surface.

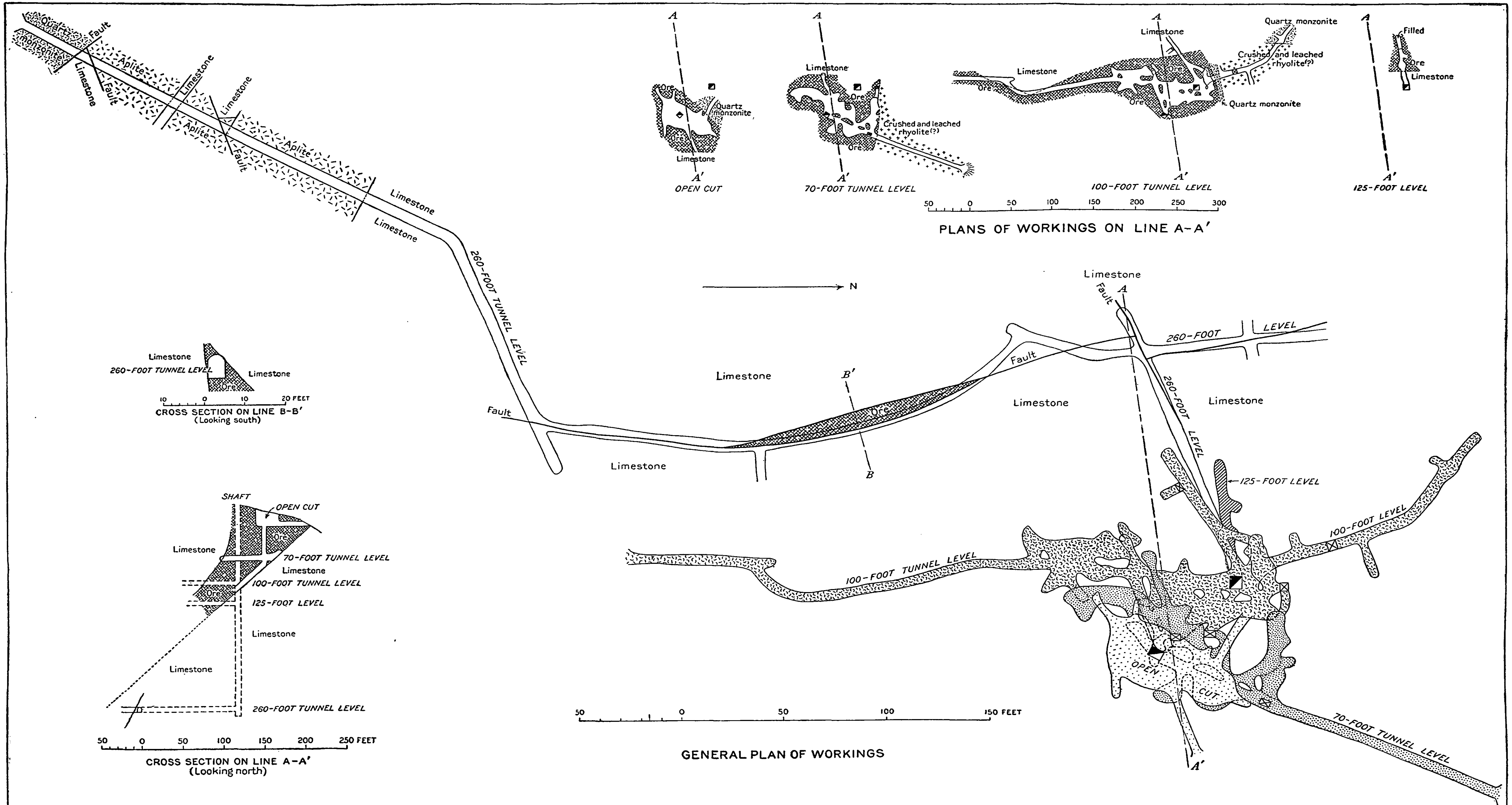
HAMPSON PROSPECT.

The Hampson prospect is about a mile southeast of the Blue Eagle prospect and three-fourths of a mile north of the World's Fair mine, at the end of the wagon road ascending Alum Gulch, on an eastern tributary that lies in the southwest base of Red Mountain, at an elevation of about 4,600 feet. It is on a fault fissure in the red porphyritic rhyolite, and an area of sharply upfaulted diorite 800 feet wide lies only 20 feet distant on the south, the formational contact being parallel with the fissure. Sheeting common to both the rhyolite and the diorite dips 45° E.

The ledge is opened by a 60-foot crosscut tunnel, 100 feet of drift, and two shallow winzes which owing to the steepness of the slope give a considerable depth. The fissure dips steeply to the south and ranges from 9 inches to 3 feet in width. It contains mostly crushed, altered, and in part soft rhyolite and rhyolite gouge with some quartz and in places a 3 to 4 inch quartz vein or stringer, all more or less impregnated with pyrite and a little chalcopyrite, black copper sulphide, and some carbonates of iron and copper, in which, however, the percentage of copper as a whole must be small.

FLUX MINE.

Location.—The Flux mine, at one time called the Goshen mine, is 4 miles south of Patagonia and 2½ miles from the railroad, about a mile within the mountains from their north edge, in the head of Flux Gulch, a parallel southwestern tributary of Alum Gulch about half a mile southwest of the Blue Eagle mine, at an elevation of about 4,800 feet (Pl. I). It is reached by a good wagon road of easy grade.



PLAN AND SECTIONS OF WORKINGS OF FLUX MINE.

History and production.—The Flux is reported to be an old Mexican mine and to have been located in the early fifties. In 1858 ore from it was smelted in the adobe furnace in Alum Gulch, near Sonoita Creek, and later, it is said, the mine furnished lead used for ammunition in the Civil War. It was relocated in 1878. It and the Hardshell mine together are reported to have shipped more than 50,000 tons of ore, most of which came from the Flux mine.

It was worked about 1882, and several thousand tons of ore was shipped to the Benson smelter. Later it was taken up by R. R. Richardson and partners, of Patagonia, under the present location title, which dates from January, 1897. During that year it produced nearly 1,000 tons of ore. Still later, through purchase, the title passed to Mr. Richardson, who is the present owner.

In 1896 the property, together with other Hardshell mines, was bonded to the Arizona Gold & Copper Co., which built the smelter at Patagonia, more fully referred to under "Hardshell mine." This company took from the Flux mine about 2,000 tons of ore, made a payment of $10,000 on the two mines, and after smelting the ore at Patagonia relinquished the property.

Besides the ore treated by the Alum Gulch, Patagonia, and Benson smelters, about 10 carloads of high-grade galena ore, averaging from $60 to $100 to the ton, were shipped to El Paso in 1904. In 1905 Benjamin Heney, of Tucson, took a bond on the mine, organized a company, and did much work on it, and by extension of time he still controlled it in 1909. He sunk the mine from 110 to 260 feet in depth, did about 800 feet of tunneling and drifting, passed from the oxide into the sulphide zone at a depth of about 250 feet, and in 1909 suspended operations. In October, 1914, the property was said to be bonded to California people, who will install a mill. It comprises a group of 11 claims.

Development and equipment.—The mine is developed by more than 5,000 feet of work, about all concentrated on the Flux claim, at the mine, where several veins or lodes seem to come together in the south shoulder of Flux Ridge in a large deposit that was first mined in an open cut just southeast of the shaft. The work consists mainly of tunnels, shafts, drifts, crosscuts, and stopes and is distributed on four levels, 70, 100, 125, and 260 feet below the surface, as shown in the cross section in Plate XVIII. This plate also shows the ground plan of the levels and some of the main workings, together with the ore deposits and the geology on the separate levels somewhat more in detail.

All the levels are entered by adit tunnels and the topography is such that another can still be driven at 400 feet below the collar of the shaft. The work includes a 260-foot main shaft. an 800-foot west tunnel, a 500-foot south tunnel, and 200 feet of crosscut on the second and fourth levels.

The lower tunnel connects with the shaft by a 120-foot crosscut on the 260-foot level. Most of the stoping, as shown in Plate XVIII, is on the 70-foot and 125-foot levels, from which most of the underground ore has been produced. There is also much open-cut work, for instance, the cut or pit east of the shaft, 75 feet long, 22 feet wide, and 15 feet deep. Most of the upper work is old and was done in the most irregular manner.

Topography and geology.—The topography, as shown in Plate XVII, *B*, is hilly but not rugged. As the ores are exposed at the surface in the upper end of the steep, narrow north-south ridge and a canyon or gulch several hundred feet deep lies on either side and a saddle almost as deep at the adjoining end, nature has all but mined the deposits herself.

The oldest rock formation at the mine is a small area or nucleus of principally Paleozoic limestone with some associated conglomerate and shale. These sedimentary rocks are intruded by quartz monzonite (?) and granitic aplite and together with them are surrounded, overlain, and intruded by the Tertiary rhyolite or so-called porphyry, while but a few hundred yards distant, in or near the deep gulch on the west, occurs the great fault contact between the rhyolite of the Flux mine and the granite porphyry of Three R Mountain, which probably also intrudes the Paleozoic beds in the vicinity of the mine. The course of this fault, which is about N. 30° W., is approximately followed by the 2½-mile canyon near by on the west and is marked by a boldly cropping silicified reef extending for several miles across the country from a point about three-fourths of a mile southwest of the World's Fair mine to the north base of the mountains.

The general structure common to the formations of the region is a sheeting which dips 40° NNW. and is well shown in the north end of Flux Ridge where the road ascends the hill. Prior to the advent of the sheeting, however, the older rocks were variously disturbed, as is shown by their variation in character and attitude.

The limestone is exposed mainly on the southeast slope of the hill at the mine, seemingly dipping off southeastward into the gulch, and it is present on all levels in the mine, being especially prominent in the lower ones. In places it is highly crystalline, crushed, brecciated, and altered. The west or lower 800-foot tunnel, 50 feet above the gulch, starts in quartz monzonite but soon passes into crystalline limestone, in which it extends throughout the rest of its course to the main shaft. The south tunnel starts and extends for 250 feet in highly crystalline limestone, somewhat crushed and brecciated, to the shaft, where the limestone gives way to rhyolite fault breccia.

The shale, which is dark greenish and is not known to occur in the mine, is well exposed in the road cut on the top of the ridge just northwest of the camp. It dips to the southwest.

The quartz monzonite occurs at the portal and in the forepart of the west tunnel. It is a dark altered, highly sericitized and crushed granitoid rock. It is medium grained and is composed mainly of quartz and orthoclase, including some microcline, with hornblende and a little acidic plagioclase. That it is intrusive into the sedimentary rocks is inferred from its contact with the crystalline limestone in the lower tunnel.

Later the rock mass at the mine was seemingly intruded transversely by an east-west dike of aplite locally called quartzite and greatly resembling that rock. The aplite occurs in the large open cut on the west, where the ore deposits lie in association with it, as does also much milky-white quartz. It is apparently present also in the forepart of the lower tunnel. It is purple or reddish gray, fine to medium grained, with chiefly greasy-lustered quartz, and is more or less silicified. On the weathered surface it is stained reddish and yellowish by iron and altered. The microscope shows that it is composed mainly of quartz and orthoclase with a very little oligoclase and a little hornblende or biotite and that the feldspars are mostly sericitized and considerably kaolinized.

The rhyolite as exposed in its less altered form in the east slope of the hill west of the trail and about 100 feet above it is a normal gray pyritic rhyolite and on the weathered surface is stained reddish brown by iron, somewhat like the rhyolite of Red Mountain. At the mine, however, it is considerably brecciated and somewhat tuffaceous and by replacement seems to form the main repository for the ore.

Ore deposits.—Though several veins or ledges seem to center at the mine, particularly from easterly directions, the deposits occur principally in or associated with a main north-south shear zone or lode, the Flux lode, which approximately coincides with the axis of the ridge. The lode is said to have a known extent of 1½ miles. On the south it extends beyond claim No. 7 to the Powers and Keep properties, a mile distant, and on the north for half a mile to a point beyond the California claim, which is patented ground owned by Allison Bros. The portion of the lode south of the mine is said to be associated with limestone which accompanies it in the form of a reef, but to the north it lies mainly in rhyolite, in which openings on the California ground, for instance, show silver-lead ore similar to that of the Flux mine.

At the Flux mine the lode dips 45° W. and ranges from 30 feet or more in width at the surface to about 8 feet in the bottom of the mine, as indicated in Plate XVIII. This comparatively great width at the surface, however, should probably be regarded as a local enlargement of the mineralized zone by contributions received from the feeders coming in from the east and seemingly from the transverse aplite dike. The southeasterly foot wall of the less altered rhyolite probably retarded the circulation of the ore-depositing solutions.

The lode seems to be composed mainly of crushed altered, silicified ore-bearing rhyolite that may perhaps represent a dike. The entire mass in the upper workings from the surface down to the 125-foot level is said to have been ore, and much good ore, probably several thousand tons, seems to be still available.

The ore contains lead and silver with considerable associated iron and in the lower part of the mine a very little copper and zinc. The ore which has been produced was about all oxidized and averaged $12 or more to the ton.

The ore, especially the oxidized ore, is stained reddish brown and yellowish by hematite and limonite and some lead carbonate. It is mostly siliceous, rough, porous, or cellular and honeycombed, the feldspar having been dissolved out of the replaced rhyolite which forms the gangue. Some of it is chiefly a friable mass of crystalline gray and whitish cerusite or other lead carbonates and iron, with a very little quartz, which is mostly pyramidal, as shown in the north tunnel, and with it are associated the secondary silver minerals, mainly argentite.

In the bottom of the mine, however, on the 260-foot level, a body of sulphide ore has been opened. Here the lode or vein narrows to 8 feet in maximum width, the ore shoots are generally short, and the ore minerals, as shown on the dump of the tunnel, are principally galena, pyrite, a little chalcopyrite, and considerable sphalerite. According to later reports an important body of zinc ore has been opened at greater depth, where also the copper minerals increase in amount.[1]

The deposit in the open cut, 75 feet long, 22 feet wide, and 15 feet deep, located east of the shaft, is all in mainly altered, mineralized, or iron-stained rhyolite or ore whose contact with the unaltered rhyolite or rhyolite breccia on the north dips 75° SE. All the material removed from the cut was ore, which was treated in the Patagonia smelter and shipped elsewhere. The southeast side of the workings is still all in ore, which to judge from other openings and croppings near by probably extends 50 feet farther southeast.

The north tunnel runs S. 20° W. in rhyolite breccia, and as it nears the ground beneath the open cut enters and continues in a 6 to 8 foot ore shoot dipping 40° W., or toward the shaft. It has been stoped by an upraise to the east and mined by an incline to the west. The mine, it is said, now has about 50,000 tons of $10 ore in sight.

[1] Eng. and Min. Jour., Jan. 15, 1910.

The ore contains about equal values in lead and silver, being about two-thirds lead and one-third silver, and averages $1 to the ton in gold.

From the roof in the inner part of the south or 260-foot tunnel and adjacent parts of the crosscuts hang great masses of closely spaced acicular or filiform silky white cerusite about a foot in length.

A partial record of the ore shipments made from February 23 to August 27, 1897, shows 942.8 tons of ore, which averaged about 17 per cent in lead and 20.5 ounces to the ton in silver. Other shipments of about 450 tons made from August 16, 1900, to January 23, 1905, showed lead about 30 per cent, iron 8 per cent, manganese 1½ per cent, sulphur 4 per cent, and silver 30 ounces to the ton. At present, however, the average run of mine ore contains about 7 ounces to the ton in silver and 15 per cent in lead. The ore contains also much iron, which makes it a very good flux, and for this reason much of it was formerly packed to the Mowry smelter, 6 miles distant, and used as flux in smelting the more refractory ore from other mines. Some of the lead ore, it is said, smelts easily on a common domestic stove.

According to the estimates of a mining engineer who examined the mine for an outside company there is in the upper levels about 5,000 tons of ore averaging about 19 per cent in lead and 4 ounces to the ton in silver, with an average value of $19.20 to the ton, and in the 100-foot level 8,000 tons averaging about 30.5 per cent in lead and 10 ounces to the ton in silver, with a value of about $32.60 to the ton. In the 125-foot level there is a 12-foot vein averaging 14 per cent in lead and 5.4 ounces to the ton in silver, with a value of $15.45 to the ton. The siliceous ore in the lower workings is reported to average about 11 per cent lead, 30 per cent silica, 30 per cent iron, 2.5 per cent manganese, 14 per cent zinc, 15 per cent sulphur, and 6 ounces to the ton in silver, from which it would seem that the mine should prove to be a profitable producer of lead and silver ore of concentrating grade.

The deposits of the Flux mine owe their origin in part and probably in large part to solutions that accompanied and followed the intrusion of the rhyolite, but those occurring in the limestone may in part have been derived from solutions that accompanied the Mesozoic intrusives, of which the monzonite, aplite, and granite porphyry occur at or near the mine.

AZTEC GROUP.

The Aztec prospect is 2 miles south of Patagonia in the northwest slope of Red Mountain, in the upper part of Aztec Gulch, a northeast tributary of Alum Canyon, at an elevation of about 4,850 feet. The property, comprising a group of 24 claims, is owned by R. R. Richardson, of Patagonia, and covers a large area of mineralized or partly mineralized rhyolite which is medium to coarse grained, partly porphyritic, and in places crudely and dimly banded and bedded.

The principal exposures are in the southern part of the group, on claims Nos. 8 and 11. Here the rhyolite is more or less heavily impregnated with pyrite and chalcopyrite and is coated with copper glance, bornite, and malachite. The latter minerals are particularly concentrated as secondary replacement deposits in a 12-foot lode or ore bed which dips 75° SE. and is said to have an extent of 2,000 feet, mostly to the northeast of the main opening. The lode is opened by an open cut and an inclined shaft and tunnel, each about 30 feet in extent.

In one or more places the openings show the deposit to be at least 50 feet in width and to have a horizontal extent of more than 100 feet. Some of the ore is banded or consists of shoots of relatively pure secondary chalcocite and chalcopyrite 1 inch in maximum width and containing inclusions of orthoclase and quartz of the replaced rhyolite. A microscopic section of the medium-grade ore or partly mineralized rhyolite shows the rock to consist mainly of orthoclase, tridymite, quartz, muscovite, and a little glass. Embedded in the rock in the form of grains and irregular small masses is a mixture of chalcocite and chalcopyrite, some of which, owing to the complete manner in which it is inclosed in the rock matrix, appears to be primary. Nearly everywhere the ore minerals are surrounded by a fringe of muscovite or embedded in a mass of it, and the feldspar and quartz show a tendency to a radial arrangement around the ore.

ELEVATION GROUP.

The Elevation group is 2½ miles southeast of Patagonia, in the northeast slope of Red Mountain, at an elevation of about 5,000 feet. It was located in 1890 by Mr. Weatherwax and relocated in 1892 or 1893 by Jacob Johnson, Pete Hansen, and F. R. McAlstin, the present owners, who have done most of the development work on the group. It is opened by a 600-foot crosscut tunnel at an elevation of about 4,775 feet and by drifts and crosscuts at 4,975 feet. The tunnel is tracked.

The country rock is the rhyolite of Red Mountain, locally capped and seemingly intruded by andesite. The deposits contain chiefly copper and lead minerals. At the lower workings they are associated with an east-west vertical fault or shear zone which lies 450 feet in from the mouth of the tunnel. The zone contains dense chertlike quartz or very siliceous rhyolite and a 5-foot band of breccia and gouge which carries pyrite, chalcopyrite, and galena. Between this fault and the relatively unaltered andesite near the mouth of the tunnel is 50 feet of gray-white soft altered andesite, in which occur disseminated sulphides. Beyond the fault, toward the face, the formation is very much broken up and altered rhyolite porphyry comes in. This rock contains widely disseminated pyrite and chalcopyrite, which are concentrated along some of the fissures and are locally coated with chalcocite.

The upper work is located about 600 feet northeast of the lower tunnel and 200 feet higher. It consists mainly of an old 50-foot shaft, 100 feet of drift, and 220 feet of crosscuts and opens a silicified brecciated fault zone 25 feet or more wide in which are shown disseminated pyrite and chalcopyrite, and which is said to average 2 per cent in copper for the entire width. On the south wall there is about 13 inches of quartz containing pyrite, chalcopyrite, and galena, which is said to average 16 per cent in copper, 10 per cent in lead, and 30 ounces to the ton in silver. The zone lies in the altered rhyolite porphyry and is supposed to cross the projection of the lower tunnel about 25 feet beyond the breast of the drift.

In September, 1914, a good body of lead-silver ore was said to have been opened at the 700-foot station in the tunnel.

CHRISTMAS GIFT MINE.

The Christmas Gift mine is half a mile east of the Elevation group and a quarter of a mile west of Harshaw Creek and the United States Geological Survey bench mark 4223, at an elevation of 4,500 feet. It was worked in 1887 by Frank La Monte and is now controlled by the Bland Mining Co., of Kansas City, Mo.

At least two carloads of ore are known to have been shipped from this mine and are reported to have averaged 90 ounces in silver to the ton. The property is opened by three shafts, the west one of which is timbered and is said to be 100 feet deep. The country rock is dark-red to black andesite. It is cut by a fissure that strikes N. 65° W. and dips 87° SW. The ore from the dump is very siliceous and is cream to lemon-yellow in color, apparently from lead carbonate and iron oxide.

HARDSHELL MINE.

Location, history, and production.—The Hardshell mine, one of the most important mines in the district, is about a mile south-southwest of Harshaw, in Hardshell Gulch, at an elevation of about 5,150 feet. The deposit was discovered in 1879 by David Harshaw and José Andrade by observing large bowlders of ore in Hardshell Gulch. In 1880, when but little more than the necessary development work had been done on it, the mine was purchased by the present owner, R. R. Richardson, of Patagonia. The property then consisted of four claims. It now contains 23 claims, aggregating about

400 acres. In 1881–82 Mr. Richardson did 200 feet of work on the Hardshell No. 2 claim, and in the 10 years following he did considerable work in various places on No. 1 claim to find the ledge which was the source of the rich bowlders but was unsuccessful and finally, in 1890, abandoned the property. Later he located two claims, the Hardshell Nos. 1 and 2, the rest of the adjoining country having been at this time located and relocated by various parties. By relocation and purchase he acquired the remainder of the group. Finally, about 1895, he discovered ore on the Hardshell No. 1 by sinking a 40-foot shaft near the present inclined shaft, and continued sinking in the ore body to a depth of 230 feet.

In 1896 Mr. Richardson bonded the property to Mr. Fitzgerald, of the Empire Mining & Milling Co., who sunk the incline to the 400-foot level and took out 4,000 tons of ore, of which about 3,000 tons was shipped to the El Paso smelter and most of the remainder was treated in the Patagonia plant, some shipments being also made to Colorado. This company, which was later known as the Columbia Co., built the smelter at Patagonia mainly for treating the ores from the Hardshell and Flux mines, but the smelter also did custom work. It was a 90-ton plant installed at a cost of $125,000. The plant was operated for about three months, handling about 50 tons of ore a day. The company took out most of its Hardshell ore in 1896 and 1897, after which the property reverted to Mr. Richardson, the owner. He then installed a 50-ton concentrating plant or mill, which, however, handled but a little over 30 tons a day. It was operated from late in 1899 to 1901, about one and one-half years, producing in all about 15,000 tons of ore, including some rich galena ore shipped to the El Paso smelter.

Late in 1905 the Hardshell and Flux mines were bonded to Mr. Heney, of Tucson. In 1906 and 1907 he sunk 100 feet deeper, made the 200-foot crosscut, and sunk the rear 100-foot winze. The winze was all in ore, which he took out. Since 1907 Mr. Heney has held the property by extension of time. Recently this mine, it is said, is being worked on a small scale.

Development and equipment.—The mine is developed by more than 3,000 feet of work, which is concentrated on the Hardshell No. 1 and adjoining Hardshell No. 3 and Camden claims. The workings consist of a 500-foot shaft, inclined 30° (fig. 33), sunk on the vein, 2,000 feet of drift, and several hundred feet of winzes and raises, besides a large amount of irregular stoping, as indicated on the mine map (fig. 34). About the latest work of importance is 250 feet of drifting from the bottom of the incline and a 100-foot winze, inclined 30°, sunk from the 325-foot level. There is also an additional 1,000 feet of work, consisting mainly of shaft and drifts, on the Hardshell No. 3 claim, about half a mile from the mine.

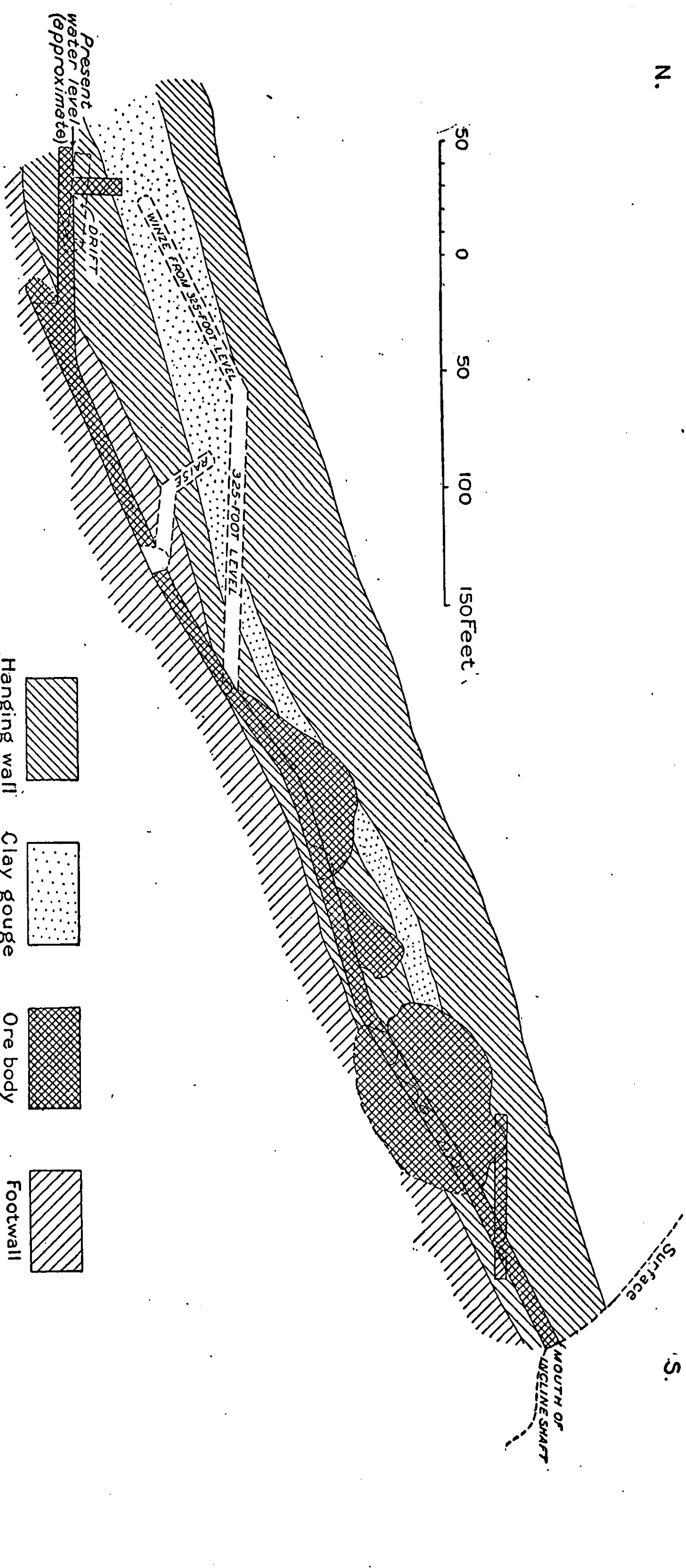


FIGURE 33.—Cross section of Hardshell mine on line of main shaft.

The equipment consists principally of a 40-horsepower steam hoist and a 50-ton concentrating mill. An excellent permanent camp with comfortable adobe buildings is conveniently located on the stage road about half a mile from the mine.

Topography and geology.—The topography is mountainous but not rugged. The mine is opened in the steep north slope of Hardshell Gulch about 60 feet above the gulch and is reached by a wagon road of easy grade.

The prevailing rock at the mine is rhyolite, locally known as porphyry, which, as shown on Plate II (in pocket), connects with the rhyolite area of Red Mountain. It occurs in heavy beds or flows about 3 feet in thickness and contains intercalated beds of quartzite, which it seems to have penetrated as intrusive sheets. The two formations are apparently conformable and dip 30° N. The quartzite also occurs in massive or heavy beds, as seen at the second raise and elsewhere in the deep parts of the mine, and on the east top of Hermosa Hill. It is a fine-grained or dense pale olive-green rock and in places resembles hornstone. It seemingly belongs to the Paleozoic limestone and quartzite series, which, as shown on the map, forms the country rock in American Mountain and the nearer foothills a short distance south of the mine. A little limestone and conglomerate are also reported to have been found in some parts of the mine. Diorite occurs in the gulch below the mine and in the surrounding hills, especially to the north.

The rhyolite is a medium-grained reddish-gray rock having a microfelsitic to glassy groundmass with flow structure in which are a few small phenocrysts and smaller intermediate forms, principally of orthoclase and quartz, with the orthoclase about all altered to sericite or kaolin. Water stands in the shaft at about the 400-foot level, and the mine makes about 200 gallons of water a minute.

Ore deposits.—The deposits occur chiefly in a shear-zone lode of rhyolite, and this rock, altered, partly replaced, and silicified, forms the principal part of the gangue. In a few places the more ferruginous phase seems to replace the quartzite, but as a rule the deposits do not appear to be particularly associated with the quartzite or any of the other sedimentary rocks.

The lode is from 10 to 60 feet wide and averages about 30 feet. It dips about 30° N., conformably with the quartzite and the interbedded rhyolite. On the hanging-wall side is a sheet of light-brown or whitish, more or less consolidated kaolin or clay gouge, which ranges in width from a few feet near the surface to 30 feet in the deep part of the mine, as shown in figure 33, and which seemingly represents a plane of extensive movement. On the footwall, which is hard, impervious rhyolite, there is in many places an intervening veinlike deposit from 1 to 2 feet thick of ferruginous manganese-silver ore that

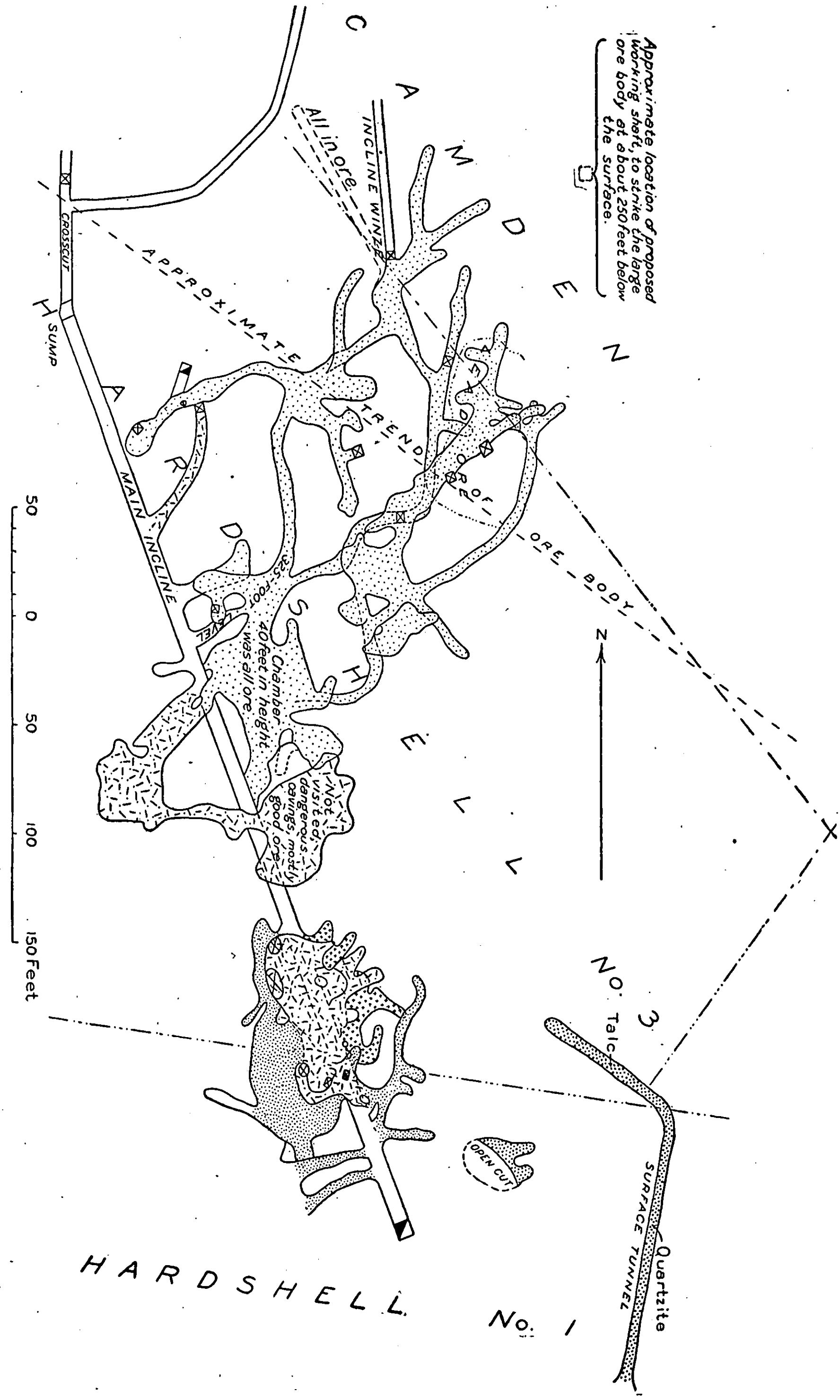


FIGURE 34.—Plan of underground workings, Hardshell mine.

averages, it is said, about 40 per cent in manganese and 15 ounces to the ton in silver and is reported to be a valuable factor as a flux.

In the lode the deposits, as shown in the cross section of the mine (fig. 33), are concentrated in irregular bodies or ore shoots which pitch to the east. The general distribution of the deposits, so far as now exploited in a belt about 300 feet wide along the strike and nearly 600 feet deep on the dip of the vein, is indicated on the level map (fig. 34).

The drift on the lower level, which is mostly in the footwall, has not yet found ore, but the 60-foot winze, whose lower part is but 40 feet east of the drift, is all in ore, which is leached above the water line, 12 feet above the bottom of the winze. An ore body is said to have been encountered in the last drifting in the bottom of the main shaft but could not be satisfactorily examined on account of the rapid influx of water.

About 2,100 tons of ore produced between February 24 and October 11, 1897, averaged, it is said, 15.1 per cent in lead and 7 ounces to the ton in silver. According to the smelter records of the shipments of about 3,000 tons to the El Paso smelter, from March 24, 1898, to January 23, 1905, the shipments in 1900, amounting to about 900 tons, ranged in value from $15 to $30 to the ton and averaged about $24 to the ton, with lead figured at $4 a hundredweight and silver at 62 cents an ounce. Some of these shipments, however, were crude concentrates from the small mill which was operated on the ground. The mill assays of this plant show the ore there treated to have averaged about 9 per cent in lead and 12 ounces to the ton in silver. Though the mill failed to save much of the metal content of the ore, a fair profit was earned. The smelter sheets giving the analyses of the 3,000 tons of ore shipped to El Paso show that the ore contains also about 30 per cent silica, 8 per cent iron, 5 per cent manganese, and 0.4 per cent sulphur.

Considerable ore of concentrating grade, estimated by some at about 100,000 tons, is in sight in the mine. The estimate of one mining engineer is 20,000 tons between the surface and the 200-foot level, and 10,000 tons from the 200-foot to the 325-foot level, besides which there are about 4,000 tons of shipping grade and 5,000 tons in the tailings dump at the mill. The ore in the dump is said to contain about 6 per cent in lead and 6 ounces to the ton in silver.

Besides the Hardshell vein there are several other veins on the property. Among them are what is regarded as the southeasterly extension of the vein worked in the Trench mine, the well-known pioneer producer. An old shaft and surface stope on another vein, on claim No. 2, yielded several carloads of silver ore of shipping grade. Here the vein is chiefly crushed, altered, and mineralized rhyolite. It is 3½ feet in average width and dips 70° N. in fine-grained quartzite. The ore mineral, like that of the Hermosa mine near by, is principally cerargyrite. On the Camden claim an open cut shows the rhyolite dipping 40° NNW., and it contains a 16-foot body of low-grade silver ore in the red altered oxidized portion. This ore body or bed is also encountered in a cut tunnel driven some 40 or 50 feet farther down the slope to the north.

ALTA MINE.

The Alta mine is one-third of a mile north-northwest of the Hardshell mine, about midway between the Hardshell camp and mine, in the mouth of a southwestern tributary of Hardshell Gulch, at an elevation of about 5,050 feet. It is on open ground and easy of access by a wagon road ascending the gulch by way of Hardshell camp.

The Alta is an old mine. It was worked in 1877 and 1878, the ore being treated in a lixiviation plant at Harshaw. In 1879 a new company opened the mine more extensively, and in 1880 and 1881 this company shipped considerable ore to a small mill called the Boston, on San Pedro River, near Charleston, Ariz., about 3½ miles from Fairbanks and 9 miles from Tombstone. About all the Tombstone ore, it is said, was milled at the Boston mill in those days.

Later other operators shipped a quantity of what is locally known as "lixiviation plumbago" ore at a profit of several thousand dollars. In 1897 the mine was acquired by the present owner, the Melba Mining Co., of New York. It was worked with good results for a year or two but has since lain idle and is now dismantled. It is regarded as a good property, however, and is patented. The mine is opened to a depth of 300 feet or more by shafts and drifts. The size of the dump shows that a large amount of work has been done, probably about 4,000 feet, most of which seems to lie within an area about 150 feet square.

The country rock is the dark-reddish medium-grained quartz diorite or quartz monzonite, and at the mine it is cut by a 20-foot dike of light bluish-gray flow-banded rhyolite breccia, which, as seen in the gulch on the east and in the road, is heavy bedded, dips 40° NNE., and weathers yellowish brown with limonite stain.

Extending over the top of the tank hill to the west of and 100 feet above the mine, the diorite along the footwall side of the dike forms a broad band of silicified croppings which stand up in low relief, suggesting that the faulting that produced the fissure now occupied by the dike was probably normal. Slickensides show also postvein movement.

The deposits are obviously associated in origin with the rhyolite dike and seem to occur in its hanging-wall side or in the adjoining portion of the wall-rock diorite, which is silicified and mineralized for 200 feet back from the dike and in which an inclined shaft reported to be several hundred feet in depth descends to the north. Horizontally the lode seems to extend for at least a quarter of a mile westward, to a point on the county road just south of Hardshell camp.

The ore is principally silver-bearing galena contained in a gangue of quartz and reddish fluorite, mostly replacing rhyolite. To judge from the composition of the material on the dump it contains also considerable pyrite, specularite, sphalerite, a little chalcopyrite, malachite, and embolite (silver chlorobromide).

At a depth of 250 feet there was encountered a body of high-grade ore 2 to 3 feet wide, said to average about 37 per cent in lead and 2 ounces in gold and 15 ounces in silver to the ton and to resemble the ore of the Lead Queen mine. This ore shoot, or a similar one 2 feet in width, is said by the two foremen who were last in charge to continue in the deeper part of the mine where a drift had been run on it for 45 feet with no indications of decrease in volume or grade when operations ceased. It is also reported that in the deeper part of the mine occurs a rich 4-inch ore shoot of pyrargyrite, or ruby silver.

HERMOSA MINE.

The Hermosa mine is about three-fourths of a mile south of Harshaw, a thriving camp and town of which it was the making. It is about one-third of a mile southeast of the Hardshell mine, in the easterly slope of the same ridge, at an elevation of 5,000 to 5,500 feet. It is easy of access by wagon road ascending the gulch from Harshaw.

The mine was first located in 1877.[1] In 1878 or 1879 it was sold to the Hermosa Mining Co. of New York. This company, which later became the Prietus Mines Co., one of the strongest companies of Sonora, built a 20-stamp mill at Harshaw, operated the mine from October, 1880, to November, 1881, with 150 men, and ran the mill for 18 months, producing during that period about $1,000,000 in silver chloride ore, all of which was amalgamated directly on the ground and the bullion shipped. The company held the property for several years thereafter, but did no work. It sold the mill for $18,000 to the Quijotoa Mining Co., of Quijotoa, 80 miles west of Tucson, and in 1887 sold the mine for $600 to James Finley, of Tucson. Mr. Finley, beginning in 1890, worked the mine for about two years on a moderate scale, treating the ore at first in a 3½-foot Huntington mill at Harshaw and later in a 5-foot mill which he installed. He worked mostly near the surface, above the company's

[1] Most of the information on history and production is given by Mr. N. A. McDonald, who has been in charge of the property for the last 20 years.

stopes, and took out $150,000 in silver chloride ore. In 1891 he bonded the mine for $50,000 to Senator McGoverney, of Canon City, Colo., who worked it for five months with the Finley mill and took out $15,000, mostly from the stope on the second level west of the original shaft.

In 1892 Mr. Finley resumed operations and in three months took out $10,000 from the continuation of the McGoverney work. After this, up to 1903, $25,000 was taken out of the mine by lessees, among whom was the Hermosa Mining Co., of Guthrie, Okla., which in 1902 remodeled the mill, put in a new 5-foot Huntington mill, and produced $7,000 in a 22-day run. This company did considerable work in the mine, but it was about all dead work, consisting principally in driving the 900-foot tunnel below the former company's old stopes, and depleted their treasury before ore was reached.

With the death of Mr. Finley and the decline in the market value of silver in 1903, work ceased. In 1906 the present owner, James Cochran, of Bradford, Pa., acquired the property by purchase from the Finley estate, but it has not been worked since. The property is patented. The estimated total production of the mine is about $1,500,000 in silver.

The mine is developed to a depth of about 500 feet below the surface at the top of the ridge by 7,000 feet or more of work, principally drifts, stopes, and tunnels distributed mainly on five levels. The first, second, third, and tunnel levels are spaced 50 feet apart vertically, and the fourth or lowest level is 170 feet below the tunnel level. The four upper levels are connected by three upraises and the four lower levels by one upraise. The tunnel level contains a 600-foot crosscut and extends through the ridge, having both a south and a north entrance. It is all in rhyolite breccia, and from its west drift is sunk a 300-foot winze.

The country rock is an ash-gray rhyolite which is mainly breccia and is locally called by miners from Colorado "Cripple Creek breccia." It is crushed, recemented, and locally closely banded by flow structure. It is also secondarily banded, largely with quartz, and is more or less altered, stained dark reddish or yellowish-brown by iron, and mineralized. It is practically all oxidized, no pyrite or sulphide being found at any point. The mine is dry.

The deposits occur mainly in a more or less tabular sheet or main lode contained in a shear or fault breccia zone in the rhyolite. The lode ranges from 1 foot to 20 feet or more in width and dips 33° N. It is in general highly oxidized, though to a somewhat less degree in the deeper part of the mine than near the surface.

Paralleling the main lode at a distance of 50 feet on the north at the surface is another or subordinate lode known as the North vein.

It has a steeper dip, and for that reason is on the tunnel level but 30 feet distant from the main lode, which it is supposed to intersect in depth.

The ore mineral is cerargyrite, or horn silver, and except a little molybdenite stain and iron and manganese oxides the ore contains no other metal. The mine is the only exclusively silver mine in this part of Arizona.

The ore has been formed by a process of metasomatic replacement in the altered, mineralized, and in part silicified rhyolite gangue, the depositing solutions having dissolved out the less resistant rock minerals. Much of the ore is highly altered and stained yellowish, black, and reddish by limonite, psilomelane, and hematite. Some of it has been made porous by the dissolving out of the pyrite. Comminuted fine-grained quartzite contained in it denotes that the sedimentary rocks probably occur near by. The source of the ore seems to be hydrothermal solutions that attended and followed the faulting and shearing which took place subsequent to the eruption and intrusion of the rhyolite.

The ore in general is of low grade, averaging for the most part about 5 ounces in silver to the ton—for instance, in the main tunnel, where the lode is 6 feet wide and is about all ore—but there are also some very rich pockets scattered throughout the lode. It is said that the ore can be mined and milled for $3 a ton. During the periods of operation 87 to 90 per cent of the metal content was extracted, and the silver bullion was 0.998 fine. The present mill can handle 50 tons a day.

The mine seemingly still contains much ore which extends in depth beyond the present lower workings. It is said that when the Hermosa Mining Co. of New York ceased work the ore in the bottom of the mine was becoming basic with iron, but this seems unlikely, for the increase in iron with depth, if any, is small, and the iron is all in the oxide form. At no point was any sulphide observed. That there is a decrease in the value of the ore, however, in the bottom of the mine seems probable, and a further decrease is to be expected at water level or at the sulphide zone, which, to judge from conditions in the neighboring Hardshell and other mines, should soon be reached. This fact should be borne in mind in considering the view held by some who have examined the property, that there is still the making of a great mine here and that it should be opened to a depth of at least 1,000 feet. It is also probable, from the geology of the surrounding country, that the underlying quartzite will be encountered at a depth less than 1,000 feet, and the persistence in this formation of the ore tenor found in the rhyolite is certainly not to be expected.

SALVADORE MINE.

The ground of the Salvadore mine adjoins that of the Hermosa mine on the west and is situated in the east slope of the same ridge. It was discovered, located, and patented at the same times as the Hermosa mine and was likewise mined by the Hermosa Mining Co. of New York. It has produced about 1,000 tons of good-grade ore, averaging 30 ounces in silver to the ton. It contains about 1,000 feet of development work, including a 200-foot tunnel, a 50-foot shaft, drifts, crosscuts, and stopes.

Though located almost on the projected course of the Hermosa vein, the mine is thought to be on another vein, seemingly separated from the Hermosa vein by up-faulted quartzite. The deposits occur in the rhyolite and are similar to those of the Hermosa mine, but the ground is harder and costs more to mine. The ore, however, is cleaner and is said to mill easier than the Hermosa ore.

WIELAND GROUP.

At a point about midway between Harshaw and Red Mountain and about a mile east of the World's Fair mine, on the Harshaw Creek side of the divide, occur a dozen or more small mines and prospects, for which the Wieland group and camp, owned mostly by George Wieland and Theodore Gebler, and lying at an elevation of about 4,900 feet, forms a sort of nucleus or center. The properties are mostly reached by wagon road from the stage road 1½ miles distant on the east. The topography is generally rough and the country rock is mainly calcitic andesite which is intruded by rhyolite. Locally some older silicated limestone and altered shale are also present. Among the properties are the Great Silver, Basin No. 1, Dewey, and Red Rock.

GREAT SILVER MINE.

The Great Silver mine, according to report, in 1882 and 1883 produced and shipped two carloads of ore which averaged 52 per cent in lead and 35 ounces in silver and $1.90 in gold to the ton. The work on this claim and the adjoining Milford claim shows a strong siliceous vein or ore bed which dips 30° N. in the andesite. It consists of an altered mineralized sheet of intrusive rhyolite from 2 to 3 feet thick, largely replaced by heavily iron-stained quartz and gypsum, which are the principal gangue minerals, especially next to the hanging wall. The ore mineral is dark, highly argentiferous galena.

On the Great Silver claim the vein is opened by a 50-foot drift tunnel, whence it is stoped up 60 feet to the surface. In the tunnel it is underlain by andesite containing about 2 feet of soft decomposed vein material.

BASIN NO. 1 PROSPECT.

The Basin No. 1 prospect is about a quarter of a mile west of the Great Silver mine, at an elevation of 5,060 feet, just east of the Alum Gulch divide. It is opened by a tunnel which runs 188 feet N. 64° W. on a fault fissure in andesite that dips 70°–80° SSW. It follows the south or hanging wall of the vein, which is marked by 2 to 8 inches of chocolate-colored gouge. Slickensides on the wall pitch 15° E. The ore occurs in lenses or shoots that apparently pitch westward on the vein. The first lens is cut at the mouth of the tunnel, the second at 45 feet from the mouth, and the third at 90 feet. The lenses are as a rule about 2½ feet in maximum width, and thin down to 6 inches or less in the distance of 20 feet. A 30-foot shaft in the first lens shows the ore to be 5 feet wide. At 140 feet in from the mouth of the tunnel a 20-foot vertical winze is sunk in the hanging wall and intersects the vein at the bottom, showing 10 inches of ore.

The ore is entirely oxidized material, being a mixture of azurite, malachite, limonite, cuprite, and chrysocolla with crushed and altered andesite, a little quartz, and some potash feldspar. There is a carload of ore on the dump, which was sampled by the Copper Queen Smelter Co., it is said, and gave returns of 7 per cent in copper, 1 to 1½ ounces to the ton in gold, and a little silver. Besides this carload, the rest of the dump, about 800 tons of ore, is said to average 4 per cent in copper.

DEWEY PROSPECT.

The Dewey claim of the Wieland group covers a vein 600 feet south of the Basin No. 1 prospect. There is an old caved shaft on the west end of the claim and an open cut near the center. The cut shows a 2-foot vein containing cuprite, malachite, azurite, and chrysocolla between good andesite walls, with gouge on each side. The vein dips 75° NNE. The shaft also is on it.

BUFFALO GROUP.

The Buffalo group, owned by James Cochran, of Bradford, Pa., is just southwest of the Wieland group. It was formerly known as the Jefferson group. It comprises five claims and contains two east-west persistent veins about 600 feet apart.

The most extensively developed property of this group is the Lead Queen mine, located on the south vein of the group. It was discovered in 1897 by Sullivan & Powers, purchased by Mr. Wieland, and later sold to a New York syndicate, which was subsequently organized into the Jefferson Mining Co. This company, however, ceased operations in March, 1902. In 1910 it was reported that the property was being extensively developed by the T. E. Munn Mining Co., of San Antonio, Tex., which was shipping from a newly opened 3-foot ore shoot considerable ore that averaged 21 per cent in copper and 20 ounces in silver and $4.50 in gold to the ton. The total production is about 500 tons of ore, of which Mr. Wieland produced 200 tons in 1898 to 1900 and the Jefferson Co. 100 tons in 1901. About 30 tons of second-grade ore lies on the dump.

The mine is developed to a depth of 166 feet by about 1,200 feet of work, including besides the shaft drifts, crosscuts, and stopes on two levels. Water now stands at 70 feet below the surface in the shaft. The country rock is dark-purple porphyritic andesite. The lode or vein containing the deposits, like all others in this camp, dips north-northeast. The croppings are not prominent but weather evenly with the country-rock surface, and the course of the vein is indicated by only a little stain at the grass roots, which just below the surface gives way to lead-silver ore, which, in turn, at a depth of 40 to 50 feet, is succeeded by ore containing lead, silver, and copper. The ore is about all sulphide, though much of it is yellowish with carbonate and chloride of lead, and in places it is associated with a barite gangue. In general it averages about $50 to the ton and contains 56 per cent lead, 9.2 per cent iron, 2.8 per cent copper, 2 per cent zinc, and 55 ounces in silver and from $1 to $2 in gold to the ton. The copper occurs mostly in chalcocite.

AMERICAN MINE.

The American mine is 1½ miles south-southwest of Harshaw, half a mile southwest of the Hardshell mine, about a quarter of a mile east of the Mowry stage road, in the short, steep gulch at the northwest slope of American Peak, at an elevation of about 5,400 feet. The deposit was discovered about 1880 and has produced more than $80,000 worth of ore, of which the better grade was shipped to Douglas and the rest concentrated at Harshaw in the old mill below the Park place. The mine is said to have been leased recently to a Tucson man who is installing machinery.

The mine is developed to a depth of 112 feet by about 500 feet of work, which includes three 90-foot shafts, all connected by drifts on the 90-foot level.

The mine is on what seems to be the contact of silicified limestone, or quartzite, with intrusive porphyritic brecciated rhyolite. The dominant structure in the sedimentary rocks dips steeply to the southeast, and the rhyolite shows a north-south vertical flow structure and banding. Rhyolite occurs in considerable amount in the north slope of American Peak south of the mine. Blue limestone is said to form the hanging wall on the north in the mine, and the Paleozoic limestone is well exposed in the mountain above and in the gulch below the mine toward the road. Water standing in the shaft is said to be rain water.

The vein containing the deposit seems to trend west-northwest, and dips to the north. The openings extend interruptedly west-northwest for a length of 150 feet and a width of about 50 feet. Prominent and auspicious-looking croppings of iron and manganese stained quartz and replaced silicified rhyolite occur northwest of the mine, and large bowlders from the croppings are strewn down the gulch.

The vein is normally about 3 feet in width but is said to widen to 10 feet or more in places in the mine, forming pockets or lenses which carry good ore that probably in part represents replacement bodies in the wall rock. Most of the ore mined, or more than $50,000 worth, occurred in such a lens which is likened to the "hull of an ocean vessel tilted 45° on its side." It was 75 feet in length and 14 feet in width and dipped to the north. About all the ore mined was obtained between the surface and the 90-foot level, mostly from the oxidized zone, but it contained also sulphides. The metals contained in the ore are silver, copper, iron, zinc, and lead. The ore minerals are cerargyrite, argentite, chalcopyrite, pyrite, sphalerite, and galena.

The shipping ore is said to average about 12 per cent each in lead and zinc and 100 ounces in silver and $9 in gold to the ton. The smelter sheet of a shipment of 31,230 pounds of the ore made to the El Paso plant showed the following recoveries, silver being quoted at 55¼ cents and copper at 9 cents:

Silver, 62 ounces	$32.86
Copper, 1.2 per cent	2.16
Iron, 4 per cent	.20
Zinc, some.	

BLUE NOSE MINE.

The Blue Nose, also known as the Abe Lincoln mine, is 2 miles southwest of Harshaw, near the south line of the district just west of the Mowry stage road, on open ground. It is owned by R. R. Richardson and Neil McDonald. It has produced $250,000 in lead-silver ore. About 3,000 tons of good-looking ore lies on the dump, the size of which shows that much work has been done. The mine is developed to a depth of more than 200 feet, mainly by shafts and drifts. Work ceased, it is said, because the poor equipment then on the ground was unable to handle the water.

The country rock is the Paleozoic limestone and quartzite series and it is intruded by dark-greenish, slate-colored dense glassy rhyolite, seemingly in the form of intrusive sheets. The rocks dip about 40° NW. and are sliced by a prominent sheeting that dips 80° SE.

Water, which seemingly is ground water, stands at about 200 feet below the surface.

The deposits occur in a vein or lode which dips 40° NW., about conformable with the inclosing rocks. It is about 4 feet in width. The footwall, a sheet of the dense dark rhyolite, is pyritic, being impregnated with small crystals and grains of pyrite and chalcopyrite. The ore occurs in pockets, mostly in a white talclike substance. Most of the ore produced is said to have occurred in a dipper-shaped body.

PLACER DEPOSITS.

The only placers known in the Harshaw district occur about 2 miles southwest of Patagonia, between Sonoita Creek on the northwest and Alum Canyon on the southwest. Here the Quaternary gravels underlying the mesa-like area, which is about a mile square, contain placer gold and are workable under favorable conditions. They are said to contain also native lead. They were worked by A. J. Stockton and other pioneers by jigging in the early days.

PALMETTO DISTRICT.

GENERAL FEATURES.

The Palmetto district, as shown on Plate I (in pocket), adjoins the Harshaw district on the west, lying between the Tyndall district and the Patagonia district and extending from Sonoita Creek southward for 6 miles to the divide north of Paloma Canyon. It is about 4 miles wide, being bounded on the west by a north-south line crossing Estrada's ranch. In early days the Palmetto district was regarded as the area between Sonoita Creek and the international boundary, the crest of the Patagonia Mountains on the east and Santa Cruz River on the west.[1]

The topography is rough. The western three-fourths of the district is a deeply scored plain sloping from an elevation of 4,500 feet at the base of the Patagonia Mountains on the east to 4,000 feet on the west. The closely spaced arroyos, intrenched from 20 to 60 feet below the general level, trend a little south of west. The highest part of the district is the main ridge of the Patagonia Mountains, which extends along its eastern border. The highest point is a peak 6,400 feet in elevation, situated a little south of the center of the east side. The general elevation of the Alum-Flux divide is 6,000 feet, while from the Paloma divide northward the surface declines from 6,000 to 4,500 feet in a distance of 1½ miles.

[1] Oral communication from A. J. Stockton.

Seemingly the oldest rocks are hornfels and quartzites which occur in a small area in the northeastern part of the district, a quarter of a mile east of the Gray camp. These rocks dip steeply to the west. They are apparently cut off on the north and west by faults and on the east by an acidic intrusive rock which is probably a phase of the granite porphyry. They are dull gray and brown in color, are thinly bedded, and are cut by numerous east-west and north-south joints or shear lines. Except these sediments and a small body of Tertiary rhyolite in the northeast corner of the district and of andesite in the northwest corner, both of which belong to larger areas of similar rocks in the Tyndall district on the north, the hard rocks of this district consist principally of Mesozoic granular intrusives occurring in the southeastern part of the district and containing practically all the deposits. Beginning with the oldest these rocks are quartz monzonite, diorite, and granite porphyry.

The quartz monzonite, which occupies almost the whole of the southeastern part of the district, as described on page 60, is a coarse granular rock composed of orthoclase, plagioclase, quartz, and biotite, locally with some hornblende. Some phases of it contain almost no quartz; in others quartz forms half of the rock. In composition the quartz monzonite ranges from a rock near syenite to granodiorite. Its weathered surfaces are dull gray to brown in color, and the topography of the region underlain by it is composed of rounded forms.

The diorite occurs in a narrow, tonguelike belt about 2 miles long north of the quartz monzonite, which it intrudes as dikes, sills, and larger masses. It is a dark granular rock composed of andesine and hornblende, with very minor amounts of quartz.

Granite porphyry occurs in a lens 3 miles wide occupying the middle-eastern part of the border, which is high and rugged and culminates in Three R Mountain. It belongs to the larger area of this rock in the Harshaw district, on the east. It is seemingly intrusive into both the quartz monzonite and the diorite. As seen on the east slope of Three R Mountain it is sliced by a sheeting which dips 40° NW. In general it is a light-gray or whitish medium to coarse grained rock, with phenocrysts of greasy-lustered quartz and whitish kaolinized orthoclase resting in a finer-grained groundmass composed mainly of the same minerals. It contains a little pyrite and chalcopyrite widely disseminated in both the feldspar and the quartz, also as accessory minerals considerable apatite and a little zircon. The feldspar is highly altered to muscovite.

Although the rock now corresponds to granite porphyry, it seems to have been originally a pegmatite, but it has been under great stress and locally is variously altered by dynamic and metasomatic action. For instance, at the Evening Star prospect of the Three R group of mines, as described on page 361, the orthoclase is almost completely replaced by alunite, which gives to the rock a pink or reddish color, and the quartz is mashed into a sort of gridiron or cross hatching and interlocking structure. A small area of the granite porphyry about half a mile wide and 2 miles long also occurs on the southeast, being a part of the larger area to the south, in the Patagonia district.

In the western part and in a portion of the northeastern part of the district the granitoid rocks are covered by Quaternary gravels and wash material that consists largely of sand and bowlders derived from the quartz monzonite, and in the bottom of the main arroyos are narrow belts of recent sands and alluvial soil.

ORE DEPOSITS.

The mineral deposits occur in the southeastern part of the district, in the Mesozoic intrusive granular rocks. They comprise lead-silver ores in the quartz monzonite, copper ores in the granite porphyry, and copper ores in the sedimentary rocks.

The lead-silver ores, which are seemingly the oldest, are similar to the deposits of this class in the Harshaw district. They consist mainly of argentiferous galena and cerusite, with a little chalcopyrite, gold, malachite, azurite, and wulfenite, contained in banded quartz veins in the quartz monzonite in association with the intrusive diorite. Besides the quartz the gangue also contains considerable limonite and psilomelane.

The next younger type consists mainly of copper deposits in the sheared granite porphyry. The rock itself contains widely disseminated pyrite and chalcopyrite, and the numerous shear zones that traverse it have acted as conduits for circulating waters which have concentrated these metallic minerals along these zones. There is usually very little gangue other than gouge and crushed rock, but here and there narrow bands of drusy quartz are frozen to the walls. The surface of these zones is usually marked by a yellowish-white deposit of alum and limonite. The zones are impregnated with quartz, pyrite, and chalcopyrite, and along the more open joints these minerals are concentrated into narrow metallic veins. The pyrite and chalcopyrite are in some places coated by thin films of black iridescent covellite or chalcocite.

The youngest type of deposits occurs in the area of hornfels and quartzites east of the Gray camp. It consists of impregnations of the sediments along joint and shear planes by chalcopyrite, which has later altered to malachite and azurite. In this type epidote and quartz are apparently the gangue minerals, with limonite, psilomelane, and white mica in the surface ores. Very little work has been done in this area and the extent and conditions of the deposits at depth are not known.

MINES AND PROSPECTS.

The deposits of the district are opened by about a dozen mines and prospects, most of which are given in the following list:

Three R.	New Hope	Sulphide.
Domino (Chief).	Palmetto.	
Jarilla (Bullion).	Sonoita.	

THREE R MINE.

Location.—The Three R mine, which, by reason of its reported rich copper deposits, has been attracting the attention of the mining world for the last two years and has stimulated activity in this and the surrounding districts, is situated at the eastern border of the district, 4½ miles south of Patagonia. It is in the upper west slope of the Patagonia Mountains near the axis of the range, mostly between elevations of 5,100 and 5,500 feet. It is reached circuitously by ascending Three R Gulch near the Gray camp on the west by a wagon road, and thence its northern tributary by a steep trail.

History and production.—The property comprises a group of 30 or more claims containing about half a dozen small mines or good-looking prospects. It was discovered in 1897. Several years later it was bonded to W. R. Green, of Cananea, who paid about $13,000 on it and did several hundred feet of work, mostly on the Three R and Colossus openings, but in 1907 relinquished it together with his third payment. Later the Lewisohn people, through H. S. McKay, took an option on it, did about 1,600 feet of work, and relinquished it in about four months. Their work was mostly on the Colossus, Three R No. 6, and Blue Rock No. 8 openings.

The production at the time of visit in 1909 had been about four carloads of hand-sorted ore averaging about 20 per cent in copper. The property was then owned by the Three R syndicate, consisting of five or more members with headquarters at Patagonia, and was developed by several thousand feet of work consisting of tunnels and drifts distributed through a vertical range of about 400 feet. Later in that year the Calumet & Arizona Mining Co. was said to have secured an option on the property. By May, 1911, under the development of R. R. Richardson, a leading owner, a substantial body of chalcocite ore extending from near the surface to the 125-foot level had been opened, and from it the mine had shipped to the El Paso smelter four carloads of 15 per cent copper ore. From this time on shipments continued to be made at close intervals, and considerable 5 to 10 per cent ore was accumulating on the dumps. By October, 1911, developments had demonstrated the extension of the ore body to the 200-foot level, and this led to the driving of a 600-foot lower tunnel and the construction of a wagon road to its mouth to facilitate transportation of the ore from the mine, for previously the ore had to be packed down the steep slope on burros.

By April, 1912, the mine, according to report, was bonded to the present operator, N. L. Amster, of Boston, Mass., for $550,000, $20,000 being paid down and the balance being due in three semiannual installments. By October 1, 1912, it was reported that the mine had shipped under the Amster management 65 carloads of ore netting more than $1,000 a car and that more than all payments had been taken out of the mine in ore, besides which a large quantity of ore had accumulated on the dump. By October 15 it was said that the mine had been purchased by Mr. Amster upon developments having demonstrated the extension of the ore body to the 250-foot level, and that it was shipping two carloads of high-grade ore daily and continued to accumulate a large amount of good ore on the dump. Later reports announce that shipments were continued throughout the months of November and December at the rate of about four carloads a day, and that 6,000 tons of ore was blocked out ready to stope. In April, 1913, it was reported that the mine was continuing very regularly to ship more than 100 tons of ore a day, and by January, 1914, the activity and rate of production had materially increased, and further sinking had encountered a considerable body of high-grade copper ore extending from the 800-foot level downward. By August, 1914, the Amster management was reported to have shipped approximately 30,000 tons, or more than a million dollars' worth of ore gross, averaging 9 per cent copper. In October the management was reported to have relinquished its bond, owing to litigation between the owners of the mine.

Development and equipment.—The developments at the time of visit consisted principally of three tunnels, located, respectively, at elevations of about 5,200, 5,300, and 5,500 feet, with lengths of about 200 to 300 feet. The Colossus or main working tunnel, which is driven to the north on the lode, contained also about 70 feet of crosscut to the east and as much more to the west, and a 70-foot winze. The principal equipments were tram tracks in about all the tunnels, and the workings were reached by steep trails only. At present writing (November, 1912) the developments, made mostly under the new management, are said to include a 600-foot lower tunnel, giving the mine about 700 feet of backs, and a 375-foot double-compartment shaft. The tunnel contains 500 feet of drift on the vein and a 90-foot winze with drifts at 60 feet below the tunnel level. A 65-horsepower gasoline hoist, a plant for operating six machine drills, ore bins, and substantial camp buildings have been installed, and a good wagon road over which the ore is hauled to Bloxton station, 3½ miles distant on the railroad, extends to the mouth of the tunnel.

Topography and geology.—The mine is in the upfaulted block of the Patagonia Mountains, described in the section on the Flux mine.

The topography is mountainous and in part rugged. The raise from Three R Gulch to the mine is 1,000 feet in about a third of a mile.

The country rock is mainly the granite porphyry, which has been described on pages 64–66. It is composed of quartz and orthoclase in large aggregates with rarely a little biotite. It is much weathered, altered, pyritic, and iron stained, and is vertically sliced by two systems of sheeting, of which the dominant system trends about north-south, parallel with the Colossus lode, and the other about N. 75° E. Mineralized shear zones, on which mines are located, occur in both systems, some of them being marked by ledges with enormous croppings, such as that of the Blue Rock No. 8, southeast of the Three R mine, belonging to the east-west system. The rock, especially in the vicinity of the north-south shear zones, has also been pressed and sheared to a high degree, so that it weathers like a schist, which it locally resembles. It is cut by dikes of rhyolite and a younger granite porphyry, but these rocks seem to be only sparingly present. At the Evening Star prospect the orthoclase is largely replaced by pink alunite, as shown in Plate XIX, *A*, and described more fully on page 61.

Ore deposits.—The deposits, which are valuable principally for copper, occur in a north-south shear zone about parallel with the axis of the range, traversing the granite porphyry country rock, which as shown in all the tunnels is heavily impregnated with iron pyrites, apparently cupriferous, and a little chalcopyrite. Along the shear zones there is a concentration of these minerals, forming crude stockworks and veins. Alum and copper sulphates coat the workings.

The last 100 feet of the lower tunnel and the back 140 feet of the middle one show clearly the sheared, altered nature of the rock. In both of these tunnels the chief shearing trends north and the country rock is more heavily impregnated with sulphides in the zone of greatest shear. There are practically no gangue minerals with the exception of a little gouge, and in the two tunnels mentioned all the rock broken could well be milled.

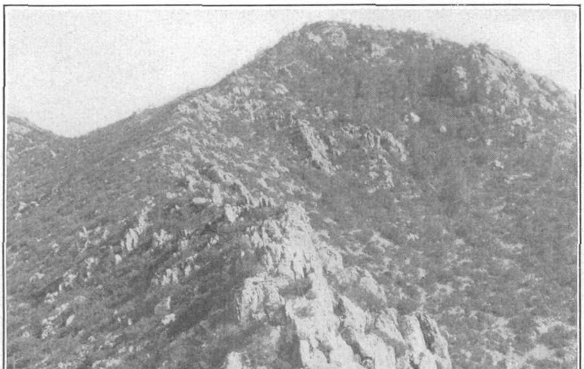
Pyrite, the principal metallic constituent of the ore, is well crystallized, and masses as large as 8 inches in diameter were noted. Striæ show on most of the crystals, and twinning is common.

Chalcopyrite occurs as a widely scattered constituent of the ore. It is seldom found intergrown with the pyrite, but rather as small, separated masses. Very small amounts of azurite and malachite occur locally as films on the walls near the mouth of the lower tunnels.

At and in the vicinity of the mine the shear zone, as indicated by iron-stained silicified croppings (Pl. XIX, *B*), has a width of 40 to 100 feet or more, and is variously traversed by parallel stringers, seams, and bands of ferruginous rock or hematite. One of these

A. ALUNITIZED GRANITE PORPHYRY FROM EVENING STAR PROSPECT OF THREE R GROUP OF MINES, NEAR PATAGONIA.

The light-colored portion is mostly pink alunite replacing orthoclase. The dark portion is quartz. The many veinlets traversing the field horizontally from left to right and producing the schistlike structure are also alunite. Photographed from polished surface of hand specimen. Natural size.



B. CROPPINGS OF COPPER DEPOSITS OF THREE R MINE ON MINERALIZED SHEAR ZONE IN GRANITE PORPHYRY.

Looking south-southwest.

bands is about a foot in width, is partly honeycombed, and in part has a laminated or platy structure, being apparently pseudomorphic after calcite or some other spar mineral. This band is said to carry some copper and gold, and farther up the mountain side it contains also lead minerals.

The Colossus tunnel, driven in the shear zone or lode, largely follows a slip or fault plane, which dips 75° W. and is associated with a ½-inch to 1½-inch band of hematite or reddish-brown ferruginous rock, on the footwall side of which occurs from 1 to 3 feet of crushed and partly mineralized reddish-brown iron-stained granite porphyry. The zone also contains seams, stringers, veins, and lenses of rich copper ore, consisting of malachite and chalcopyrite with pyrite, bornite, and chalcocite, of which the largest observed is a band about 2 inches wide, composed of pure chalcocite, inclosed in slickensided porphyry and whitish gouge, showing that more or less profound movement has taken place since the chalcocite was deposited. Native copper, apparently derived from chalcocite, occurs in beads and films or thin sheets facing the sheeting or shear planes in the shaft and open cut above the tunnel, and a sample of it, consisting of a thin sheet about 1½ feet in diameter, was presented, it is said, to the University of Arizona, at Tucson. As a rule the sulphides begin at or very near the surface, about the only exception being the Mayflower opening, at the top of the hill, where, owing to leaching, much carbonate is encountered.

To judge from later accounts the new work under the Amster management has shown a continuity of the ore body from the surface or early workings down to and below the 250-foot level and seemingly below the new 600-foot lower tunnel, which gives to the ore body a vertical range of about 700 or 800 feet. Where it has been crosscut at two points on the 600-foot tunnel level, the ore-bearing portion of the zone or lode is said to be 40 feet in width and to contain chiefly chalcocite, bornite, and chalcopyrite—presumably not in a solid body, however, through this entire width, but in stringers, veins, and lenses with intervening rock and gouge as already described, containing in the aggregate a large amount of rich ore. Shoots of chalcocite averaging 70 to 75 per cent in copper are said to be common. The average of the daily ore shipments is about 10 per cent in copper, and a large amount of good lower grade ore, by estimate more than 300,000 tons, is in sight or on the dump.

The ore now being mined is said to be nearly all secondary chalcocite. According to later and more extensive examinations of Probert[1]—

Masses of pure glance several feet across are found, the high-grade lens being at the main adit level (215 feet below the surface) 37 feet wide. The horizontal

[1] Probert, F. R., The Three R mine, Patagonia district, Ariz.: Min. and Sci. Press, vol. 109, No. 5, p. 176, 1914.

limits of the ore body are marked only by the change in value, not by any structural detail. This ore body has been followed a vertical distance of 500 feet, with high-grade ore still showing in the bottom of the winze. The stopes extend to within 40 feet of the surface, where the glance slowly fades into the ocherous hematite. On the footwall side of the stopes the chalcocite is finely disseminated around bright glistening pyrite grains in a soft sericite felt. The center of the ore body is more completely alunitized and sectile slabs and masses of pure glance have the appearance of a conglomerate, so striking is the black and white contrast of mineral and gangue. On the hanging-wall side perfect stubby octahedra of pyrite 2 and 3 inches across are found coated with a thick film of chalcocite. The compact masses of pyrite are but surficially altered. On the 500-foot level, 110 feet below the surface, stope No. 100, the pyrite was found coated with covellite of a purplish blue color, while on the Three R claim bornite envelops the crystal faces of pyrite. The high-grade ore is always found in close proximity to the major fractures and fades gradually into noncommercial unaltered pyrite on either side. Where the cupriferous pyrite is definitely crystalline it is but coated with chalcocite; enrichment seems to advance with distortion or crushing of crystal forms. * * *

Other small lenses of high-grade ore have been exposed by drifts along the main fractures, but their distribution is very erratic between high-grade shoots. The rock on either side of the fault fissure contains disseminated chalcocite, 3 to 4 per cent ore, which may later be mined and milled.

The source of the ore is here referred to the cupriferous pyrite and chalcopyrite which are widely disseminated in the granite porphyry country rock and are regarded as primary constituents. From these minerals, by processes of leaching and the action of percolating solutions, the bornite, covellite, chalcocite, and chalcopyrite have been concentrated to secondary forms of the vein class of deposits, as stringers, lenses, and shoots in the fault fissures and shear-plane fractures of the shear zone, and as metasomatic replacement deposits in the crushed rock in the zone and the wall-rock porphyry.

The process of this enrichment, as shown by microscopic study of ores from this mine by Graton and Murdoch,[1] consists of several steps or stages of mineralization, approximately in the order of the minerals named above, though all the minerals are not invariably present. With this process the results of later studies made by Probert[2] in the mine and described further on essentially agree.

The shear zone contains also an intrusive dike of a siliceous granite porphyry of reddish tinge, much finer grained than the inclosing rock. This dike seems to have been intruded during the epoch of shearing, and it is possible that thermal solutions accompanying or following its intrusion have also exerted an influence in the formation of the ore deposits. It is also possible that solutions accompanying or following the eruption of the rhyolite which occurs in the east base of Three R Mountain may have been influential in the

[1] Graton, L. C., and Murdoch, Joseph, The ores of copper; some results of microscopic study: Am. Inst. Min. Eng. Trans., vol. 46, No. 77, pp. 754–755, figs. 5 and 6, 1913.

[2] Probert, F. R., op. cit.

ore deposition, but the absence or paucity of secondary or vein quartz leaves the theory of contributions from these eruptive sources very much in doubt. This doubt is further strengthened by the fact that "development to date shows that the largest ore bodies are found under an outcrop where the pyrite has been completely oxidized to earthy hematite."[1]

The hematite and the copper ore in this place were derived by oxidation from the pyrite, cupriferous pyrite, and chalcopyrite that were contained in probably a very great thickness of the overlying pyritized porphyry, now eroded away, and were concentrated along the sheer zone or fissures, the copper deposits mainly by chalcocitization and covellitization.

WEST SIDE MINE.

A new property, known as the West Side mine, located near the Three R mine, is said to be shipping considerable ore from an ore body 30 feet wide, the most of which is said to average 8 per cent copper and $4 in gold and 8 ounces in silver to the ton.

DOMINO MINE.

The Domino or Old Chief mine is about three-fourths of a mile west of the Three R mine, at the west foot of the Patagonia Mountains, near Gray camp, at an elevation of about 4,200 feet. It is on open ground and easy of access by wagon road.

The mine was located in 1881 by A. J. Stockton and partners, who held it until 1885, sinking two shafts 83 and 62 feet deep. In 1884 a pocket of galena coated with cerusite was opened at the surface, from which 7 cars of ore were taken that averaged 61 per cent in lead and 58 ounces to the ton in silver. In 1885 Mr. Stockton sold the property to Douglas Gray, who still owns it. Mr. Stockton reports his production from this property to be $8,000. Later W. D. Gray shipped from it 16 tons of cerusite ore that carried 86 ounces of silver to the ton.

The mine is opened by an 83-foot vertical shaft, drifts, and stopes. The shaft is timbered and has stations and drifts at the 40 and 75 foot levels. As the drifts are untimbered and the ground is very soft, caving has locally closed them up. The 40-foot level runs east and west from the shaft with curvature to the north. Most of the vein above the 40-foot level has been stoped for a distance of 75 feet west from the shaft, and surface ore has been removed from a few shallow pits.

The veins or deposits occur principally in an east-west shear zone in altered and leached diorite, and in association with the contact of

[1] Probert, F. R., op. cit., p. 175.

the diorite and quartz or granite. Quartz monzonite crops out on a hill just north of the mine and diorite to the south. In a contact belt about 100 feet in width, between the two croppings, the rocks are very much sheared and altered. In some places the rock appears more granitic and in others dioritic, and it is probable that both varieties occur in this altered contact zone.

The ore consists largely of cerusite enveloping cores of galena. It occurs in seams and elongated masses which have a general east-west strike and steep southerly dip.

As the ore bodies are of the same reddish-yellow color as the altered rock they are difficult to find. A little native silver, it is said, was found at a depth of 35 feet in the main shaft, and small pockets of wulfenite occur throughout the deposits. Both the cerusite and the wulfenite are beautifully crystallized.

About 2 feet of water standing in the 80-foot shaft is said to be permanent and seems to represent ground-water level. Apparently it indicates the beginning of the sulphide zone, in which the cerusite of the upper workings will probably soon give way to galena.

JARILLA MINE.

The Jarilla mine is located in the south-central part of the district 3 miles south-southwest of the Domino mine. It is on open ground at an elevation of about 4,350 feet and is easy of access by wagon road. The mine was worked by Mexicans prior to 1880. In that year A. J. Stockton, of Patagonia, and partners, located it and sank a 125-foot shaft. After shipping to the smelter at Selby, Cal., a few tons of ore, which, it is stated, averaged 38 per cent in lead [1] and 232 ounces to the ton in silver, Mr. Stockton abandoned the mine in 1886. In 1904 and 1905 the property was worked by E. L. Ish, who states that as the result of five months' work he shipped $5,000 worth of argentiferous galena and other ore whose value lay chiefly in horn silver. The ore as a whole averaged 40 per cent in lead and 175 ounces in silver and 1 ounce in gold to the ton and contained a little copper.

The mine is developed by four shafts sunk on the vein (fig. 35). The shafts are located about 50 feet apart. Beginning on the west they are 40, 40, 75, and 125 feet deep, respectively. A new or fifth shaft (2, fig. 35), at least 70 feet in depth and extending seemingly to ground water, is located about 100 feet south of the vein.

Together with the other buildings about a quarter of a mile southwest of the mine is an adobe smelter, which was built by Mr. Stockton when the mine was first worked, but like a score of similar pioneer plants of its kind in the Santa Rita Range it had only temporary

[1] Oral communication from A. J. Stockton.

success and treated but a few tons of ore. One charging of the furnace with galena, cerusite, and horn silver ore, it is said, yielded 7 pounds of silver.

The country rock at the mine is a pink to yellowish-gray coarse granitoid rock, corresponding megascopically to quartz monzonite. It weathers dull yellow or red. It is composed mainly of pink orthoclase, plagioclase, and slightly smoky quartz, with biotite and hornblende as the ferromagnesian minerals. The orthoclase alters to a dull yellow.

At the mine the rock is cut by a fault striking N. 60° E. Along this fault in several places is a coarsely granular intrusive rock corresponding to diorite. It is composed of hornblende and plagioclase, seemingly andesine, with a little secondary quartz and accessory magnetite and apatite. When fresh it is almost black, but even slight weathering produces a reddish color which is extremely pronounced

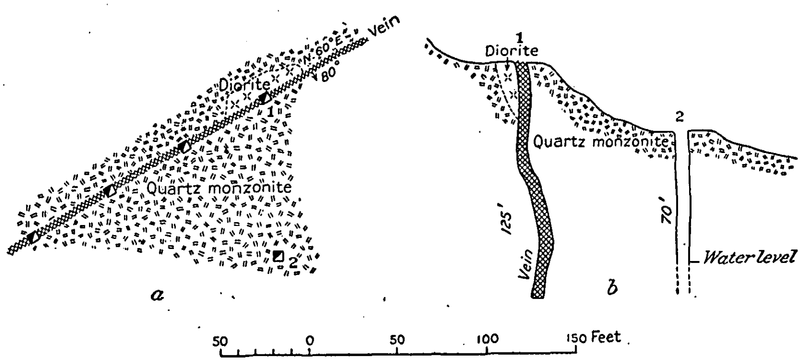


FIGURE 35.—Plan and partial section of Jarilla mine. *a*, Plan; *b*, longitudinal section.

in the croppings. The contacts of the diorite and quartz monzonite are almost invariably marked by broad green epidotized belts, and at some time later than the intrusion of the diorite mineralization occurred along the fault.

The deposits occur in a quartz fissure vein associated with the intrusive diorite contact just described. At the surface the vein is about 4 feet wide. It consists largely of banded drusy quartz and earthy limonite, psilomelane, malachite, and azurite. The vein strikes N. 60° E. and stands nearly vertical or dips steeply to the south. Where opened the walls are good and they are separated from the vein filling by gouge showing slickensided surfaces.

The ore seen on the dump is well-banded quartz containing the usual copper and iron minerals of the oxidized zone, with scattered small patches of earthy lead carbonate surrounding kernels of galena. The limonite and psilomelane in the surface material give reactions for both lead and silver, and it is probable that there is a good deal of silver chloride and lead carbonate mixed with all the iron and manganese minerals. Post-mineral movement has crushed the ore to a considerable extent, the gouge produced being made up largely of limonite, malachite, psilomelane, and fragments of quartz.

Messrs. Stockton and Ish state that the oxidized ores occur in the 100-foot workings but that galena is the more abundant constituent of the ore. Below the 100-foot level water was encountered, with marked decrease in the oxidized ores and in silver content. On the 65-foot level small pockets of wulfenite were found with the galena.

PALMETTO MINE.

The Palmetto mine is a little south of the center of the district and a mile north of the Jarilla mine, on open ground at an elevation of about 4,300 feet. It was located by A. J. Stockton and partners, of Patagonia, in 1880, when there were at this place some old shafts that were probably sunk by Mexicans in the early days.

It is opened by three shafts sunk on the vein. All the shafts contain water, and in the south shaft, located in a gulch, water stands within 6 feet of the collar. Several pits show the surface ores.

The country rock is quartz monzonite intruded by small disconnected masses of diorite in the form of sheets and dikes. The quartz monzonite and the diorite near the contacts are both chloritized and epidotized, the diorite having apparently suffered the greatest alteration.

The deposits occur mainly in two veins situated about 300 feet apart and contained in the quartz monzonite in association with the intrusive diorite. The vein filling is white quartz, limonite, and psilomelane, all much sheared and broken, forming a brecciated mass of yellowish-brown to black color. A considerable part of the filling as locally shown on the surface is sheared, broken, and altered quartz monzonite. The black mineral consists of manganese with a little lead and seemingly some argentite. The southwest vein, on which the shafts are sunk, dips 85° SW. It is 2 feet wide between walls of sheared quartz monzonite separated from the ledge matter by gouge. The principal ore mineral is argentiferous galena, but the mine has also produced considerable ore rich in horn silver.

SONOITA MINE.

The Sonoita mine, not visited in this work, is a mile northeast of the Palmetto mine, on open ground at an elevation of about 4,400 feet. It was located in 1879 by William Keegan and partners and was worked until 1888. It is said to be on a north-south quartz vein in quartz monzonite. Hand-sorted ore shipped from it is reported to have averaged about 25 per cent in copper and $100 in gold and 100 ounces in silver to the ton. The ore, according to Mr. Stockton, consisted mainly of copper glance, galena, and "petanque," or dark ruby silver.

NATIVE SILVER PROSPECT.

The Native Silver prospect, now abandoned, is about a quarter of a mile northeast of the Gray camp, on a shear zone that strikes N. 75° E. and dips 85° S., in granite porphyry. It is opened by an old shaft whose dump shows yellow and red stained drusy quartz containing a little pyrite.

BIG STICK PROSPECT.

The Big Stick prospect is about an eighth of a mile southeast of the Gray camp, near the contact of sheared altered granite porphyry that is intrusive into diorite, as shown in one of the tunnels. The ore minerals, which are disseminated in the country rock and concentrated in seams, are pyrite and chalcopyrite, locally coated with covellite and chalcocite.

LEDGE PROSPECT.

The Ledge prospect is three-eighths of a mile southeast of the Gray camp. It is on a 50-foot siliceous ledge which dips steeply to the south and is traceable for about 1,000 feet and which in this distance cuts across the contacts of quartz monzonite with diorite and diorite with granite porphyry. This ledge is opened at intervals by several pits and seems to be a sheared dike of the granite porphyry, for soon after passing into the main area of this rock it terminates or becomes lost and the vein matter of the ledge, which is largely quartz with seemingly altered feldspar, resembles the granite porphyry.

The metallic minerals, consisting of copper and iron sulphides which begin 4 or 5 feet below the surface, are concentrated in the fractures and shear-plane faces of the ledge, mostly in association with quartz.

COX GULCH PROSPECTS.

Along the contact of quartz monzonite intruded by granite porphyry, which extends from the Gray camp southeastward up Cox Gulch for nearly 2 miles, a number of prospects have been opened by short tunnels and pits on small veins which show in general very similar characteristics. The granite porphyry is impregnated with pyrite and chalcopyrite, as at the Three R mine, and the quartz monzonite is silicified, altered, and impregnated with the same minerals for a short distance from the contact. The quartz monzonite is jointed along east-west and north-south lines. Along many of these joints, particularly those of the east-west system, there are ½-inch veins of pyrite, chalcopyrite, and a black iridescent copper-bearing sulphide, either covellite or chalcocite. These veins are pseudo-banded, the banding being apparently due to alteration and replacement of the original constituents. They were probably at first composed of pyrite and a very little chalcopyrite, and the latter mineral is still present in the middle of the vein. The sides of the vein next to the wall, however, are altered, the original sulphides being coated with a thin film of the dark sulphide mineral.

In the granite porphyry at the head of the gulch there are several openings on shear zones or fault lines that strike in north-northeasterly directions and dip to the west. The country rock is impregnated with pyrite and chalcopyrite, which are concentrated in the shear zones and faults. The deposits are in the main crudely banded, and the country rock is more siliceous along the veins. Some of the smaller veins are separated from the walls by a narrow band of drusy quartz, which is usually frozen to the walls. There is generally but little gangue other than gouge and roughly crushed and ground country rock. In many places, beginning at about 6 feet below the surface, the pyrite and chalcopyrite are coated with films of chalcocite.

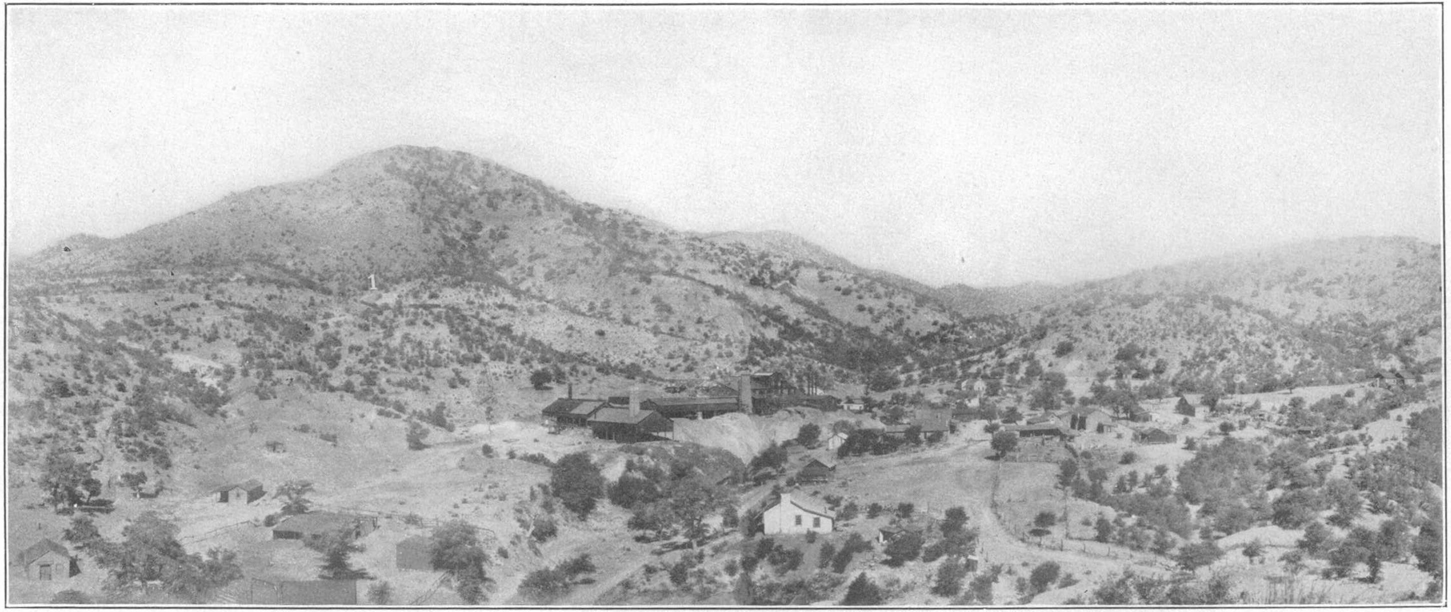
The croppings of these deposits, as at the Three R mine, are peculiarly free from copper carbonates, and relatively little limonite was noticed. In the tunnels, however, alum and copper sulphate commonly coat the walls, and iron tools left in contact with the mine water soon become copper plated.

PATAGONIA DISTRICT.

GENERAL FEATURES.

Location and settlements.—The Patagonia district is on the Sonoran border in Santa Cruz County. It covers the southernmost part of the United States portion of the Patagonia Mountains and lies south of the Harshaw and Palmetto districts, already described. It is about 12 miles broad from east to west and 8 miles from north to south. (See Pl. I, in pocket.) On the west the boundary of the district for 4 miles north of the Mexican line follows Santa Cruz River. On the east it roughly follows the upper or western edge of the wash or valley plain of the river, which toward the north coincides with the west or upper boundary of Meadow Valley Flat. The northern boundary, starting on the west, follows the divide north of Canada de la Paloma to the crest of the Patagonia Mountains on American Peak, whence it continues eastward across the Harshaw Creek drainage basin to Meadow Valley Flat.

The principal settlements are Mowry, Washington, and Duquesne, all good-sized camps located in the eastern part of the district. A daily mail and stage service is maintained between these camps and



CAMP WASHINGTON AND DUQUESNE REDUCTION PLANT ON WASHINGTON GULCH.

Pride of the West mine at left (1) and Patagonia Mountains in background. Looking west.

Patagonia, on the railroad 16 miles to the north, which is the shipping point for the mines east of the main range. Washington and Duquesne also have intermittent stage service to Nogales, about 18 miles to the west. It is said that a new wagon road will soon be built from Patagonia to Washington and Duquesne, passing near the Three R properties, the Chief mine, and the Volcano group. This road will shorten the route to the railroad by several miles and will give the mine owners an easy down grade for hauling their ore into Patagonia for shipment.

Mowry has a concentrating mill and smelter, and at Washington there is an elaborate concentrating plant and a 50-ton smelter.

Of the other camps in the district, Four Metals, O'Connors, and Benton are on the east side of the range, and Old Soldier, Gross, Golden Rose, and Buena Vista on the west side. Besides the mining camps there are many small ranch houses in this region. The roads and trails between the various parts of the district are good. A telephone line extends from Mowry to Patagonia and another from Washington and Duquesne to Nogales.

Topography.—The principal topographic feature of the district consists of the Patagonia Mountains, which extend across the district in a north-south belt about 7 miles in width, occupying the middle and almost the whole of the eastern part and forming the divide whence the drainage is discharged to the east and to the west into widely different sections of Santa Cruz River. The mountains average about 5,500 feet in elevation, but ridges in the southern part exceed 6,000 feet and two peaks rise to about 7,000 feet. On the north the mountains are low and broad or spreading; on the south they are contracted into a single narrow ridge, whence on either side the surface declines 1,500 feet in a distance of less than 1½ miles. The topography is accordingly rough and much of it is rugged. The mountains, as shown in Plate XX, are sparsely timbered with mesquite and live oak of moderate size. West of the mountains is a broad eroded valley plain gently sloping to the Santa Cruz. The upper limit of this plain is approximately at the 4,300-foot contour, from which the rise to the crest of the range is rapid. On the east in the northern part of the region the slope from the divide to the Santa Cruz is gradual, the descent along the Mowry Wash, the main drainage line, being only 800 feet in 10 miles. In the southern part of the district Duquesne is situated at about the upper limit of the valley flat of the Santa Cruz. Westward from this camp, which has an elevation of 5,350 feet, the mountains rise to an elevation of 7,200 feet in a distance of 3 miles.

A peculiar topographic feature of this part of the area is Guajolote Flat, which is a rather level parklike area situated at an elevation of 5,800 feet. It is much above the general elevation of the region, and there are only a few peaks that rise higher than it within a radius of a mile and a half. The flat drains to the east, although it lies well to the west of the axis of the range.

Geology.—The rock formations, beginning with the oldest (see Pl. II, in pocket), are Paleozoic sediments, consisting of limestone, quartzite, and shale; Mesozoic intrusive rocks, comprising quartz monzonite, granite porphyry, diorite, and gabbo; Mesozoic sediments, consisting mainly of arenaceous limestones and shales; Tertiary rhyolite; and Quaternary gravels and wash. Their general relations are shown in cross-section *G–H*, Plate III (in pocket). All the formations except the Mesozoic sediments contain mineral deposits.

The most widely distributed hard-rock formation is the quartz monzonite, which has been described on page 60. It extends across the district in a north-south belt about 6 miles wide on the north and forms almost the whole of the Patagonia Mountains, especially the axis and west slope. It is intrusive into the Paleozoic sediments, as is shown at Mowry, Washington, and Duquesne. It is quite possible, however, that the belt mapped as quartz monzonite may include also some granite.

The formation next in abundance is the granite porphyry, described on page 64. It crosses the district in an interrupted north-south belt about a mile wide in the eastern foothills of the Patagonia Mountains and also in a north-south quadrangular area of about 2 by 3 miles in the western foothills toward the north. It is intrusive into the Paleozoic sediments, the quartz monzonite, and the diorite, and is economically important on account of its relation to the ore deposits.

The Paleozoic sediments occur in two areas, one at Mowry and the other at Washington. The Mowry area is roughly quadrangular in outline and extends from the Mowry mine to a point about 3 miles to the northwest. It is occupied mainly by limestones, some of which have furnished the fossils described on pages 49–50, but it contains also some shale and quartzite. The Washington area is crudely lenslike in outline. It trends north and has a length of 2½ miles and a width of about a mile. Washington is located at the middle of its eastern edge. It is occupied mainly by white crystalline limestone which has yielded no fossils but contains mineral deposits.

The Mesozoic sediments occur on the east slope of the range, in the northeastern part of the district, in interrupted areas extending for about 2 miles north, south, and west from Mowry. They have yielded the fossils described on page 53.

The quartz diorite occurs as small stocklike masses and dikes intruding the quartz monzonite, as to the west of the Golden Rose mine and at the O'Mara or Old Soldier mine. The gabbro intrudes the Paleozoic limestone, principally at and near Mowry. The rhyolite occurs in irregular patches in the northeastern part of the district, on the upper east slope of the range, along the contact of the granite with the overlying Mesozoic rocks, into both of which it is intrusive, and it seems to be the interrupted southerly extension of a larger body of rhyolite in the Harshaw district on the north.

LODE DEPOSITS.

DISCOVERY AND MODE OF OCCURRENCE.

As in the Harshaw district on the east and the Santa Cruz Valley on the west, mineral deposits were discovered in the district in the early Jesuit days by the padres and the Mexicans, but detailed records of these discoveries are not at hand. The Mowry mine was worked by Americans in the middle part of the last century, as were also several smaller properties. Since then production has continued intermittently from different properties down to the present time. The deposits are practically all contained in a belt 6 miles wide extending in a northwesterly direction across the district. They carry mostly silver and lead but are in part copper deposits. As a rule they occur in fissure veins similar to those in the districts already described and are present in all the Mesozoic intrusive rocks and also in the Paleozoic sedimentary rocks, where they are generally associated in origin with intrusives. At the Washington and Duquesne camps, however, the deposits are mostly of contact-metamorphic origin.

MINES AND PROSPECTS.

The district contains over 40 mines and promising prospects, the most of which are named in the following list. Many of them have been productive and a number are still producing. Most of the mines are small.

Augusta.	Four Metals.	New York.
Belmont.	Gladstone.	North Mowry.
Bennett.	Golden Rose.	O'Connor.
Benton.	Holland.	Off Pointer.
Big Lead.	Isabella.	O'Mara (Old Soldier).
Blades.	Jabalina.	Pocahontas.
Bonanza.	Kansas.	Pride of the West.
Brooks.	King.	Proto.
Buena Vista.	Lone Star (San Joaquin).	Silver Bell.
Champion.	Marché.	Shamrock.
Chance.	Morning Glory.	Tibbetts.
Ella.	Mowry.	Winifred.
Empire.	National.	

MOWRY MINE.

Location.—The well-known Mowry mine, originally called the Patagonia mine and later the Mowry silver mines, is located at Mowry, in the northeastern part of the district, 9 miles south of Patagonia. It is near the Patagonia-Washington stage road, in the south base of Mowry Hill, on open, gently sloping ground at an elevation of about 5,500 feet.

History and production.—The mine was located in the early fifties and worked in the usual primitive way by Mexicans, but it had been known to the Jesuits long before. It was relocated in 1858 and was purchased in 1859 by Lieut. Sylvester Mowry, of the United States Army, who was then stationed at Fort Crittenden and who is said to have expended about $200,000 in the purchase of the mine and its equipment with reduction plant and other improvements.[1] Lieut. Mowry operated the mine successfully for about four years, employing about 120 men, and shipped $1,500,000 worth of ore, mostly to San Francisco and to London and Europe by way of Guaymas, Mexico, 25 tons of the ore being sent to Europe as sample specimens in 1862. Some bars of the lead and silver bullion from the reduction works sold in England at $200 a hundredweight. Much of the ore was smelted and some bullion was refined in the reduction plant, which consisted of 12 adobe smelters and yielded $4,500 a week on the ground. The ore was transported to Guaymas, nearly 300 miles distant, by wagon.

A portion of the silver refined at the mine in an English cupel furnace was molded into bars worth from $2 to $300 each, and used as a circulating medium instead of money in payment of current expenses. The litharge refuse from the furnaces was sold to neighboring mines in Sonora and used as a flux in treating their refractory ores. Operations were ruthlessly interrupted in 1862, and the mine was seized by the United States Government owing to the charge that it was furnishing lead to the Confederate Army for ammunition.

In the early seventies, according to Raymond,[2] the mine was worked intermittently by jumpers, who installed an engine with good results, but it was practically abandoned after gophering and subsequent caving had ruined the workings.

Fish & Silverberg, of Tucson, acquired the mine by relocation, took out about $75,000, and in the early eighties sold it to Steinfelt & Swain, merchants in Tucson, who in the late nineties, by the expenditure of $100,000, opened the old workings and are said to have taken out $80,000 and found enough additional ore to render the mine easily salable at a profit.

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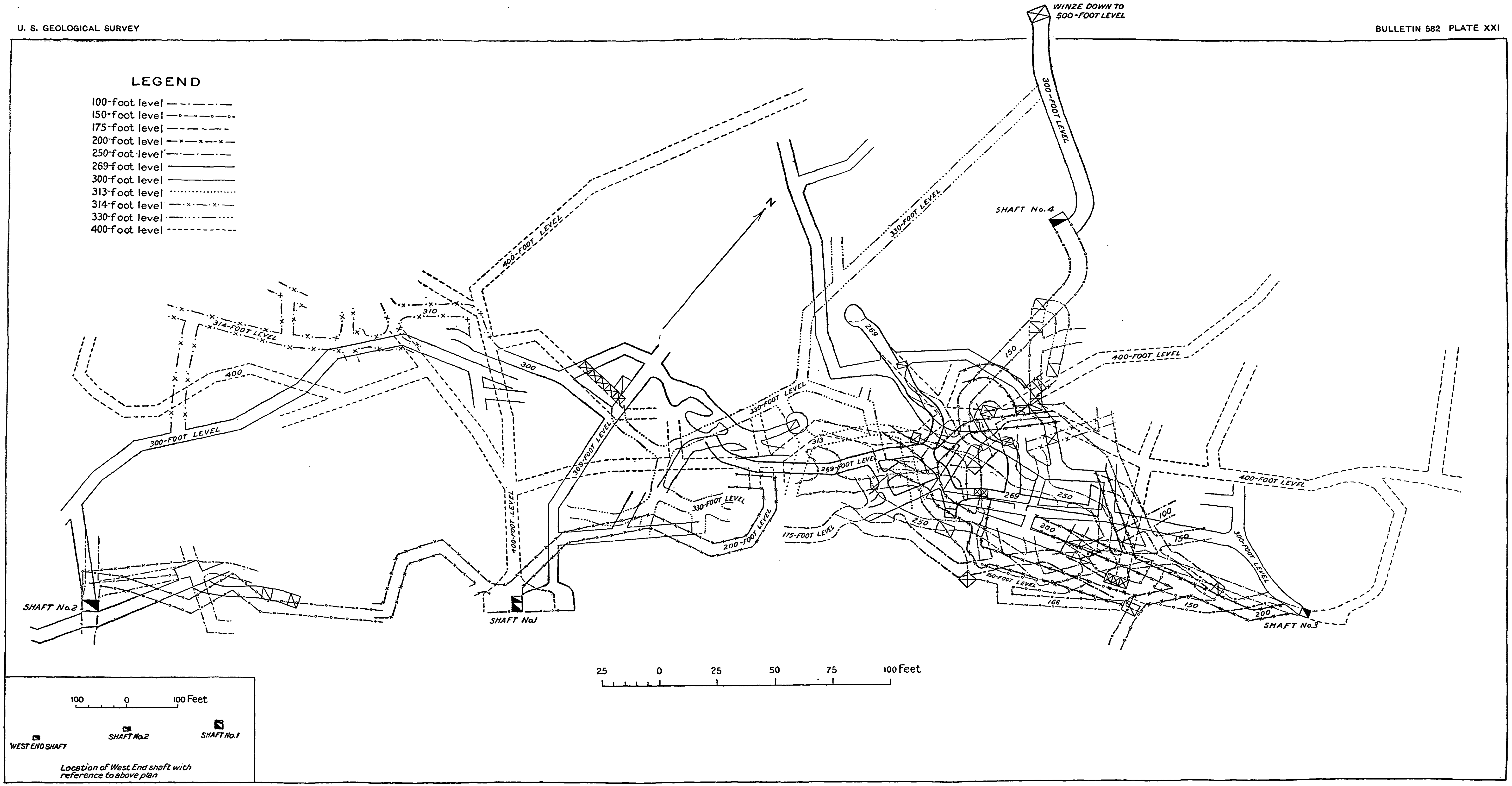
[1] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains, 1868, p. 447, 1869.

[2] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1873, p. 313, 1874.



PLAN OF WORKINGS OF MOWRY MINE.

In 1904 the Mowry Mines Co., composed essentially of the present owners, purchased the property. This company operated the mine for a short time, installed a concentrator and smelter of 100 tons daily capacity, and shipped some lead-silver bullion to New York.[1]

In 1907 the Mowry mine and plant were operated with 200 or more men until late in the year. Some sinking was done and a considerable quantity of concentrates and crude ore containing lead, silver, and gold was shipped.[2] Until about this time the Mowry was, next to Tombstone, the most important lead producer in southern Arizona.

In 1909 the Mowry mine, together with the Alto mine, in the Tyndall district, was taken over by the present owner, the Consoli-

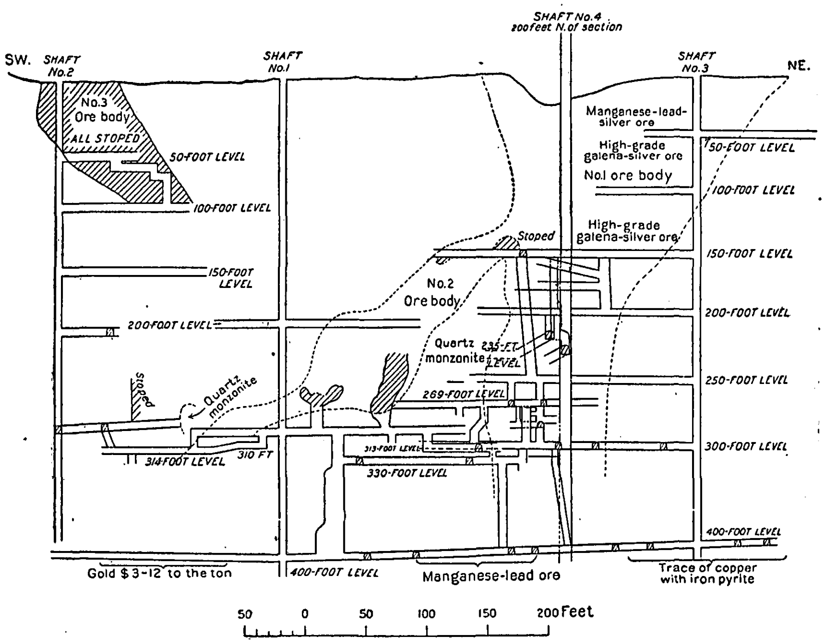


FIGURE 36.—Longitudinal section of Mowry mine.

dated Mines, Smelter & Transportation Co. This company is authorized to build a railroad from Mowry to Patagonia and to operate stores at Mowry and Alto, while the mines are operated by a subsidiary company, the Santa Cruz Mines & Smelter Co., with headquarters in New York. The property comprises a group of twenty patented claims.

Developments and equipment.—The mine is opened to a depth of 500 feet and is developed by about 12,000 feet of work, consisting principally of 2,500 feet of shafts, 6,000 feet of drifts and crosscuts, and 3,000 feet of stopes distributed mostly on 13 levels as shown on the level map (Pl. XXI) and the longitudinal section (figs. 36 and 37). The west end shaft, shown in figure 37, is 190 feet southwest of

[1] U. S. Geol. Survey Mineral Resources, 1905, pp. 138, 156, 1906.
[2] Idem, 1907, pt. 1, p. 178, 1908.

shaft No. 2, shown on Plate XXI. The main shaft is sunk to the depth of the 500-foot level. Drifts are opened down to the 400-foot level, and most of the ore has been stoped down to the third and fourth levels for 600 feet to the east and to the west on the vein, but the deeper workings have not been so extensive.

Some portions of the ore bodies were worked by a system of square sets and overhead stoping, and others by the caving and filling method. By the caving system 80 per cent of the ore mined was

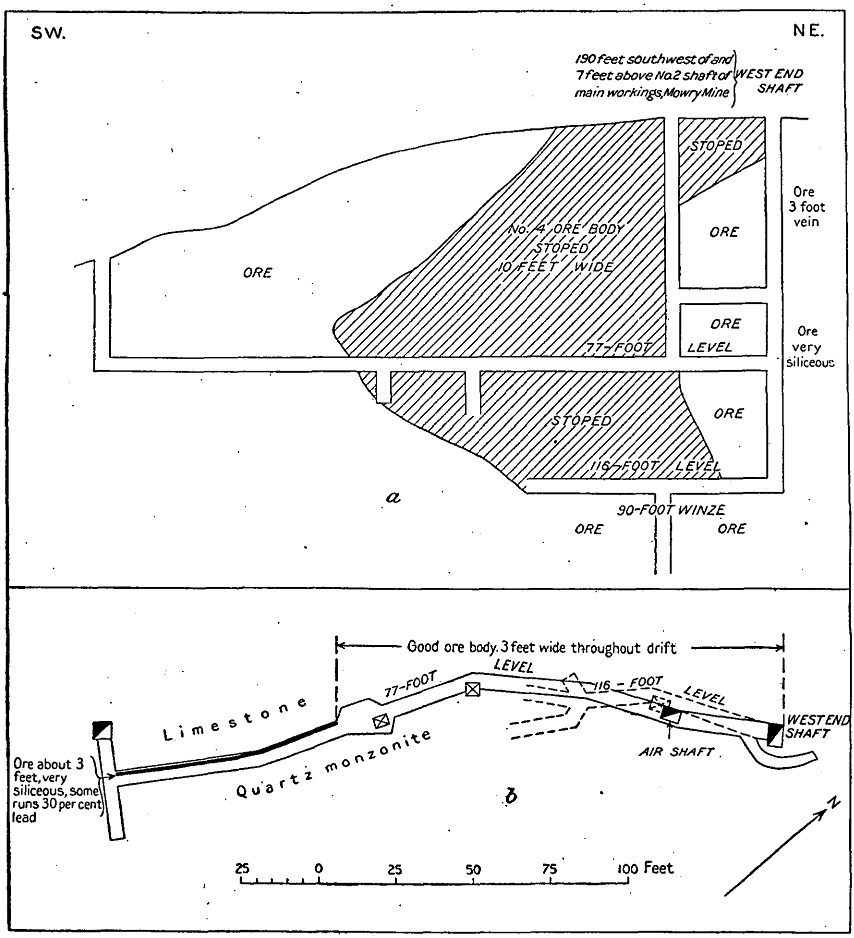
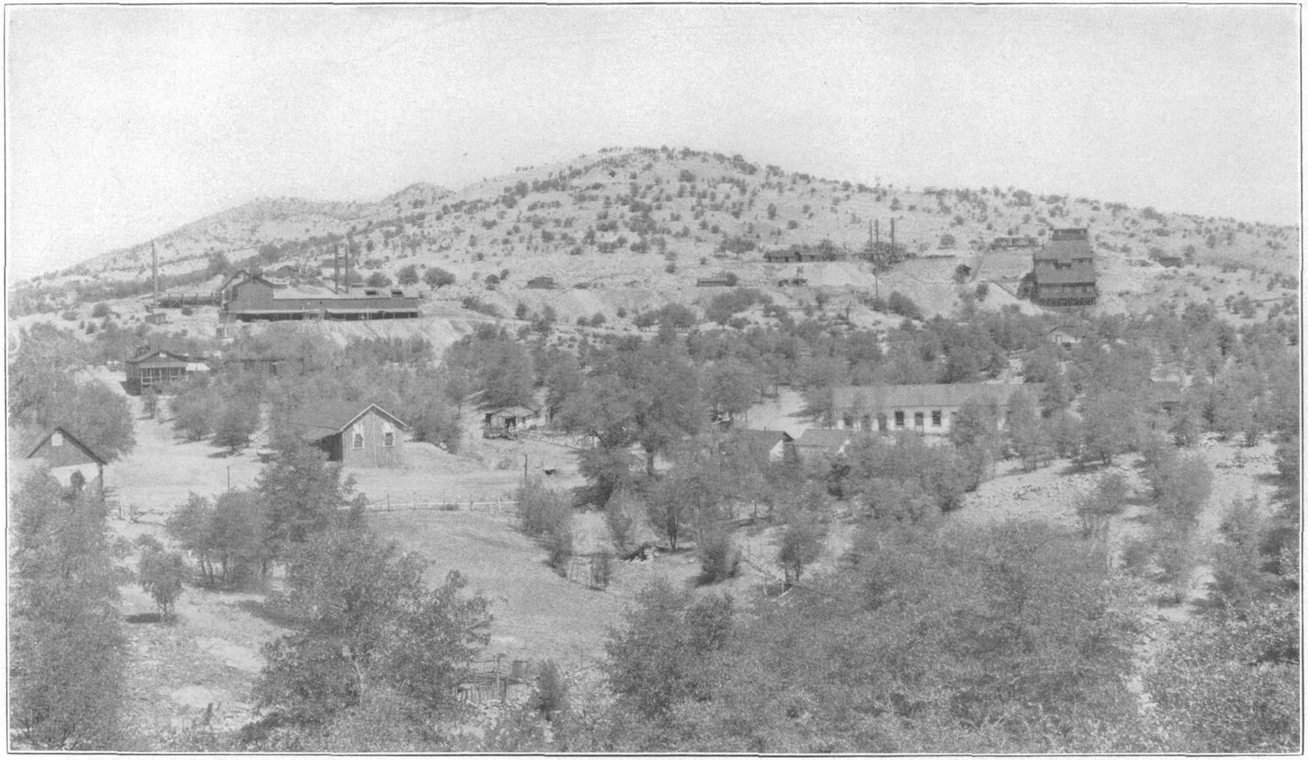


FIGURE 37.—Workings at west end of Mowry mine. *a*, Longitudinal section; *b*, plan.

removed without timber, powder, or filling and without working under an unsupported back.

The equipment at the time of the writer's visit comprised a smelter and a concentrator, each with 100 tons daily capacity. In September, 1914, however, the concentrator was reported to have been destroyed by fire caused by lightning. The smelter is of the lead-silver blast-furnace type. There are also three steam hoists, two 10-horsepower gasoline hoists, and one 5-drill air compressor.



MOWRY MINE AND PART OF CAMP.

Mill at right, smelter at left. Looking north-northeast.

When in operation the mine employs from 300 to 500 men, about 100 men working underground and the rest in the mill, smelter, etc.

Topography and geology.—The topography, as shown in Plates I and XXII, is gentle. The mine is in the south base of Mowry Hill, on the north side of a small open valley known as Mowry Wash, in which the camp, shown in part in Plate XXII, is pleasantly located. The wash heads half a mile west of the mine and joins Santa Cruz River about 8 miles to the east.

The mine is on an east-west fault contact between the Paleozoic limestone[1] and the Mesozoic quartz monzonite. The latter has hitherto been locally known as granite and macroscopically much resembles granodiorite. The fault, which will be called the Mowry fault, trends N. 75° E. and dips 78° N. and seemingly is normal (fig. 38). The limestone occurs on the north or hanging-wall side of the fault and the quartz monzonite on the south side. The limestone essentially composes the adjoining Mowry Hill, which, as shown in Plate XXII, rises about 300 feet above the mine and seems to represent the northern part of a low dome or anticline whose southern part has been cut off by the fault, for in the east slope of the hill the rocks dip 45° NE. At the top of the hill they dip to the north and in the west slope they dip to the northwest at about the same or slightly less angles. Along the fault they dip 45°–70° N., away from the contact.

At some time later than the faulting the rocks and the fault were disturbed along a fault or shear zone about 200 feet in width, which strikes N. 30° W. and stands about vertical and which, as shown on the Mowry fault at the mine, has offset the formations by a small horizontal displacement, the rock on the east being moved 45 feet to the south. To the east of this later fault, which will be referred to as the north-south fault, the limestone for a short distance strikes N. 45° W. and dips 50° NE.; west of it the strike is N. 45° E. and the dip more regularly to the northwest at about 28°. To the north up the slope the zone dies out just below the top of Mowry Hill, apparently passing into undisturbed cherty limestones that strike N. 85° W. and dip 43° N. On the south, where the fault zone is about 250 feet wide, it is composed of a red iron-stained silicified breccia, apparently composed mainly of chert pebbles, which at the top of the hill seems to run into a bed of dark-gray cherty limestone that continues northwestward down the west slope of the hill.

Away from the locally disturbed beds along the north-south fault the limestones are unaltered, dark blue-gray in color, thin to heavy bedded, and in places cherty. To judge from the occurrence in the east slope of the hills, which affords the best exposure, though the

[1] The limestone area extending from Mowry and the Mowry mine 2⅓ miles northwestward and erroneously shown on the geologic map (Pl. II, in pocket) as Devonian has since the map was printed been found on fossil evidence to be Carbonieferous (Pennsylvanian).

section is incomplete, they aggregate at least 800 feet in thickness, of which about 330 feet is shown in the mine. They contain many

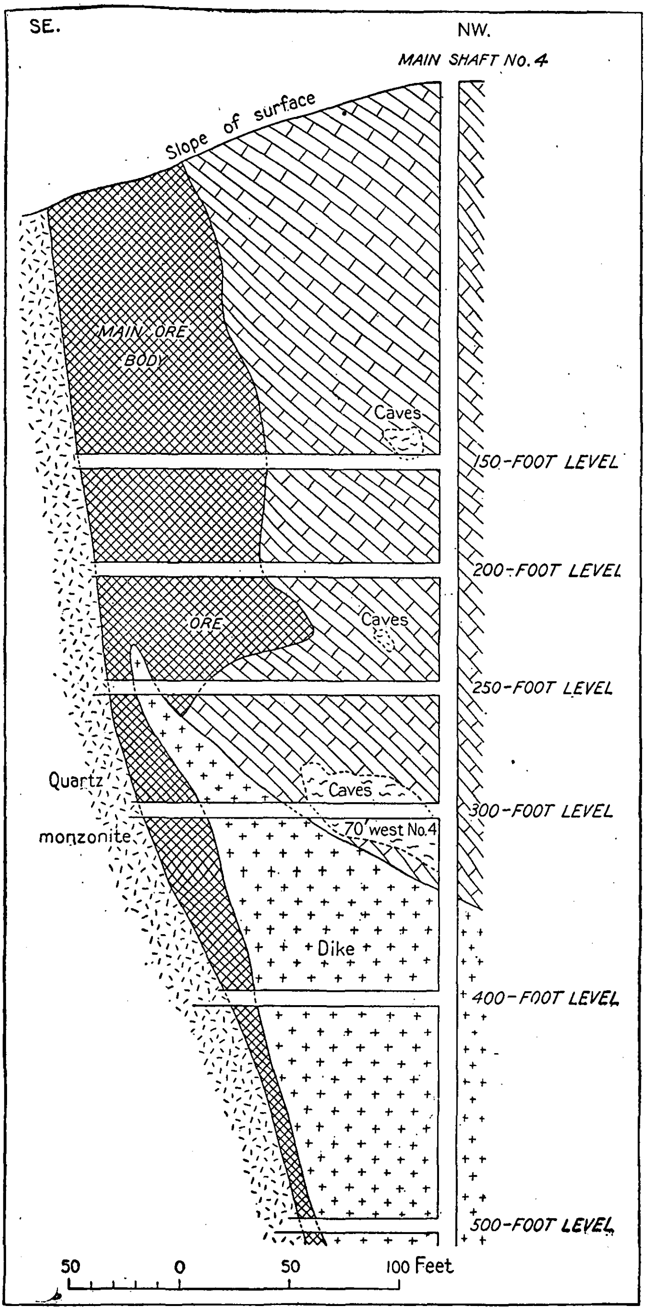


FIGURE 38.—Cross section of Mowry mine, showing fault and vein.

traces of fossils, but most of them are only poorly preserved. These limestones have supplied most of the fossils described on pages 49–51, which fix the age of the rocks as Pennsylvanian.

The limestone is much purer along the north-south fault than away from it, but along the Mowry fault some of the limestone has been metamorphosed to a fine-grained marble. The limestone contains also some interbedded quartzite.

The quartz monzonite south of the Mowry fault is a reddish-gray, massive, porphyritic granitoid rock with phenocrysts of feldspar an inch in diameter. It is composed mainly of orthoclase, oligoclase-andesine, and quartz in about equal amounts, the orthoclase including some microperthite and microcline. Considerable dark silicate is present, some as biotite but most as hornblende, which, however, is nearly all altered to heavy dark-green masses consisting principally of chlorite or allied decomposition products and oxide of iron. Apatite is present as an accessory, and some pyrite, marcasite, and chalcopyrite occur as secondary minerals. The rock on the whole is considerably altered, especially the soda-lime feldspars, which are highly sericitized. The analysis of this rock (No. 2, on p. 61) agrees fairly well with its microscopic determination as a quartz monzonite. It belongs to the Mesozoic intrusive rocks, and is regarded as intrusive into the limestone. Its outcrop belt has a considerable width at Mowry, whence it extends interruptedly southward to the main area of quartz monzonite in the Patagonia Mountains northwest of Washington. For 60 to 100 feet back from the Mowry fault the rock is much altered and stained with iron and manganese, and along the fault it is sheared and crushed, and the nearly parallel shear planes dip steeply to the south away from the fault.

Cropping out at several points in the camp southwest of the mine and seemingly intruding the limestone along the Mowry fault in the deep part of the mine, as shown in figure 38, is a dark-greenish or nearly black massive medium-grained crystalline rock locally known as basalt, and in the mine, where it approximately parallels the fault and vein, it is known as the "500-foot lime dike." Microscopic examination, however, shows it to be an almost typical gabbro. It is composed mainly of labradorite or closely allied basic soda-lime feldspar, augite, or other pyroxene and contains considerable magnetite and iron, some biotite, and seemingly olivine, with accessory apatite. The rock on the whole is highly altered. The augite, whose abundance in places is indicated by the form of the crystal casts, is mostly changed to green amphibole, smaragdite, and chlorite, and the feldspars are greatly kaolinized and altered to epidote. Calcite and magnetite are present as secondary minerals, the former occurring both in isolated crystals or grains and in macroscopic veinlets and seams on joint planes and fracture lines, together with a few seams or veinlets of secondary quartz. The chemical analysis of this rock, given on page 69, showing it to be high in potash, agrees with the microscopic determination of the rock and compares well with the published analyses of gabbros. This gabbro from surface exposures appears to be younger than the quartz monzonite. It is well exposed in the camp southwest of the mine, on the main road about halfway between the Phelps place and Mowry post office, where the quartz monzonite is regarded as the country rock but is covered by wash and débris so that the actual contact between the two rocks is not revealed. It also seems to outcrop at a point about 1¼ miles south of the mine, on the Washington stage road, where the quartz monzonite or a similar granitoid rock is intruded by dikes of a dark rock, which was thought to be the gabbro but which received only a field examination. The gabbro is also said to outcrop at a point about a thousand feet east of the mine, where it is very much altered.

Water was encountered at the 300-foot level in the mine and now stands about 250 feet below the surface. On the 400-foot level the mine makes about 200 gallons of water a minute.

Ore deposits.—The deposits are valuable for their lead and silver content. They occur on the north or hanging-wall side of the Mowry fault, on the contact between the limestone and the quartz monzonite, primarily in a fairly continuous 6 to 8 foot ore body or tabular lode or vein which strikes N. 75° E. and dips 78° N. This is probably the body seen by J. Ross Browne, who visited the mine in 1864 and described the vein as about 4 feet in width.

The croppings, consisting mainly of oxides of manganese and iron, kaolin, and some argentiferous galena, extended interruptedly along the contact fissure for half a mile or more and continuously along the 600-foot stretch now occupied by the mine openings, being especially prominent over the ore bodies. From the surface or base of the croppings the vein extends downward to the bottom of the mine in a continuous tabular sheet and was ore-bearing almost throughout, the ore minerals being lead carbonates and galena. At the mine, therefore, the deposit has a known horizontal extent of 600 feet or more. It is separated from the monzonite footwall by a 2 to 6 foot tabular sheet of argillaceous gouge (fig. 38), whose width, it is said, varies roughly in proportion with that of the adjoining ore body. West of the mine, as shown by openings just beyond the smelter, this ore body has the form of a quartz vein about 8 feet wide.

Most of the ore bodies, however, occur apparently as replacements of the adjoining limestone, principally in an area of crescentic outline in ground plan, with its outer or convex edge extending 100 feet or more back from the fault and fissure into the limestone. In this area the ore bodies occur mainly in the shape of large, nearly vertical lenses lying parallel with the fault contact. The largest body, said to be crudely cylindrical in cross section, is at the intersection of the two faults, mainly east of the north-south fault. Associated with the ore bodies in the upper levels are pockets of cerusite that carry as many ounces in silver as units of lead. Besides these lenticular ore bodies, there are also ore sills or beds from 1 to 10 feet in thickness following the bedding planes in the limestone for several hundred feet from the fault or main bodies. The limestone here dips 45° N., away from the fault. The deposit at the North Mowry mine (p. 305) is regarded as probably one of these sills.

The ore consists mainly of the argentiferous ore minerals, cerusite, coarse galena, anglesite, and bindheimite, all contained in a manganiferous and ferruginous gangue consisting principally of psilomelane and massive pyrolusite and hematite. The manganese and iron together are said to form about one-fifth of the ore body in volume. There is but little if any quartz, and a remarkable feature is the absence of zinc. The ore is mostly oxidized down to or below the 300-foot level, and scarcely any sulphide other than galena, not even pyrite, was found above this level. Copper and iron sulphides first began to appear on the 400-foot level. Much of the ore is a friable argillaceous mixture of silver-bearing cerusite and anglesite, with calcium carbonate, hematite, psilomelane, and pyrolusite, and in many respects is similar to the ore deposits at Leadville, Colo., but the lead carbonates occur also in the indurated siliceous form. The ore is said to become less manganiferous and more siliceous with increasing distance from the gabbro dike.

The galena is in the main coarsely crystalline. It occurs in lenses and masses of considerable size embedded in the manganiferous gangue, and when associated mainly with pyrolusite, as in the lower workings, it is said to form the richest ore, averaging several thousand ounces in silver to the ton. Much of the ore is mottled white, yellow, and greenish, with cerusite and anglesite, bindheimite, and malachite, respectively, and associated with it, beginning on the 300-foot level, is also a little wulfenite. On the 400-foot level vanadinite and arsenopyrite appear. The bindheimite, which is a yellow hydrous antimonate of lead, is apparently a secondary product probably derived from the alteration of jamesonite or possibly some antimonial silver mineral not yet observed in the ore.

At a depth of about 235 feet the limestone gives way to the gabbro, which, as shown in figure 38, becomes the hanging wall and continues as such to the bottom of the mine, the quartz monzonite being the footwall. The vein or ore body in general narrows downward from this depth and seemingly deteriorates in value. In the lower workings the ore is to some extent associated with the gabbro, but it does not maintain the development which it has in the limestone above, nor, to judge from the regularity and apparent smoothness of the hanging wall extending from the 250-foot to the 500-foot level, as shown in figure 38, does the gabbro form by any means as favorable a repository for the deposits as the limestone.

The presence of the gabbro seems to have facilitated oxidation and increased the amount of iron, for between the 200-foot and 300-foot levels the ore, vein matter, gouge, and adjoining wall rock are all highly oxidized and stained red with iron ore. The galena is altered and largely changed to cerusite, which is more plentifully present than it is just above the upper limits of the gabbro. The manganese of the gangue, however, which continues from the surface to the bottom of the mine, is relatively unaffected. The 400-foot level in general is characterized by an abundance of calcite and kaolin, in addition to the usual manganese and iron minerals.

The ore in general, it is said, averages about $40 to the ton, but much of it is very rich, especially the galena ores, which carry about 68 per cent of lead, are variably argentiferous, with 100 to 4,000 ounces of silver to the ton, and contain about $1 to the ton in gold and a trace of copper.

At about the 150-foot level occur several veins or sheets of manganese, which in one place unite and form a large body with a corresponding increase in the amount of good ore.

The main ore body, known as No. 1, of which figure 38 is a cross section, is located at the northeast corner of the intersection of the north-south and Mowry faults. It is roughly pipe-shaped or elliptical in cross section in the upper part of the mine and seemingly terminates just below the 250-foot level or flattens into a tabular sheet but 4 or 5 feet in width in the lower part of the mine. It consists, especially in the upper part of the mine, of alternating vertical coarse bands, tabular sheets, or veins of manganiferous and ferruginous material. Much of the richest ore of the mine came from this body between the surface and the 300-foot level, or about the ground-water line. It contained principally argentiferous galena, which carried about 68 per cent in lead and 400 ounces to the ton in silver, and some samples contained as much as 6,000 ounces of silver to the ton.

Ore body No. 2, shown in part in figure 36, connects with ore body No. 1 just above the 150-foot level and pitches along the dip of the contact at an angle of 40° W. down to about the 315-foot level, where the ore becomes oxidized and leached, like the ore in ore body No. 1. The ores in this body are mainly cerusite and other carbonates of lead, and where mined averaged about 40 per cent in lead and 25 to 300 ounces to the ton in silver.

Ore body No. 3 is opened near the surface, as shown in figure 38, and is also encountered in the deep part of the mine by a crosscut extending westward from shaft No. 4 on the 400-foot level, where it is on the north-south fault. It is similar to ore body No. 2 in consisting mainly of carbonates of lead. It dips west and at the surface connects with ore body No. 4.

Ore body No. 4 contains also lead-silver silicates where the siliceous ores appear.

Source of the ores.—From the nature and structure of the ores and ore bodies and the general absence of the metallic minerals in the surrounding rocks from which they might be segregated, the ores seem most likely to have been deposited by ascending metal-bearing solutions that came up along the Mowry fault. First was deposited the 6-foot tabular vein occupying the fissure next to the quartz monzonite footwall, seemingly as a true fissure vein, and from it ore deposition by metasomatic replacement extended stage by stage northward into the hanging-wall limestone, forming successively the nearly vertical tabular ore shoots or bands alternating with similar intervening bands of the manganese-iron gangue. Where the invading solutions found the limestone easier of penetration and more soluble, as along the bedding planes, they followed or descended these planes, whose dip slope was admirably adapted for facilitating the process, and there formed the ore beds or sills.

As the gabbro seems to be intrusive into the quartz monzonite and into the limestone, the solutions which deposited the ores were probably those that followed its intrusion, a view which seems to find support in the basic nature of the deposits and the paucity or absence of quartz. The solutions were probably thermal and deposited the ores at considerable depth, chiefly as sulphides of lead, manganese, and iron. The ore minerals subsequently became concentrated and oxidized to their present state down to the bottom of the mine. Although, so far as the present examination indicates, it is possible that the ore deposits may be due to the quartz monzonite, the marked difference in the character of the deposits and especially of the gangue and its metamorphic minerals from those of the Washington-Duquesne camp, which owe their origin to the intrusion of the same or a similar quartz monzonite in a similar limestone, strongly suggests that the deposits at the Mowry mine owe their origin to the gabbro.

Future of the mine.—The present company is hopeful of finding good ore bodies in the quartz monzonite by deep sinking and by extending the workings southward, especially on the north-south fault, although, so far as learned, no ore has yet been found in the quartz monzonite in this district. The abundance and purity of the pyrolusite in the gangue suggest that this mineral may prove a useful by-product.

NORTH MOWRY MINE.

The North or Old Mowry mine, which is a part of the Mowry property just described, is about a third of a mile northeast of the Mowry mine, in the east base of Mowry Hill, on open, gently sloping ground at an elevation of about 5,500 feet. It has produced some ore, which was mostly lead carbonates, associated with highly decomposed oxide of manganese and iron. Its deepest opening is a 120-foot shaft. The country rock is the Pennsylvanian limestone, which here is heavy bedded and dips northeastward and in which the deposits occur in one or more of the northward-dipping sills or replacement ore beds that have been described and in joint planes in the adjoining limestone. The sills, which now outcrop at the surface, were probably at one time connected with the Mowry vein at some distance above the present surface, but the connection has since been removed by erosion.

MORNING GLORY MINE.

The Morning Glory mine is 1¼ miles west of the Mowry mine and one-third of a mile southwest of the stage road, on the north side of a shallow gulch that drains northward into Alum Gulch, at an elevation of about 5,600 feet. It is easy of access by a wagon road ascending the gulch. The deposit was discovered late in the eighties by David Neal, who, with A. S. Henderson, soon took out considerable silver ore, which he roasted at Mowry or leached. On reaching the sulphide zone, which then seemed to contain mostly pyrite, he abandoned the mine.

About 1895 or 1896 the mine was relocated by Richard Farrell and wife, from whom it was acquired in 1908 by the present owner, C. B. Wilson, of Helvetia. At the time of visit Mr. Wilson was sinking on the property, which then had about 2,000 tons of low-grade ore blocked out or in sight. Since then the mine has been an almost steady producer on a moderate scale and has shipped during a considerable part of this period two carloads of ore a week. The production in 1907 is given as $13,371 from copper sulphide ore which yielded 54,486 pounds of copper and 3,788 ounces of silver.[1]

Recently the mine is reported to have 50,000 tons of good copper-silver ore blocked out, which is said to average about 75 per cent in iron and sulphur combined, and about 3.5 per cent each in copper and silver.

The mine is opened mainly by a 200-foot shaft, inclined 45°, and contains three levels, 50, 100, and 150 feet below the surface, on which it is developed by shafts and stopes for a horizontal distance of about 200 feet.

The country rock is the Paleozoic limestone, which dips 40° WNW. It is in part silicated, cherty or flinty, and locally pyritic and seemingly contains some interbedded strata of quartzite. It is overlain in the surrounding hills by the Mesozoic sedimentary rocks. Oxi-

[1] U. S. Geol. Survey Mineral Resources, 1907, pt. 1, p. 178, 1908.

dation extends to a depth of about 40 feet. The mine makes about 2,000 gallons of water in 24 hours.

The deposits occur principally in a so-called vein or ore bed, which dips 40° WNW., conformably with the inclosing rocks. The footwall is greenish-gray silicated and in part epidotized limestone or quartzite with very finely disseminated pyrite. The ore bed is from 4 to 10 feet in width and seems to represent a mineralized sheet or sill of intrusive rhyolite or "porphyry," which for the most part has been completely replaced. It contains mainly pyrite and chalcopyrite, with a little chalcocite and in places sphalerite. Some hematite and specularite are present near the surface, where the deposit is crudely banded. The gangue minerals besides the altered rocks are quartz and calcite in moderate amount, with a little barite.

The ore in general is oxidized and principally free-milling down to the 50-foot level, but in the north end of the mine, which contains considerable zinc, oxidation extends much deeper. The ore is chiefly of low grade, but a considerable part of it is said to yield about 17 per cent in copper and 15 ounces to the ton in silver. Some of it carries principally zinc, but the sphalerite seems to be restricted to the upper levels, where in places it constitutes a relatively pure ore containing, it is said, 60 per cent or more in zinc. If smelting facilities were installed in the district or freight rates were slightly lower this ore would be of commercial value for its zinc content.

The ore of this mine is in demand by the smelters in Sonora, across the Mexican boundary, for its sulphide content, which is useful in smelting their more basic ores. During 1912 the ore was being mostly shipped to the Pioneer smelter, at Sahuarita, the owners of which are said to have recently taken a bond on the property.

Besides the ore bed above described, which has been the source of the ore produced, there is also near the bottom of the shaft a younger undeveloped 4-foot vein which dips 45° S. and cuts the ore bed diagonally. This vein contains ore similar to that of the ore bed except that it averages a little higher in copper and carries but little zinc.

The ore was probably formed by hydrothermal solutions that accompanied or followed the intrusion of the rhyolite, which occurs near by in dikes and masses.

ENDLESS CHAIN MINE.

The Endless Chain mine, consisting of a group of claims and openings, is one-third of a mile north of the Morning Glory mine, in the side of a similar open gulch about a quarter of a mile west of the stage road, at an elevation of 5,400 feet. It is owned by the Endless Chain Mining Co. of Oklahoma and has shipped some ore. The deposits occur mainly in what seems to be a 2½-foot ore bed in Paleozoic slaty, dense light-gray brecciated pyritic quartzite, dipping 70° SE. They are opened by an inclined shaft and drifts and a little farther downstream by a tunnel, called the Cunningham tunnel. The ore contains chalcopyrite, pyrite, some tetrahedrite, and a little chalcocite. Some of it is banded.

AUGUSTA MINE.

The Augusta mine is 1¾ miles northwest of Mowry, about 750 feet west of the stage road. The deposit was discovered in 1878 and relocated in 1905. It is opened by a 110-foot shaft and contains some drifts. Ore shows in some of the workings. The deposit is a sort of compound vein or group of parallel stringers. Some chloriding has been done here. The known production is about 100 tons of ore said to average about 57 per cent in lead, 10 per cent in zinc, and 40 ounces in silver and $3.50 in gold to the ton.

O'MARA MINE.

The O'Mara or Old Soldier mine is located in the north-central part of the district, about 3½ miles west of Mowry, on the west slope of the Patagonia Mountains, in the northwest side of the head of Canada de la Paloma, at an elevation of 5,500 feet. It is connected by a good trail with the stage road 2½ miles distant on the east. The camp is about half a mile southeast of the mine and 450 feet lower in the bottom of the canyon.

The mine was first worked in 1888. It is now owned and is being worked in a small way by the Chicago & Patagonia Copper & Gold Mining Co., with headquarters at Chicago and Nogales. The property comprises a group of 19 claims covering the north head of Canada de la Paloma. It was idle in 1909.

The mine contains about 2,000 feet of development work and is opened to a depth of 188 feet by two shafts, 200 feet of drifts on the 80 and 180 foot levels, a 187-foot crosscut on the 180-foot level, and several winzes, as shown in figure 39. The main shaft is 250 feet south of the vein on its hanging-wall side. The second shaft, 140 feet deep, is sunk on an incline 70° SE., following the vein.

The deposits occur in a 5-foot vein near the middle of a lentil of quartz monzonite 1 mile wide, intruded into the much larger body of the older quartz monzonite that occupies the basin-like head of the valley on the east and the mountains to the northwest. Fibrous black tourmaline intergrown with quartz is developed along the contact of the two rocks, mainly in the older. The intrusive is a fine-grained granitoid rock composed of orthoclase and andesine-labradorite in about equal amounts, with quartz, biotite, hornblende, a little magnetite, and secondary chlorite, hematite, and epidote. Water is encountered at about the 100-foot level. On the 80-foot level the vein is offset by a seemingly almost flat-lying fault above which the rocks have been moved 12 feet or more to the northwest, the fault being normal.

The vein contains principally quartz banded with pyrite, chalcopyrite, and bornite, and these sulphides also impregnate the wall rock. The ore is said to average $10 to $20 to the ton in gold, silver, and copper. About 80 tons of the ore lies on the dumps. Some of it shows excellent intergrowths of pyrite and quartz. The croppings are mostly not prominent. The latest work is an 80-foot shaft sunk in the gulch to the east of and 300 feet lower than the mine. It is said to expose a 5-foot vein, which lies about parallel with the main vein in the mine and contains similar pyrite-chalcopyrite ore,

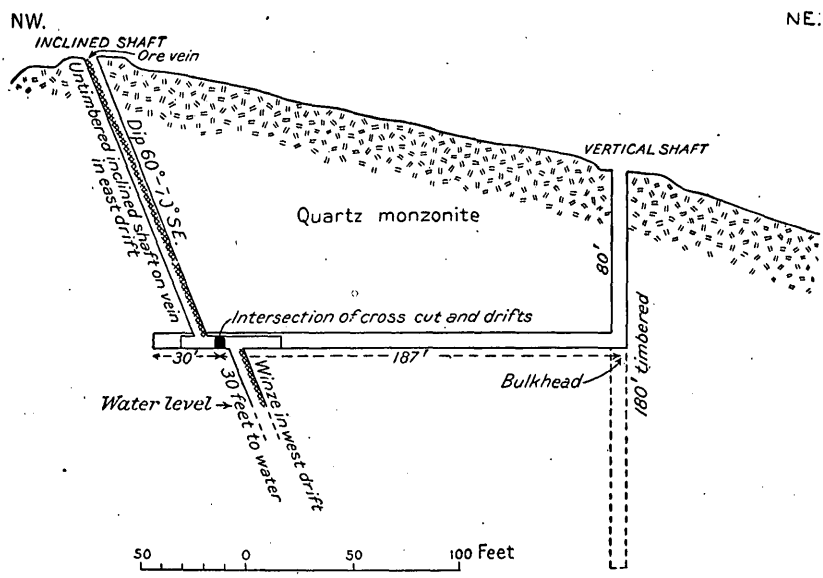


FIGURE 39.—Cross section of O'Mara mine and vein.

which assays 10 per cent in copper and 21 ounces in silver and $2 in gold to the ton. The deposits were probably formed by hydrothermal solutions that circulated soon after the intrusion of the quartz monzonite, or they may be due to the later granite porphyry, large areas of which, as shown in Plate II (in pocket), occur about 1¾ miles distant on the northeast and the southwest.

MAY PROSPECT.

The May prospect, belonging to S. M. Bailey, of Nogales, is in the border of the granite porphyry outcrop farther downstream on the south side of Canada de la Paloma, at an elevation of 4,500 feet. It is opened by a short tunnel on a fault in the granite porphyry that strikes N. 85° W. but shows no mineralization. The fissure is filled with yellowish gouge about 4 inches wide and dips 50° W. The tunnel was driven on the supposed favorable indications of a small pocket of galena found in an open cut in a north-south fissure at the surface.

NATIONAL MINE.

The National mine is 1¾ miles southwest of the O'Mara mine, in the western foothills of the Patagonia Range, on the north bank of Canada de la Paloma, at an elevation of about 4,500 feet. It is at the north end of a series of properties comprised in a belt about a mile wide, which extends from this point southward through the foothills across Paloma, Wild Hog (Jabalina), and Providencia canyons for a distance of 2½ miles and which may be referred to as the Gross belt. The deposits are mainly lead-silver veins, which strike east at about right angles to the axis of the range. They occur chiefly in the granite porphyry which occupies most of the foothills as far as Providencia Canyon, the underlying diorite cropping out in several places. The Gross and Golden Rose camps, the principal settlements, are located respectively near the middle of the western border of the belt on Wild Hog Canyon and near its south-central part on Providencia Canyon. They are reached by a wagon road ascending the canyons and connecting with Nogales, the principal supply point, 14 miles to the southwest.

The topography of the belt is rough, but the properties are mostly accessible with wagon by way of the washes or canyons from the west. The belt and its foothills are separated from the main mass and steep slope of the range by a sort of piedmont valley or longitudinal pass which extends northward for 6 miles to and beyond the Jarilla mine and seems to represent the line of a piedmont fault along which the range has been uplifted on the east. This valley naturally facilitates transportation in a north-south direction along the range.

The discovery and location of the principal veins in this belt began about 1899 or 1900, a leading pioneer in the work being George Gross, at present an extensive operator. About the only patented claim in the belt is the Providencia claim, near the Golden Rose mine, in the southern part of the belt, of which the Wilson, Moody & Morris property is an extension.

The National mine is at the foot of the mountain side, in less steeply sloping ground. It has been a moderate producer and shipped six carloads of ore in 1907. At the time of visit about 20 tons of ore lay on the dump. The mine is mainly in coarse granite porphyry near the contact of that rock with the diorite which it intrudes, and which, in turn, is intrusive into quartz monzonite, that crops out near by on the northeast.

The mine is opened by a 200-foot vertical shaft which contains about 400 feet of drifts and is equipped with a gasoline hoist. The vein dips 70° S. and is associated with the granite porphyry contact. The ore on the dump shows a considerable quantity of copper minerals, and the ore is said to become copper ore in depth.

The National No. 4 prospect, a few hundred yards to the south of the mine on the opposite side of Canada de la Paloma, in the brow of the hill, is opened by a 90-foot drift and a 90-foot inclined winze and shows a 2-foot siliceous galena-silver vein which dips 50° S. in the granite porphyry and is partly associated with a fault-shear zone. The gangue in this vein is principally firmly cemented quartz breccia. The ore, some of which lay on the dump, is said to assay 65 per cent in lead and 60 ounces to the ton in silver. The croppings about 35 feet south of the tunnel mouth are considerably iron stained.

ISABELLA MINE.

The Isabella mine is about half a mile north of the Gross camp, on the National mine trail, at an elevation of about 4,400 feet, at the head of Wild Hog Canyon, in the southerly slope of a long east-west ridge. It was located in June, 1904, by the owners, E. E. Bethell and partners. It is on a 2½-foot east-west vertical quartz vein between granite porphyry on the north and diorite on the south. Both of these rocks are altered near the vein, which is traceable on the surface by croppings and openings for nearly half a mile. The croppings consist of drusy banded quartz with limonite, psilomelane, and what appears to be earthy lead carbonate. The developments comprise cuts and shallow shafts. Some ore on the dump of a 50-foot shaft, sunk on the vein on the Victor or west claim, contains a little galena.

CHANCE PROSPECT.

The Chance prospect, owned by the Jabalina Mining Co., is east of the Isabella mine. It is opened by a 150-foot tunnel and a 50-foot shaft.

SHAMROCK PROSPECT.

The Shamrock or Gross Gold Vein prospect, owned by George Gross, is in the upper part of Wild Hog Canyon one-eighth of a mile north of the Gross camp, at the point where the trail to the National mine leaves the gulch. It is opened by a 140-foot tunnel, a drift, an upraise, and a 40-foot shaft. The deposits occur in a quartz vein which dips 60° SE. and lies mainly in intrusive granite porphyry near the contact with the diorite, which is exposed at places in the footwall. The vein contains quartz and crushed altered rock stained reddish with limonite and manganese oxide and is said to have yielded very rich gold-silver ore near the surface.

JABALINA PROSPECT.

Starting in Wild Hog Canyon at the Gross camp, at an elevation of about 4,300 feet, the Jabalina vein extends eastward through the adjoining hills for a quarter of a mile or more in granite porphyry, the croppings being exposed through a vertical range of about 200 feet. The sheeting structure in the containing granite porphyry dips to the east-southeast. Where opened by a 25-foot shaft near the top of the hill adjoining the canyon the vein dips steeply to the south. The vein is 9 feet in width and is composed of coarsely banded mineralized brecciated quartz, altered rock, and ore carrying lead and silver. About 5 tons of ore resembling that at the Shamrock prospect, just described, lies on the dump. Much of it is stained black with manganese and some is coated with greenish and brownish crystalline pyromorphite.

BIG LEAD MINE.

The Big Lead mine, also known as the W., M. & M. mine, is in an east-west gulch half a mile south-southeast of the Gross camp, on a granite porphyry dike and shear zone cutting the diorite. It is opened by shafts and drifts. The lode is about 25 feet wide and contains a 3½-foot vein. It strikes N. 75° E. and stands about vertical, the dip being steep to the south near the surface and steep to the north in the bottom of a 75-foot shaft. The ore occurs in shoots about 5 inches in width in which the ore minerals are chiefly galena and chalcopyrite with associated silver and gold, contained in a quartz gangue.

The San Joaquin prospects, seemingly on this same vein farther west, are said to be opened by 500 feet of work, including a 160-foot tunnel.

SPECULARITE PROSPECT.

A prospect about three-fourths of a mile west of the Golden Rose mine, seemingly in the diorite, consists mainly of deposits of specularite, which occurs plentifully in large bunches mixed with a more or less siliceous gangue and is suitable for fluxing, for which it is utilized.

GOLDEN ROSE MINE.

The Golden Rose mine is located in the south-central part of the belt, about a quarter of a mile north of the Golden Rose camp, at an elevation of about 4,500 feet. It is 250 feet above Providencia Canyon, a quarter of a mile to the southeast, and is reached by a wagon road of easy grade. It is owned by the Greenwell-Arizona Mining Co., with headquarters at Wooster, Ohio, and Nogales. It has been working steadily for some time with a small force of men and has made shipments of ore. The company is planning to install a 50-ton concentrator.

The property contains three claims. It is opened by a 100-foot shaft and a few hundred feet of drifts and crosscuts, giving 150 feet of backs, and has a whip hoist. There is a small supply of good water in the canyon above the camp.

The deposits are contained in a 16 to 20 foot lode which strikes N. 70° E. and dips 80° S. in fine-grained dark iron-gray quartz diorite. Granite porphyry is intruded into the diorite on the east, toward Providencia Canyon, and to the intrusion the deposits probably owe their origin. The diorite at the surface is weathered down.

The lode is composed of quartz, altered rock, and ore. The main ore shoot within the lode is said to average 3 feet in width and in places is 12 feet in width. The ore contains gold, silver, lead, and copper minerals in a crudely banded gangue of quartz and altered rock which is more or less porous and honeycombed. It is said to average $12.50 to the ton. The principal sulphide minerals noted are chalcopyrite, galena, and stephanite. Some pyrite and a little specularite are also present. The microscope shows some of the ore to be very closely banded, with bands consisting mostly of quartz, about one-fortieth of an inch in width, alternating with similar ones composed principally of the metallic minerals.

BENNETT MINE.

The Bennett mine is a quarter of a mile southeast of the Golden Rose mine, in the southeast bank of Providencia Canyon, at an elevation of about 4,300 feet and is easy of access. It is opened principally by a 200-foot shaft and a short tunnel drift. It is on an east-west fault fissure in quartz monzonite, which is intruded by diorite. In the quartz vein contained in the fissure the ore occurs in fairly persistent stringers and shoots, ranging from 1 to 4 inches in width, and consists mainly of coarse massive pyrite and chalcopyrite freely banded with quartz.

GROSS COPPER PROSPECT.

At and in the hill northeast of the Bennett mine and in fact occupying the northwestern part of the triangular area bounded by Sycamore Canyon on the south and east and Providencia Canyon on the northwest, just across Providencia Canyon from the Golden Rose mine, the quartz monzonite which is reddish, medium to coarse grained, and somewhat sheared, is impregnated with evenly disseminated small crystals, masses, and grains of chalcopyrite and pyrite and contains sparingly also molybdenite, which has much the same habit as the other minerals. These minerals seem to be primary and of magmatic origin. They are very persistent throughout the mile or more of the northwest slope of the mountain examined opposite the Golden Rose mine, where in prospecting for copper the ground has been opened at intervals by shafts and tunnels from 10 to 80 feet in depth, and the same conditions are reported to prevail over most of the area above described, which occupies 2 square miles or more, with the surface rising 800 feet above the canyon.

The Gross copper prospect occurs in this formation at the mouth of Guajolote Canyon about 1¼ miles northeast of the Golden Rose mine. It was opened by a shaft 80 feet deep, which was sunk in the quartz monzonite with the hope of finding the copper minerals more concentrated at depth, and in October, 1914, valuable discoveries of extensive copper deposits were reported to have been made.

BUENA VISTA MINE.

The Buena Vista mine is half a mile southeast of the Bennett mine in a south branch of Providencia Canyon, at an elevation of about 4,800 feet. The vein was located in 1895 by Michael Maloney, who shipped about 500 tons of ore that is reported to have averaged 28 per cent in copper and 20 ounces in silver and $2 in gold to the ton;[1] also 24 tons of ore which gave 120 ounces to the ton in silver and 30 per cent in lead. These shipments were made in 1897–98. In 1900, Mr. Maloney sold the mine to the Black Mountain Mining Co. of Prieto, Mexico. It has since become the property of the Banco del Oro Mining Co., of Magdalena, Sonora, Mexico, with headquarters in Chicago. The property contains four claims, on which this company has done considerable development work, and in 1909 there was about 20 tons of ore in the bins ready for shipment.

The property is developed by about 4,000 feet of work contained in three tunnels and their winzes on suitably spaced levels between elevations of about 4,700 and 5,000 feet, as shown in figure 40. Two of the tunnels, of which the lower is 415 feet in length and the other 670 feet, are drifts on the main vein. The other is a crosscut which opens a parallel vein.

The deposits occur in half a dozen or more quartz veins and associated bands of crushed mineralized rock, all contained in a fault shear zone in the quartz monzonite, with intrusive diorite cropping out 400 feet to the northeast of the lower tunnel and granite porphyry near by.

The veins and shear zone dip about 60° SE. The main vein is shown in the lower drift, driven in the granite footwall of the zone, at an elevation of 4,755 feet.

The 140-foot crosscut tunnel, situated 300 feet northeast and 50 feet above the lower drift, besides crossing numerous small fissures and

[1] Oral communication from J. A. Straith.

mineralized slips, shows in the face a 4-foot iron-stained zone of crushed granite and quartz carrying pyrite, chalcopyrite, and a little molybdenite.

The vein in the upper tunnel, which is about 145 feet above the lower tunnel and 100 feet below the crest of the ridge, varies from 2 to 6 feet in width and is separated from the granitic country rock by gouge. It is filled mainly with quartz and calcite, containing pyrite, chalcopyrite, and bornite, and small amounts of azurite and malachite are seen in the gouge material. Besides copper the ore is said to carry gold and silver.[1] In the vein the metallic minerals are

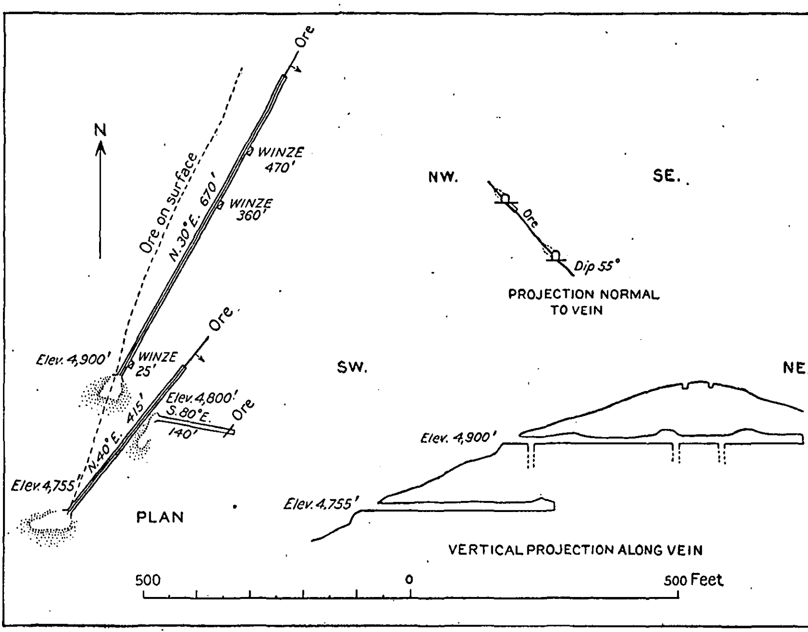


FIGURE 40.—Plan and projections of Buena Vista mine.

found next to the walls and favor the hanging wall, and accordingly they were deposited during the early stages of fissure filling. The pyrite and chalcopyrite are coated with black sulphide of copper and in places show the iridescent colors of covellite. Copper and iron sulphates are being deposited in the workings. In the face of the drift the wall rock is sheared and altered and contains disseminated pyrite. The drift contains some stoping at various points and three inclined winzes sunk on the vein to depths of 40 to 100 feet. Some surface work in the saddle above the drift shows a strong quartz vein with galena and a little chalcopyrite. A tunnel (not visited) to the north of the saddle is located on the same vein.

[1] Report of the Governor of Arizona, 1903, p. 112.

KING PROSPECT.

The King prospect is half a mile northeast of the Buena Vista mine and about a quarter of a mile south of Providencia Canyon. It is opened mainly by a 40-foot shaft and a drift. The drift was not enterable but to judge from the size of the dump must be extensive. The deposits apparently occur in a 10-inch iron-stained banded quartz vein which dips 70° SE. in coarse quartz monzonite and which as seen in the shaft carries pyrite, chalcopyrite, and bornite, with some malachite and azurite, extending to a depth of 15 feet below the surface. About 5 tons of copper ore containing principally these minerals lies on the dump.

MARCHÉ PROSPECT.

The Marché prospect is in Providencia Canyon, one-eighth of a mile northeast of the King prospect and 1½ miles east of the Golden Rose camp, at an elevation of about 4,550 feet. It is opened by two tunnel drifts driven in opposite directions on different sides of the gulch, of which the southerly one is 90 feet in length. It is on a 2-foot quartz vein which dips 35° SE. in quartz monzonite. The vein is composed mainly of iron-stained quartz and crushed rock or gouge and contains some malachite and azurite. No sulphides were noted.

GLADSTONE PROSPECT.

The Gladstone prospect is on the north side of Providencia Canyon about half a mile northeast of the Marché prospect, at an elevation of about 4,700 feet. The property comprises a group of claims. It is opened by a shaft near the center of the group and is said to have shipped a number of tons of ore, containing mainly chalcopyrite and black copper sulphide, that averaged 28 per cent in copper.

PROTO MINE.

On leaving the foothill or Gross belt just described and ascending the slope which rises eastward to Guajolote Flat, the observer encounters a different set of fissures and veins which strike more nearly north, almost at right angles to the course of the veins in the Gross belt. In the quartz monzonite ridge, followed by the trail leading from the Gladstone prospect northward up to Guajolote Flat, there are distributed through a distance of 1¼ miles in a vertical range of 1,000 feet half a dozen or more mines and prospects, including the Proto mine, located just west of the trail at about the 5,000-foot contour. This mine is opened by a series of tunnels and shafts. It is on a 2½ to 5 foot vein which dips 80° E. into the mountain, with a dike or intrusive mass of diorite forming the footwall and the quartz monzonite country rock the hanging wall. The vein at the surface is highly iron-stained. The principal ore mineral is chalcopyrite. One of the shafts, which is 100 feet or more deep, contains water. Openings of considerable extent, seen across the broad head of the canyon to the north but not visited, seem to be on this same vein.

FOUR METALS MINE.

Location.—The Four Metals mine is a mile east of the Proto mine, in the head of Providencia Canyon on its north side, on the south edge of Guajolote Flat, at an elevation of about 5,400 feet. It is 3 miles northwest of Washington and 2½ miles southwest of Mowry. The camp, which is a village of about 100 Mexican laborers and a few whites, is three-fourths of a mile to the north, on Guajolote Flat, at an elevation of 5,800 feet. Two good wagon roads connect the camp with the stage road 2 miles distant on the east, one at a point half a mile south and the other at a point a mile northwest of Mowry, and by the latter road Patagonia, on the railroad, is 16 miles distant. Nogales is 13 miles west of the mine, and the Washington-Nogales wagon road is half a mile away.

History and production.—The deposit, known as the Guajolote lode, was discovered by pioneers in the sixties or before, but not developed for some time. Browne [1] states:

> The Guajolote lode, 4 miles west of the Mowry mines, is a lode varying from 1 to 6 feet in width on the surface. At the bottom of a shaft of 60 feet there is a vein of metal 3 feet wide. The ore is chiefly sulphurets of silver and there are traces of gold.

Later the property was owned by George Gross, from whom it was bought about 1904 by the present owner, the Four Metals Mining Có. of Arizona, with headquarters at Mowry, Ariz., and Blandinsville, Ill. In the following year this company opened it with over 2,000 feet of work.[2]

In 1906 a shipment of ore containing copper, gold, and silver was made,[3] and beginning in 1907 more extensive development work was done, including the driving of the Red Hill 712-foot lower crosscut tunnel, cutting the vein, and the taking out of considerable low-grade ore, of which several thousand tons now lies on the dump. During the winter of 1908–9 80 men were employed at the mine. Since that time some work has been carried on intermittently by two small forces of men. The property comprises a group of 35 claims.

Developments and equipment.—The mine is developed by about 3,000 feet of work, consisting mainly of crosscut tunnels, two of

[1] Browne, J. R., Mineral resources of the States and Territories west of the Rocky Mountains, 1867, p. 449, 1868.
[2] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1905, p. 156, 1906.
[3] Idem, 1906, p. 171, 1907.

which, connected by an upraise, extend north and south for more than 1,200 feet through the hill, as shown in figure 41.

The company buildings accommodate 20 men, and the camp contains Mexican buildings sufficient for about 150 persons. Water for domestic use and for stock is supplied by a 20-foot well, and much of the oak timber on the flat is suitable for mine use.

Topography and geology.—The mine is in a small hill, known as Four Metals Hill (fig. 41), surmounting a steep ridge which descends from the Guajolote Flat 1,000 feet southeastward into the head of Providencia Canyon in the horizontal distance of three-

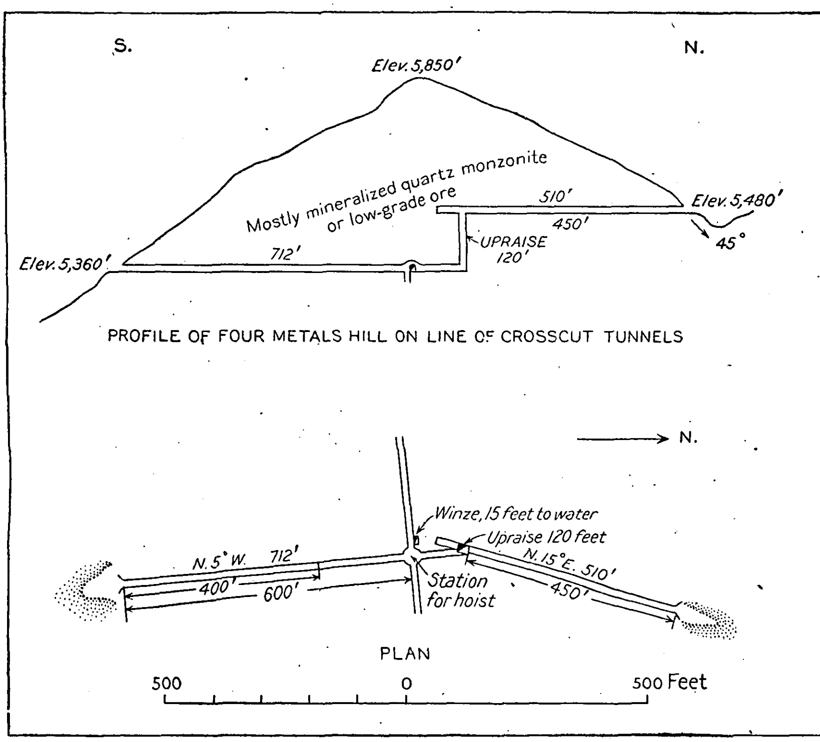
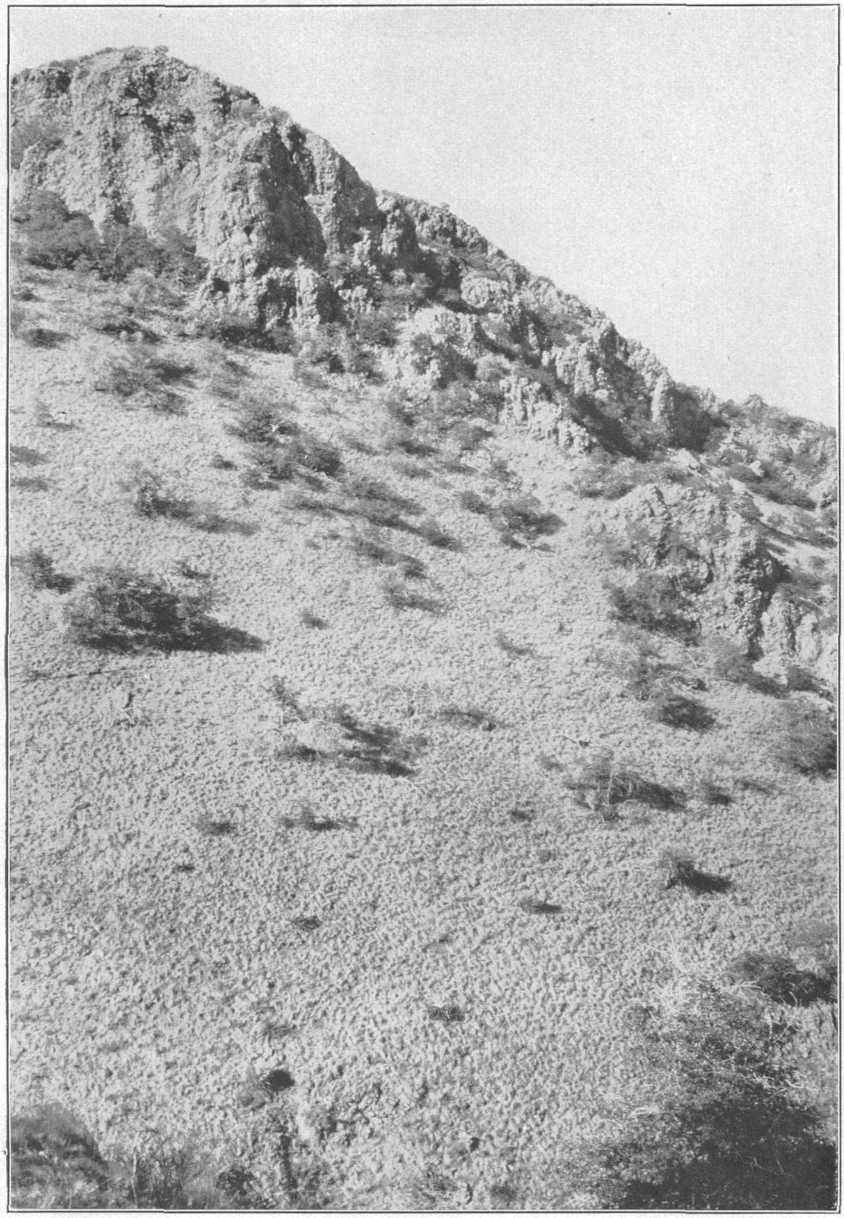


FIGURE 41.—Profile and plan of Four Metals mine.

fourths of a mile. On the northeast the hill and the ridge are separated from the mountain mass by a tributary gulch about 300 feet deep; on the south the surface from the top of the hill declines steeply 950 feet into the canyon in a horizontal distance of a third of a mile, or at an angle of about 27°. The hill is slightly oblong parallel with the ridge, with a basal or shorter diameter of about 1,200 feet, as shown in figure 41.

The deposit occurs in a stocklike body of the younger quartz monzonite or "porphyry," which forms Four Metals Hill and intrudes the older quartz monzonite. The intrusive quartz monzonite is the usual reddish-gray granitoid rock described on page 64. It



CROPPINGS OF COPPER DEPOSITS OF FOUR METALS MINE.

In mineralized shear zone in quartz monzonite. Looking northeast.

is granular and medium grained and is composed mainly of oligoclase and orthoclase in about equal amounts, with considerable biotite, magnetite, some hornblende, and quartz. It is intruded in the south fault zone of the Guajolote block, where it, together with some of the adjoining older quartz monzonite, has since been profoundly sheeted, shattered, crushed, and mineralized. As shown in Plate XXIII, it is sliced by a dominant east-west vertical sheeting about parallel with the fault scarp. Underground it is shattered and traversed by fissures, seams, and fractures trending in almost every direction, and these are largely filled by pyrite and chalcopyrite to such an extent that the rock mass as a whole forms a sort of breccia cemented by the iron content. It is stained a brilliant red on the weathered surface.

In the south or lower tunnel water and soft ground requiring heavy timbering were encountered at a kind of contact dipping to the north at 400 feet in from the mouth, beyond which to the face the intrusive rock is practically all very low-grade ore. Water stands near the top of the 15-foot winze sunk from this level.

Ore deposits.—The deposits are copper-bearing ores, occurring in the mineralized intrusive quartz monzonite. The ore minerals are principally chalcopyrite, with some secondary chalcocite and considerable pyrite, most of which is probably cupriferous. The deposits occur in the form of subordinate veins, lenses, stringers, and seams in the fissures, joints, sheeting planes, and other fractures in the rock, and also to a large extent as metasomatic replacement deposits in the body of the rock itself, notably in the walls of the fissures and fractures, where solid bodies or pockets of relatively pure metallic minerals are of common occurrence. The principal gangue mineral besides the altered rock and pyrite is quartz, which, however, is only sparingly present. The entire hill, 1,200 feet or more in width and 2,000 feet in length, is more or less mineralized and contains a large amount of low-grade ore, as shown by the crosscut tunnels indicated in figure 41. The mineralization extends through a known vertical range of nearly 400 feet, from the croppings at the top of the hill, shown in figure 41 and Plate XXIII, to and below the deepest workings or winzes sunk from the lower tunnel, where the geologic conditions show it continuing downward without diminution. From the intrusive nature of the containing rock and the profoundness of the disturbance it is inferred that the additional downward extent is considerable, probably several hundred feet below the present lower workings.

The entire volume of the hill, however, is not of workable grade, for, as seen in the forepart of the main tunnels, the mineralization is in places sporadic. The best showings are contained in a central belt or zone about 500 feet in width, extending from a point about

300 feet in from the mouth of the south or lower tunnel to a point somewhat north of the upraise in the north or upper tunnel. From the south edge of this belt, as shown in the lower tunnel, the mineralization is practically continuous for 300 feet to the station room, where a winze is sunk, and also the portion of the zone lying in and near the upraise 100 feet to the north. The drifts extend north and south on a more concentrated portion of the zone, called a vein.

From the conditions in the forepart of the tunnels it is inferred that the metallic contents are probably somewhat leached in the upper part of the hill, but not to any great extent, for the sulphides appear prominently in the croppings at the top of the hill.

The value of the ore lies solely in copper, which occurs principally in the chalcopyrite, to a small extent in the secondary chalcocite, and seemingly to some though probably less extent in the cupriferous pyrite. The chalcopyrite and pyrite occur mostly in the massive and finely crystalline form, but a little is coarsely crystalline, with crystals measuring as much as 0.7 inch on the edge of the cube. The ore contains also a little gold, lead, and silver, but not in workable quantity. A little magnetite is also present, but may be derived principally from the quartz monzonite.

Though the deposits occur in the quartz monzonite, their ore minerals are not primary in this rock as are apparently those in the quartz monzonite near the Bennett mine, already described. They were formed by infiltrating mineral-bearing solutions after the shattering of the quartz monzonite by the uplift of the Guajolote fault block. That meteoric waters have played an important part, at least in the concentration of the veinlike portions of the deposits contained in the fissures and fractures, there is no doubt, but the evidence of metasomatic replacement afforded, for instance, by bands or lenses of ore several inches in width and a number of feet in extent, wholly or in part replacing the hard wall rock, seems to indicate that hydrothermal solutions were probably a factor in the origin of some of the deposits. These solutions may have been associated with the intrusive quartz monzonite magma, or with later intrusions of granite porphyry or rhyolite. Rhyolite intrudes the quartz monzonite at a point half a mile north of the mine. Some of the altered rock seen in the forepart of the north tunnel was provisionally recorded in the field notes as granite porphyry, but it received no further examination.

WINIFRED MINE.

The Winifred mine is 1¼ miles east of the Four Metals mine, 2 miles northwest of Washington, and 3½ miles south-southwest of Mowry, in the head of a small canyon at the southwest head of Mowry Wash, at an elevation of about 6,000 feet. It is connected by wagon road with the Guajolote road, a mile distant on the north.

CLAIM MAP OF DUQUESNE MINES AND PROPERTIES.

It is owned by the Four Metals Mining Co., which purchased it from George Gross in 1905. It is developed by 1,000 feet of tunnels, drifts, and stopes, mostly on the lower level, at an elevation of about 5,725 feet. The lower level contains a 415-foot tunnel driven to the south with 175 feet of drift in which there is a 60-foot winze.

The country rock is the Paleozoic quartzite and shale, which is intruded and overlain by a much-altered vitreous rhyolite porphyry. In the face of the tunnel appears also a dark basic altered intrusive rock, seemingly andesite or diorite, which contains considerable hornblende and magnetite.

The deposits, so far as seen in this work, occur in the upper workings in an irregular, nearly flat-lying body or ore bed, a little to the northwest of and 200 feet above the mouth of the lower tunnel. The ore body dips 20° ENE. and is interbedded in the silicified sedimentary rocks and capped by the rhyolite. It contains mainly limonite, together with the ore minerals malachite, azurite, and cuprite, in a banded quartz gangue. In 1904 Mr. Gross, it is said, shipped from it a carload of ore which averaged 80 per cent in copper.

The lower workings are principally in altered rhyolite, underlain by quartzite and traversed by several north-south fissures and an east-west fault which is followed by the drift. They show no indication of mineralization other than a little iron stain on the gouge of the east-west fault, which is about 7 inches in width.

DUQUESNE-WASHINGTON CAMP.

LOCATION AND GENERAL FEATURES.

The Duquesne mines, also known as the Westinghouse mines, are located at the Washington and Duquesne camps in the western part of the Patagonia district, about 3 miles south of Mowry and the same distance north of the Mexican boundary. They are situated on the lower eastern slope of the Patagonia Mountains at an elevation of about 5,500 feet. The camps, shown in Plate XX, are three-quarters of a mile apart. The property comprises 80 claims, of which 42 are patented, and covers 1,600 acres of mining ground. It includes about half a dozen mines and a large reduction plant and extends beyond Washington on the north and to points about a mile west and southwest of Duquesne on the south (Pl. XXIV). Washington is the older of the camps, and the area for the last 30 years or more has been known to the mining world as the Washington camp or district. For convenience of reference the area as a whole will here be called the Washington-Duquesne camp.

The property is chiefly owned by the Duquesne Mining & Reduction Co. of Pittsburgh, Pa. The local headquarters of the company are at Duquesne, and the reduction plant is at Washington (Pl. XX).

HISTORY AND PRODUCTION.

Mineral deposits were found here in the early Mexican days, when some of the ore was treated in a few arrastres just across the Mexican border in Sonora. The ruins of an old adobe smelter used in those days stand in the southern part of the camp on the trail between the Belmont mine and San Antonio Pass. The ore body of the San Antonio mine, near the south end of the camp, was discovered in 1862.[1]

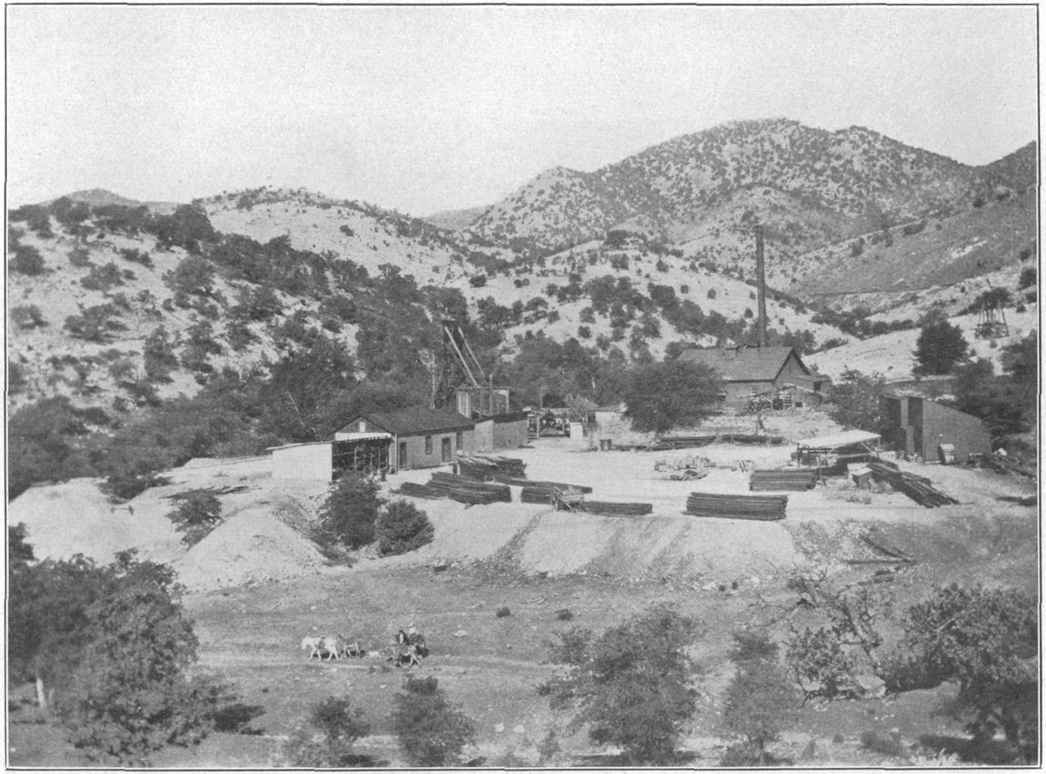
A few white pioneers were settled in the camp in the early seventies or before, Thomas Gardner being among the earliest. In the middle or late seventies considerable work was done in places for the surface silver ore, but as the ores in depth became basic or sulphide ores with copper and zinc, the workings were largely abandoned and quiescence followed for about 20 years, until late in the nineties, when the possibilities of the camp for copper attracted attention. The history of the camp is essentially the history of the Pride of the West and Bonanza mines, and, therefore, the historical sketch of these two mines is given here. The two oldest claims in the camp are the Empire and San Antonio, which were patented in 1870 and 1872, respectively. The Belmont claim is one of the oldest producers. Ore from it was smelted in the adobe smelter south of Duquesne. The present company in the early eighties purchased the Pluto and Illinois claims and later many others, among them the Bonanza in 1889.

The Bonanza mine (Pl. XXV), situated just north of Duquesne, was discovered and located by Thomas Shane and N. H. Chapin in the early eighties or before. They sold the mine to a Mr. Hensley, who discovered a large body of high-grade carbonate ore at a depth of 40 feet but made no shipments worthy of note. About 1889 he sold the mine to the Duquesne Co., which operated it for two years, until sulphide or basic ore was encountered at depth, and then endeavored to discover a process to treat the ore successfully.

In 1896 the company leased a small furnace in El Paso, in which carbonate ores taken from the 40, 60, and 70 foot levels of the Bonanza shaft were treated for about five months, 200 carloads in all being shipped, but when sulphides were encountered in the lower workings the smelter was shut down.

The company resumed operations at the mine about 1899, and continued for a period of about three years, during which the Bonanza shaft was enlarged and sunk to the 635-foot level. Considerable drifting was done, and several thousand tons of ore was taken out, most of which lies on the dump. In 1905 the company acquired the Holland, and in 1906 the Belmont and Pride of the West mines.

[1] Browne, J. R., Mineral resources of the States and Territories west of the Rocky Mountains, 1867, p. 448, 1868.



BONANZA MINE, LOOKING S. 70° W.

The Pride of the West, formerly known as the Washington mine, is one-third of a mile southwest of Washington (Pl. XX). It was located about 1880 by a party of prospectors, who soon began to develop it. Very early in the eighties they leased it to a Mr. Salisbury, who took out considerable ore, which he treated in his smelter at Benson, and from this time on the mine was worked steadily for some years. Later W. A. Clark took a bond on the mine, sunk the Giroux shaft, did other development work, and took out ore occasionally. In 1898 N. H. Chapin leased from his partners their interest in the mine, and for a period of three months shipped daily to the Silver City smelter 30 tons of ore that averaged 12 per cent in copper, or an aggregate of about 3,000 tons. In the early part of 1899, according to Blake,[1] 5,000 tons of ore were shipped and 200,000 tons were blocked out in the mine.

Beginning in April, 1899, C. R. Wilfley, taking an option on a half interest in the mine and purchasing the other half, mined and shipped ore at about the same rate as Chapin had for a like period of three months and then began building a 50-ton mill. This new mill he operated successfully until the spring of 1902 and then enlarged it to 100 tons, and operated the enlarged plant until December, 1903, since when it has been in operation twice for short periods. The camp, with a population of over 1,000 people at Washington alone, reached the zenith of its development about 1901.

At about the time the mill was enlarged the property, then owned by Mr. Wilfley and the Corey brothers, was organized as the Pride of the West Co., with headquarters at Denver, Colo. About 1906 the property was acquired by the Duquesne Mining & Reduction Co., which at about this time or late in 1905, having resumed operations at the Bonanza mine, operated the mill intermittently, trying new processes on the ores, and also in 1907 worked the Pride of the West mine for six months and installed an aerial tram connecting the Bonanza mine with the mill. For several years following 1907 nothing was done but assessment work.

The total production of the Pride of the West mine to 1909 is estimated to be 90,000 tons of ore, of which about 4,500 tons shipped to the smelter averaged 12 per cent in copper and contained a little silver. The production in 1907 was $95,661. Late in 1912 the Duquesne mines were said to be shipping a carload of ore a day.

Although most of the development work has been done on the Bonanza and Pride of the West mines, considerable ore has also been taken from the Holland, Belmont, New York, California, Kansas, and other ground. On the dump at the Bonanza shaft are 15,000

[1] Blake, W. P., Mining in Arizona: Report of the Governor of Arizona for 1899, pp. 64–66, 88–94.

tons of ore said to average 6 per cent in copper and 18 per cent in zinc, and at both the Holland and the Pride of the West are a few hundred tons of similar ore. The dump at the mill near Washington contains 30,000 tons of ore, said to average 15 per cent in zinc, 1 to 2 per cent in copper, and a trace of lead and to be worth $250,000.

Processes for treating these ores, some of which seem to be very refractory, are now being investigated on the ground.

Since 1899 the company has produced and sold 2,200 tons of ore and concentrates that gave 500,000 pounds of copper, 70,000 pounds of lead, 80,000 pounds of zinc, and 10,000 ounces of silver. The zinc concentrates were sold to the Lanyon Zinc Co. The copper-lead concentrates went to the Copper Queen smelter, at Douglas, Ariz., together with some carbonate ore.

EQUIPMENT AND PROCESSES.

The equipment at the Pride of the West comprises a 50-ton smelter,[1] a 100-ton electric mill with astatic, magnetic, and electric separators, Wilfley tables, crush rolls, a 150-horsepower Corliss engine, a small Atlas engine, a reverberatory mat furnace, and a 60-horsepower Stetson hoist. The plant has shipped considerable matte.

The ore is crushed, sized, and then passed to the Wetherill magnetic machine or to a Dings magnetic separator. Final concentration is made on eight Wilfley tables. A Sutton dry concentrator was tried direct after crushing and sizing and gave good separation of lead from iron and copper.

Next to the mill there is a 100-foot mechanical roaster and a 25-ton reverberatory furnace that has produced one car of matte that averaged 46 per cent in copper. This was made from copper-iron concentrates.

The surface equipment at the several shafts is extensive. At the Bonanza shaft there are two 100-horsepower wood-burning boilers, operating a 6-drill compressor, a 50-horsepower hoist, two 4-inch discharge sinking pumps raising water 600 feet, and three small Cameron pumps. The shaft, which has three compartments, is well timbered and equipped with safety devices. At the mouth are a machine shop, a blacksmith shop, and a sawmill. At the Duquesne shaft, one-eighth of a mile south-southwest of the Bonanza, there is a 12-horsepower gasoline hoist used for sinking a three-compartment shaft to the 100-foot level.

The company plans to operate all the property from a central power plant to be located on Grasshopper Flat about a quarter of a mile west of the Bonanza shaft. The machinery ordered for this plant includes two 125-horsepower Diesel turbines. Two shafts are to be used, one on the Duquesne ground for the central part of the

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[1] U. S. Geol. Survey Mineral Resources, 1905, p. 156, 1906.

area and one on the Texas ground for the southern part. The Buena Vista land grant, on Santa Cruz River, 10 miles to the west, has been purchased for a mill site.

During the six months' experimental work in 1907 the ore was taken largely from the Bonanza shaft, though some came from the Pride of the West, Belmont, and Holland claims. While the mill was running the product was 38 tons copper concentrates (12 per cent copper), 18 tons lead concentrates (46 per cent lead), and 107 tons zinc concentrates (35 per cent zinc). In the early part of 1913 it was reported that the company was operating with a large force of men and shipping daily about 50 tons of 14 per cent copper ore. Similar shipments were regularly made in the earlier part of 1914.

TOPOGRAPHY AND GEOLOGY.

The surface in general slopes gently eastward. The topography, as shown on the map (Pl. I, in pocket) and in the photograph (Pl. XX), is hilly and in the western part mountainous but in few places rough. The area is drained principally by Washington and Duquesne gulches, which issue southeastward into Santa Cruz River, 6 miles distant.

The country rock, locally called "quartzite and limestone" (Pl. II, in pocket), consists mainly of limestone with a small amount of quartzite and other sediments occupying a north-south belt 2½ miles long and, between the two camps, about 1¼ miles wide. This belt is almost surrounded by igneous rocks, being bounded on the northwest, west, and south by quartz monzonite, locally called "granite," and on the east principally by granite porphyry. Both of these latter rocks also occur as detached masses and dikes in the belt and are seemingly intrusive into the sedimentary formations. Both the quartz monzonite and the sedimentary rocks are cut by dikes of aplitic granite, as at the Pride of the West mine, and also by diorite (?) dikes. The rocks of the sedimentary belt, like those of the Mowry area, are but the remnants of formations which once had a much wider extent but have since been removed by erosion, and they have been preserved because they were downfaulted or more deeply engulfed in the igneous magmas.

The rocks in general have been much disturbed and apparently overturned but seem to be conformable. They dip steeply to the west, mostly at angles of 60° or more, but locally the dip varies greatly in direction and amount. The older members—the quartzite, some of which is micaceous, and the more altered limestone—occupy the upper position in the section next to the quartz monzonite on the west. The limestone is medium to heavy bedded or massive. In the western part of the camp it lies in crude north-south bands or zones of relatively pure rock, alternating with rock that is impure, metamorphosed, silicated, or cherty. In places it contains some interbedded quartzite. The limestone is mostly contact metamorphosed to white and bluish or greenish crystalline marble, much of which is coarse grained. In places the rock is otherwise altered and silicated. At intervals, mainly along the contact with the igneous rocks, particularly the quartz monzonite, and to a less extent as inliers in the sedimentary area, roughly paralleling the bedding of the limestone, occur extensive and well-developed garnet zones from 10 to 100 feet or more in width, containing the usual assemblage of other contact-metamorphic minerals described below under "Mineralogy."

A body of the limestone which has escaped the metamorphic effects of the intrusive granite porphyry within a few hundred feet of the contact, at a point about a quarter of a mile north of Duquesne, is dark bluish, compact, and indistinctly stratified and contains seams or veinlets of calcite approximately parallel with the bedding. This rock is lithologically identical with the dark Pennsylvanian limestone of Sycamore Ridge, in the crest of the Santa Rita Mountains east of Helvetia, and at the Total Wreck mine, in the Empire Mountains. It is seemingly also similar to the Martin limestone (Devonian), at Bisbee, described by Ransome.[1]

From outcrops elsewhere and from the dark-blue color of much of the crystalline limestone and the general bluish or greenish cast pervading the so-called white crystalline part of the rock, it seems probable that this formation, including the portion of it now metamorphosed, may occupy a considerable part of the area of the camp, the bluish and greenish tints being derived from the darker constituents of the unaltered rock.

The most extensive exposure of the quartzite is along the western edge of the sedimentary belt, where it intervenes between the limestone and the quartz monzonite and probably forms the basal member of the sedimentary series.

These sedimentary rocks are at least several hundred feet in thickness; how much thicker it is difficult to say, because they have been extensively disturbed. The Bonanza shaft, 635 feet deep, is all in the limestone.

No fossil remains have been found in the limestone or other sedimentary rocks, but they seem to be Paleozoic and are probably of the same age as the limestone in some of the camps already described, as Mowry or Greaterville. The western and seemingly lower part of the section is provisionally correlated by Crosby,[2] with the Bolsa quartzite and Abrigo limestone, of Cambrian age, in the Bisbee district, described by Ransome.[1]

The quartz monzonite is a greenish-gray, black-speckled granitoid rock with a reddish tinge and weathers reddish brown. It is medium

[1] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, Pl. XII, 1904.

[2] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, pp. 628–629, 1906.

to coarse grained and locally porphyritic. It is fairly fresh and is composed principally of oligoclase, oligoclase-andesine, quartz, orthoclase, biotite, hornblende, augite, and magnetite and contains considerable pyrite and some titanite. The plagioclase, which is the main constituent of the rock is especially fresh. It occurs mostly in stout or elongated prisms, some 0.3 inch long, and it is well striated, the striations being conspicuous to the unaided eye on the fresh surface of the rock. The biotite is relatively abundant and together with a less amount of green hornblende constitutes about one-fifth the volume of the rock. The orthoclase and quartz, which are later in order of crystallization, occur mostly as filling or interstitial minerals. Some of the augite is bordered by hornblende, which apparently is derived from it by a process of alteration.

The fact that the quartz monzonite is intrusive into the sedimentary rocks is well shown in the southwestern part of the camp, on the north fork of Duquesne Gulch, about 2,000 feet southwest of the Pride of the West mine, near the four-corner post of the Lauretta, Holland, Comet, and Indianapolis claims. Here the sedimentary rocks are thin to medium bedded and dip 60° W., and the sharply welded contact of a 100-foot quartz monzonite dike with the quartzite irregularly but clearly descends the north side of the gulch. A band of greenish-black endomorphic medium-grained crystalline hornblende is developed along the granitic side of the contact, and the sedimentary rock in places is altered to a dense greenish phase resembling hornfels.

A somewhat similar example of the intrusive nature of the quartz monzonite may be seen in the northeastern part of the camp, in the south side of Washington Gulch near the schoolhouse, on the Morning Star claim. Here the endomorphic hornblende is present in the granitic rock, some of the limestone is seemingly changed to calcium silicate and diopside, and the two rocks in general are separated by a 100-foot belt of chalcopyritic blackish fine-grained pressed quartzite or sort of hornfels.

The general coarseness of the quartz monzonite indicates that it was probably intruded into the sedimentary rocks at considerable depth. The granite porphyry on the east, so far as observed in this examination, has been considerably pressed and deformed and consists mainly of a relatively fine grained gray groundmass of orthoclase and quartz in which the phenocrysts of coarser feldspathic constituents are segregated and drawn out into pale-reddish streaks and thin lenses an inch or more in length. Aplitic granite occurs as dikes, some of which are associated with the ore deposits, as at the Pride of the West mine. It is a relatively fresh dull-gray fine or medium grained monzonitic rock, composed mainly of orthoclase and quartz with a moderate amount of oligoclase, a little biotite and hornblende, accessory apatite and zircon, and secondary hematite.

Most of the mines are dry, but in the Pride of the West water stands at a short distance below the 50-foot level. From the Bonanza mine, 635 feet in depth, the water is kept removed by operating the pumps for four and a half hours every five days, a 2½-inch stream being discharged.

MINERALOGY.

The metamorphic minerals occurring in the contact zones of the limestone consist mainly of garnet, quartz, and several varieties each of the amphibole and pyroxene groups, chalcopyrite, pyrite, pyrrhotite, magnetite, tourmaline, and arsenic.

The garnet is dark reddish and brownish green or dark greenish brown with adamantine luster. Much of it is coated on the crystal faces a bright metallic black with oxide of manganese and iron. It occurs in large, relatively pure crystalline masses of medium grain in dodecahedral crystals which are mostly of medium or small size, but some are nearly 2 inches in diameter. The rhombohedral faces of many of the crystals are striated. An analysis of a sample of the garnet collected from the Empire mine, which seems to be representative of the garnet of the camp, is given on page 83, and shows the garnet to be the calcium-iron variety andradite.

The quartz occurs mostly in irregular masses locally developed in association with the garnet along the contact zone and in the impure cherty zones or metamorphic bands in the sedimentary rocks. Here and there it replaces chert and the earlier metamorphic minerals, such as calcite and actinolite, whose crystalline forms are preserved in masses of relatively pure pseudomorphic silica. On the Belmont and Lead King ground, in the southwestern part of the camp, occurs a body of mainly massive vitreous quartz, 100 feet wide, containing bunches or clusters of coarsely crystalline material with some crystals 2 feet in length and 5 inches in diameter. Crosby[1] refers the origin of the quartz mostly to the metamorphism of the chert, but much of it seems to be derived from the monzonite magma or its solutions.

The amphibole minerals are principally hornblende, tremolite, actinolite, and gedrite. Of these, tremolite is the most abundant and is intimately associated with many of the ore deposits as gangue. Its abundance obviously denotes considerable dolomite in the limestone. Gedrite, a greenish-brown magnesium-iron silicate, a variety of the orthorhombic amphibole anthophyllite, with a refractive index of about 1.634, occurs also in association with the deposits.

The pyroxene minerals are mainly diopside, wollastonite, and hedenbergite. Considerable portions of the limestone are locally

[1] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, p. 633, 1906.

altered to diopside, and on the weathered surface show the fine stratification lines of the limestone. The wollastonite occurs principally in association with the cherty portion of the limestone, especially the chert nodules. Hedenbergite occurs as a massive dark yellowish-green mineral in considerable amount associated with the deposits. In the andradite gangue in the Empire mine is a pale-green or colorless pyroxene in radial or fan-shaped bunches, 4 inches or more in length, with which most of the prismatic or columnar crystals approximately coincide but whose specific characters were not determined. It is so thoroughly stained black by oxide of manganese and iron on the surface that it might readily be mistaken for some other mineral. Epidote occurs locally with the garnet. Tourmaline, which is not common as a metamorphic mineral, occurs in aggregates associated with galena in the partly silicated limestone just west of Washington on the Nogales road.

Native arsenic, not certainly of metamorphic origin, was found in the Double Standard mine[1] in reniform masses, some of which weighed several pounds, associated with the contacts between limestone and granite and between limestone and granite porphyry.

ORE DEPOSITS.

The deposits contain principally the base metals copper, zinc, and lead, with some silver and gold. They are, to speak broadly, principally replacement deposits in the limestone. They occur mainly in or near the metamorphic zones along the limestone and quartz monzonite contact and are also associated with the north-south metamorphic zones in the limestone and other sediments away from the contact, where they approximately follow the so-called "ore contacts" indicated on the claim map (Pl. XXIV). The latter zones are probably connected with the quartz monzonite in depth if not at the surface.

The deposits occur mostly in irregular bodies in or near the garnet formation of the zones and the adjoining limestone. Where the deposit is marginal it occurs on the inner or limestone side of the garnet zone and not on the outer or quartz monzonite side. Where quartzite of no very great width intervenes between the limestone and the quartz monzonite, as on the west, where the quartzite is about 200 feet wide, the ore deposit occurs between the quartzite and the limestone and not between the quartzite and the quartz monzonite, the limestone being everywhere the most favorable receptacle for the ore.

The ore minerals are mainly chalcopyrite, bornite, chalcocite, malachite, azurite, cuprite, chrysocolla, sphalerite, smithsonite, cerusite, and the sulphates of lead and copper. They occur chiefly in a

[1] Warren, C. H., Native arsenic from Arizona: Am. Jour. Sci., 4th ser., vol. 16, pp. 337–339, 1903.

garnet or garnet-quartz gangue, which contains also a varying amount of pyrite and the other contact-metamorphic minerals already described and in some places pyrrhotite and magnetite. The sulphides begin almost at the surface.

From the geologic and mineralogic conditions which have been described and which are discussed more in detail in the sections on the Pride of the West, Belmont, and other mines, it is apparent that the ore deposits are essentially contact-metamorphic deposits and owe their origin to the intrusion of the quartz monzonite and, to a less extent, to that of the granite porphyry, the hydrothermal solutions and pneumatolytic gases that accompanied or followed the intrusion having dissolved out the limestone and replaced it metasomatically or otherwise by depositing the ores and their associated minerals. Some of the minerals, as chalcopyrite, are probably in part at least of pneumatolytic origin.

From the large volume of the limestone which has been replaced by the ore deposits and from the altered condition of the inclosing rock, it is reasonable to infer that certain of the elements composing the metamorphic zone were derived from the limestone. For instance, the magnesium and calcium in the tremolite and other minerals were probably contributed from dolomitic or impure facies of the limestone, but the ore deposits themselves and the bulk of the metamorphic minerals contained in the metamorphic zone, some of which lie in pure white crystalline limestone, are apparently extraneous to the limestone and were introduced by the invading quartz monzonite magma and its attendant solutions and gases. They can not have been supplied in any other way.

It would certainly not be possible for any normal limestone, such as now occurs in the Washington-Duquesne camp or in the limestone area around Mowry to the north, equal in volume to that of the contact-metamorphic zone, to supply the iron constituents, the total amount of which, contained not only in the metallic minerals pyrite, chalcopyrite, specularite, pyrrhotite, etc., but also in the garnet, augite, gedrite, and other iron-bearing minerals, is obviously very great. It is probably due to the plentifulness of the iron contributed by the quartz monzonite that the garnet which is produced is andradite, an iron-bearing variety, instead of grossularite, the iron-free variety, which is most commonly found in other contact-metamorphic zones. That the materials were not derived from the surrounding limestone for any great distance without the contact-metamorphic zone is indicated by the purity of the bordering limestone and by its wholly unaltered condition in many places very near the contact, as north of the Bonanza mine and at the Kansas and Belmont mines, where the limestones within 50 feet of the metamorphic zone and contact are little changed.

For the source of the iron we can, as one possibility, at least in the Washington camp, look to the quartz monzonite, which, being rich in biotite and hornblende and containing considerable augite and magnetite and some pyrite, could supply the iron element, for whose concentration in the deposits the fluid magma and its accompanying hydrothermal solutions and pneumatolytic gases, containing the ingredients, were admirably adapted. Moreover, the hypothesis that the iron ingredients were derived from the limestone would require a most remarkable system of circulation in the limestone and a long period of time to enable the solutions or waters to collect and take the material into solution or suspension before it could be deposited.

The abundant quartz occurring in or associated with the deposits and the metamorphic zones is largely accounted for by the siliceous character of the quartz monzonite magma.

Besides the examples of metamorphic deposits which have been cited in the description of the mines and those in the pure crystalline limestone, there occurs also just west of the road northwest of Washington a 5-foot north-south vertical garnetiferous metamorphic zone with no indications of impure limestone in the vicinity. In tracing individual beds of the limestone here as elsewhere, away from the intrusive contact, the garnet in the pure beds is not found to differ appreciably in amount from that in the beds which are less pure.

The geologic and mineralogic conditions and apparently their causes are, on the whole, similar to those in the Silverbell district, 40 miles west of Tucson, described by Stewart,[1] who says:

> The intrusion of both alaskite porphyry and biotite granite was followed by the emission of magmatic waters, which sericitized and silicified the alaskite porphyry and granite and produced in the limestone, by the addition to it of silica, iron, and alumina, great masses of garnet, quartz, and wollastonite. Following close upon these solutions came metal-bearing magmatic waters, which impregnated porphyry, granite, and alaskite with cupriferous pyrite and deposited in the garnet zones chalcopyrite and copper-bearing pyrite that make important bodies of contact-metamorphic ores.

The results of more recent and detailed investigations of similar deposits at Mackay, Idaho,[2] including numerous analyses of the limestone, of the silicate rocks resulting from it, and of the intrusive rocks, are essentially in agreement with the conclusion of the present writer, made in the Duquesne-Washington camp, that the great amounts of iron, silica, and alumina represent contributions from the magma and can not have been supplied from the limestone.

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[1] Stewart, C. A., The geology and ore deposits of the Silverbell mining district, Arizona: Am. Inst. Min. Eng. Bull. 65, pp. 455–505, 1912.

[2] Umpleby, J. B., The genesis of the Mackay copper deposits, Idaho: Econ. Geology, vol. 9, No. 4, pp. 307–358, June, 1914.

PRIDE OF THE WEST MINE.

The Pride of the West mine is one-third of a mile southwest of Washington, at an elevation of about 5,700 feet, in the lower east slope of a lobelike ridge descending from the crest of the range, which is a mile distant on the west. It is about 250 feet above the smelter and mill on Washington Gulch, with which it is connected by a tramway ascending a small side gulch in which the principal openings occur, the ground being otherwise open. (See Pl. XX.) The Giroux shaft is on slightly higher ground a little to the southwest. The history, production, and equipment of the mine have already been set forth (pp. 323–324).

The mine is opened by a 400-foot shaft, a 700-foot tunnel driven S. 7° W., and winzes. The tunnel taps the vein at 180 feet below

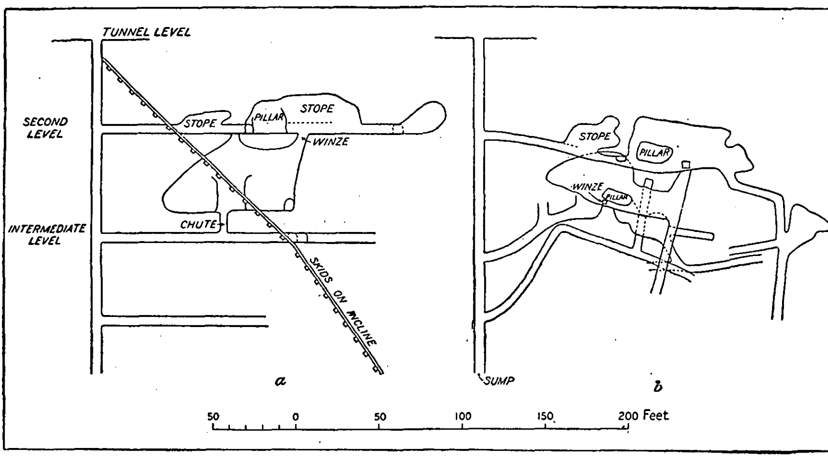

FIGURE 42.—Longitudinal section (a) and partial plan of lower levels (b), Pride of the West mine.

the surface, and from it is sunk a 400-foot winze and a 50-foot inclined shaft containing three levels with drifts and stopes. Plans of some of the workings are shown in figure 42. Some of the stopes are 30 feet wide and 70 feet high, ascending the dip of the deposit. The workings comprise also a large surface cut 32 feet wide and 250 feet long, a 120-foot double-compartment shaft, the Giroux shaft, with a 25-horsepower steam hoist, and a prospect tunnel.

The ore deposit is a contact-metamorphic deposit, as shown in figure 43.[1] It lies in the crystalline limestone along the footwall side of a dike of the quartz monzonite. The dike strikes N. 17° W. and dips about 50° W., but the dip flattens in the lower part of the mine. At the mine the dike is apparently conformable with the limestone

[1] This figure and field notes on the deposit have been kindly furnished by Mr. Waldemar Lindgren.

and is about 60 feet wide, but it widens southward to 250 feet at the Giroux shaft, which is about 200 feet distant, and at a point 500 feet south of the shaft it incloses a horse, of crystalline limestone 100 feet long and 20 feet wide, whence it extends southward into the main area of quartz monzonite.

At the mine the dike, especially in the footwall or under side, as shown in the accompanying sketch (fig. 43), is composed of a peculiar siliceous facies of the rock, which is fine grained and resembles aplite, as described on page 328, and it may possibly be a slightly later intrusion than the main body of the dike, but it is monzonitic, contains the same minerals as the rest of the dike, and is apparently derived from the same general magma.

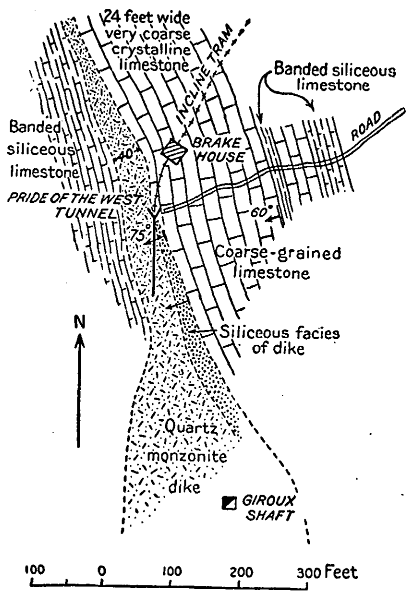

FIGURE 43.—Map showing geology at Pride of the West mine.

The dike separates a body of coarsely crystalline, apparently very pure limestone 200 feet wide, from a considerable mass of siliceous banded limestone on the west side. So far as can be seen, and the exposures are good, all the rock adjoining the east side of the dike consists of this coarse limestone. Close to the dike and north of the tunnel the limestone is extraordinarily coarse. The contact between the dike and the limestone is further well shown in the northwestern part of Washington, about a quarter of a mile north of the mine and 500 feet west of the doctor's house. Here the same coarse limestone adjoins the monzonitic rock and for a width of about 25 feet from the contact is changed to massive garnet. Beyond this is a zone 50 feet wide in which the limestone contains irregular bunches of silicified material and small masses of yellowish-green garnet.

At a point 100 feet northwest of the Pride of the West tunnel and 6 feet east of the dike the limestone is composed of coarsely crystalline white calcite and is very pure, but at the mouth of the tunnel it is silicified or completely changed to diopside. In the vicinity of the mine garnet appears along the footwall side of the dike and the ore deposit, as shown in the mine, forms a zone 30 feet wide, consisting mainly of irregularly mixed coarse calcite, garnet, yellowish-brown zinc blende, chalcopyrite, pyrite, pyrrhotite, and a little magnetite.

Locally it is vertically banded or bedded. At one place on the 50-foot level 3 feet of very coarse crystalline limestone adjoins the dike, and next to the limestone is a 2-foot zone of sphalerite and garnet. The garnet contains many druses filled with well-developed quartz crystals, some of them a foot in length. In the interstices between the crystals are pyrite, sphalerite, and other ore minerals. At another place in the mine there occurs next to the dike nearly 2 feet of magnetite, which is succeeded by 3 feet of sphalerite mixed with chalcopyrite, which in turn is followed by crystalline limestone containing chalcopyrite.

Garnet and quartz are associated with nearly all the ore. Tremolite is common, and hedenbergite and gedrite are also present in considerable amount intimately associated with each other in bunches or lenses 3 inches or more in diameter. The hedenbergite occurs in the yellowish-green massive form and is penetrated and in part interlaminated by the surrounding yellowish-brown crystalline gedrite.

A microscopic section of the ore shows an intergrown mixture of calcite, pale-brown hornblende in masses and spherulitic radial bunches, diopside, epidote in small, almost colorless crystals and grains, a clear, colorless mineral with good cleavage and low double refraction, a little garnet, chalcopyrite, and specularite.

The deposit is developed to a depth of 200 feet below the tunnel level, but water now stands a short distance below the 50-foot level. On the tunnel level the ore consists almost wholly of sulphides and on the 50-foot level there is no oxidation. In the surface cut, which closely follows the contact, the ores are mostly oxidized and seem to lie exclusively in the crystalline limestone.

At the Giroux shaft, sunk in the dike at a point about 200 feet to the south of the mine to cut a branch given off from the Pride of the West deposit, the contact has been reached underground, and ore with tremolite and garnet has been revealed. On the 80-foot level at 25 feet to the west of the shaft is exposed a 6-foot vein of sphalerite and chalcopyrite which dips steeply to the west.

At the prospect tunnel, 250 feet southwest of the Giroux shaft, on the west contact of the monzonite dike, which here retains its characteristics close to the contact, some pyritic ore with sphalerite, tremolite, and massive garnet is exposed.

That the ore minerals with garnet and quartz replace the pure coarse limestone is shown by the underground exposures, which allow of no other explanation.

The ore is stoped out down to a depth of about 200 feet below the surface. It probably extends to a greater depth, but the deeper portion of the deposit contains so much zinc that it could not be handled at the time the mine was in operation. Most of the zincky ore, owing to the large admixture of calcite or spar, carries only 18 to 20 per cent zinc. The ore in general is said to average about

$30 to the ton in copper and zinc.

BONANZA MINE.

The Bonanza mine is in the eastern part of the camp just north of Duquesne and Duquesne Wash, on gently southward-sloping ground at an elevation of about 5,400 feet (Pl. XXV). Notes on the history, production, and equipment of the mine are given on page 322.

The developments, besides the three-compartment 635-foot shaft, include about 7,000 feet of underground workings distributed on six levels and intermediate upper workings, mainly between the 135-foot level and the surface, approximately as shown on the accompanying map (fig. 44) and in the longitudinal section (fig. 45). The main levels are spaced 100 feet apart vertically, the first level being 135 feet below the surface. The work comprises about 1,000 feet of shafts, 3,700 feet of tunnels, 1,000 feet of crosscuts, over 100 feet of winzes, and 600 feet of raises. There is but little work on the sixth level and not much on the fifth.

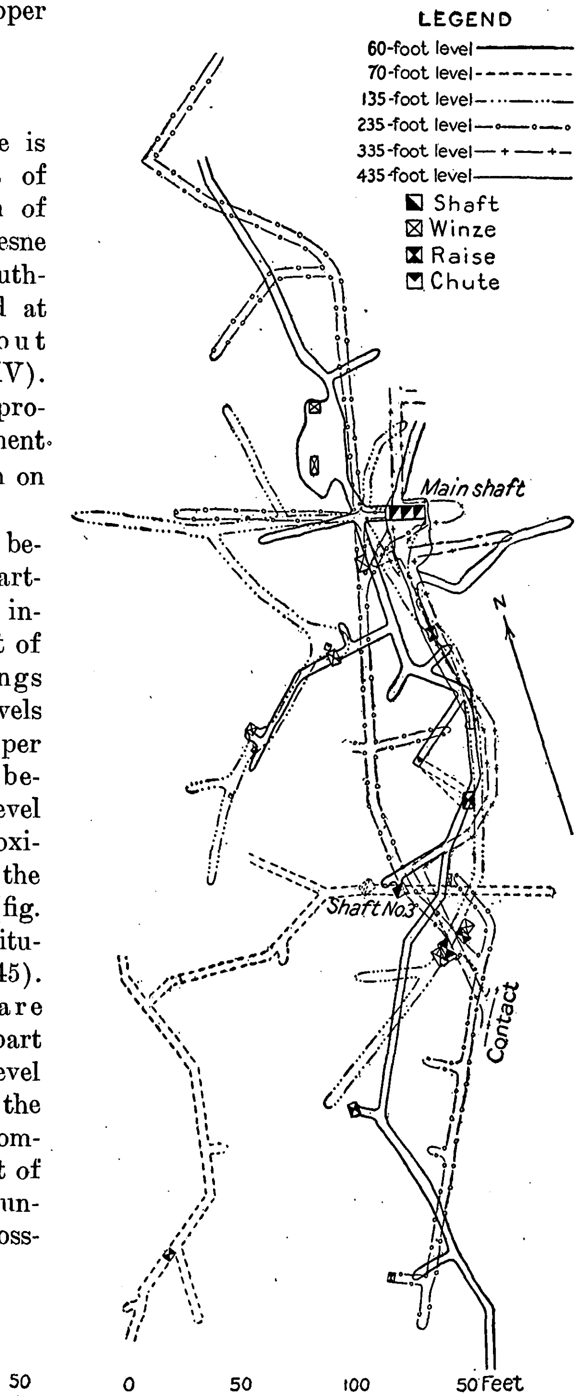

FIGURE 44.—Plan of workings of Bonanza mine.

Many of the drifts and other workings are crooked or winding, especially in the upper levels, where considerable "chloriding" was done in the early days, and cave-ins have occurred at several places.

The mine is on the contact of the limestone belt of the camp with the intrusive granite porphyry on the east. The deposit trends mainly north and stands about vertical or dips steeply to the east,

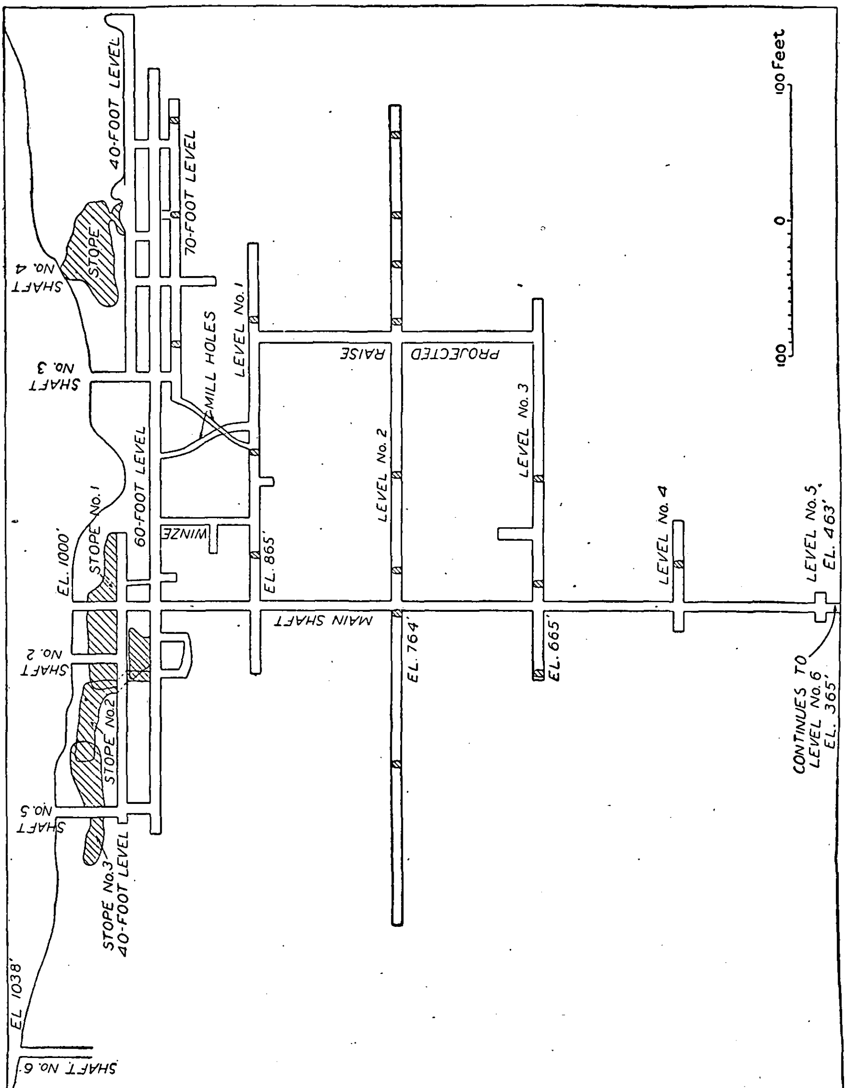

FIGURE 45.—Longitudinal section of Bonanza mine.

tending to parallel the contact. The contact and seemingly the limestone or sedimentary rocks dip to the east or outward. The Bonanza shaft, which is vertical, starts in the granite porphyry a little to the east of the contact, but the lower part of the shaft is about all in coarsely crystalline white limestone. The shaft passes through the ore zone between the 435-foot and 535-foot levels and the bottom of the shaft is in the limestone about 65 feet west of the contact.

As at the Pride of the West mine, the ore deposits occur in the crystalline limestone, mainly in the usual garnet-quartz gangue. They have been opened through a horizontal extent of about 600 feet and in the vicinity of the shaft to a depth of the 535-foot level. They have been mined chiefly, however, in the oxidized zone in the intermediate workings, which are mostly within 100 feet of the surface and were not extensively examined in this work but which have produced considerable ore.

At 30 feet below the surface the early operators encountered a large horizontal or bedlike body of zinc ore which extends laterally throughout the mine and was not removed at that time.

On the 60-foot level occurs a large body of copper sulphide ore. It is well exposed just southwest of the shaft and is said to be extensive horizontally and vertically. The ore minerals are medium-grained chalcopyrite and sphalerite in a firm garnet-quartz gangue. Much of the ore is said to average 28 per cent or more in copper. The high-grade ore, which consists mainly of chalcopyrite with a little quartz, occurs in bodies or bunches from 1 foot to several feet or more in diameter, surrounded in places by almost pure zinc blende with but a sprinkling of chalcopyrite. In mining, this high-grade ore is kept separate from the low-grade ore.

On the 135-foot level, consisting mainly of a 250-foot drift to the south, the principal showing of ore is about 120 feet south of the shaft, where the ore shoots descend from the 60 and 70 foot levels, mostly without definite walls. The ore here looks well but carries considerable zinc.

On the 235-foot level the main showing is in the north drift, where a zone of ore 15 feet wide begins 15 feet north of the shaft and continues, seemingly in undiminished quantities, about all the way northward to and beyond the end of the drift, a distance of 210 feet. The ore is sulphide and is said to be a fair-grade copper ore, but it contains considerable zinc—not so much, however, as the ore of the level next above. Good ore also occurs just west of the shaft and in the drift to the north, in the winze on the left near station 11. Ore is shown also in entry station No. 211, near the winze about 700 feet south of the shaft, and in the crosscut about 100 feet south of the shaft.

On the 335-foot level, at the shaft, in a large chamber 25 feet high, and in the drift to the south, the ore zone is 20 feet wide. It is limited on the east by a fairly well defined hanging wall which dips 60° E. and apparently contains quartzite, in which the crosscut to the east ends. This ore body, which, owing to cave and fill, could not be examined for more than 50 feet south of the shaft, contains mainly chalcopyrite, sphalerite, pyrite, and a little gray copper and bornite in a gangue composed principally of massive or fine-grained garnet and quartz with other metamorphic minerals. The copper minerals in general are segregated into bunches, but in some places medium to fine grained chalcopyrite and sphalerite in about equal amounts form a very intimate even-grained mixture. In the north drift good ore is exposed in the crosscut and in the upraise about 50 feet west of the shaft.

On the 435-foot level ore occurs at the shaft and in the crosscut of the south drift about 60 feet from the shaft. The ore zone measured from the west side of the drift is more than 25 feet in width and the deposit here contains principally chalcopyrite in a quartz gangue. Farther south in the drift, however, garnet becomes abundant with increasing indications of zinc.

On the 535-foot level the ore zone is exposed in the terminal chamber of the last crosscut of the south drift, about 150 feet southeast of the shaft, in the crystalline limestone. Here practically the entire chamber, about 25 feet in diameter, is excavated in low-grade ore contained in a coarse-grained greenish and blackish garnetiferous gangue with considerable quartz, while farther south occur also some large quartz crystals. Associated with the copper minerals is a little galena.

The average ore of the Bonanza body assays 18 per cent zinc, 6 per cent copper, 1 per cent lead, and 5 ounces to the ton in silver. It is estimated that the 15,000 tons of material on the dump will average 18 per cent in zinc and 5.9 per cent in copper.

HOLLAND MINE.

The Holland mine is in the southwestern part of the camp, nearly half a mile south of the Pride of the West mine and two-thirds of a mile west of Duquesne, on the south fork of Duquesne Gulch, at an elevation of about 5,800 feet. It was located about 1880 by Henry Holland, who, after opening it in a small way, sold it to Dr. Luttrell and others, from California. The new owners mined it until they encountered sulphide ore of lead and iron in garnet. Not being able to treat this ore in their water-jacket smelter installed at Sonora, near the Mexican border, they abandoned the mine. In the early nineties the mine was worked by lessees, who took out much ore. B. Coughlin worked it in 1891 and shipped seven carloads of ore, averaging about 22 per cent in lead, 3 to 5 per cent in copper, and 35 ounces to the ton in silver. The cost of freight and treatment at that time was about $18 a ton.

About 1896 the mine was purchased for $15,000 by F. L. Bartlett, of Denver, and others, and in the next few years they took out considerable ore, which was treated in a concentrator that they built for the purpose about 1 mile southeast of the mine. The ore was crushed in Huntington mills and concentrated on Wilfley tables. This plant recovered most of the lead, zinc, and silver, but not the copper. The zinc was sent to Canon City, Colo., for the manufacture of zinc oxide.

The present owner, the Duquesne Co., acquired the mine in 1905 but as yet has done no work on it. The mine has produced, by estimate, more than 30,000 tons of ore, probably with a greater clear profit, it is said, than any other mine in the camp. A few hundred tons of ore, averaging 6 per cent in copper and 18 per cent in zinc, lies on the dump.

The mine is opened to a depth of 200 feet by four inclined shafts, which descend steeply to the west from the bottom of an open cut 100 feet long and 40 feet wide in the east side of the mineralized zone, and in places the ore is worked out for a width of 20 to 25 feet, except for a few pillars. No timbering has been required.

The mine is in the crystalline limestone near the contact of the quartz monzonite on the west and is probably on the southerly extension of the same general mineralized zone as the Pride of the West. The deposit occupies a zone about 50 feet in width, which dips about 60° W., conformably with the limestone. It has a fairly regular footwall of crystalline limestone on the east, from which it is separated by about 2 feet of gougelike material containing a mineral that is mostly iron. The deposit and the inclosing limestone are cut by a jointing or coarse sheeting that dips 25° E.

On the hanging-wall side the surface is covered with débris and the contact can not be definitely located or traced, but from what could be observed of it the rock here seems to be mostly hard silicified material and is locally regarded as the northerly extension of the "quartz dike" that occurs on the adjoining Belmont ground and is described on page 328.

The zone is composed mainly of a hard greenish-brown garnetiferous gangue which contains considerable quartz. Some ore minerals are distributed throughout the zone, but the ore occurs chiefly in irregular, crudely tabular bodies, mostly dipping to the west. The ore bodies are composed of a mixture of the ore minerals, sphalerite, galena, chalcopyrite, pyrite, oxide of iron, manganese, and carbonates of copper, lead, and zinc, in a garnet-quartz gangue, together with tremolite and other metamorphic minerals. The lead ores, which contain most of the silver, occur mainly on the footwall side of the deposit; toward the hanging-wall side the ores contain principally zinc with a little copper. Most of the ore produced came from the footwall side of the zone. On the hanging-wall side there remains almost intact a body of ore about 30 feet wide, said to average 15 per cent in zinc and a small amount of copper.

The mine originally contained a large body of carbonate ore extending in general from the surface to a depth of about 10 feet, and in places to 25 or 30 feet, below which occur the basic sulphides of lead with silver, copper, iron, and garnet, and some sporadic native silver. Beginning at about 40 feet below the surface the ore grows leaner with increasing depth.

BELMONT MINE.

The Belmont mine is in the southwest corner of the camp, about 2,000 feet south of the Holland mine, on the upper south slope of a low hill of metamorphosed limestone, at an elevation of about 5,500 feet. The deposit was discovered by the Mexicans prior to 1860, and the mine is about the oldest working in the camp, except possibly the San Antonio. The deposit was opened soon after its discovery, but on the whole no great amount of work has been done nor has much ore been produced. The mine was worked mostly for silver and lead, but some high-grade copper ore has also been shipped from it.

Through Thomas Yerkes, a miner, it was acquired by Mr. Bacon, of San Francisco, early in the seventies. The Bacon heirs, after sinking a 90-foot shaft and doing other development work, sold the mine to the Duquesne Co. in 1905. This company soon after acquiring it took out and shipped some ore, but since that time the mine has been idle, though it is regarded as a good property.

The mine is developed principally by an open cut, an inclined drift, a 200-foot shaft, extensive stopes, a 200-foot tunnel, and winzes. The cut is 150 feet long and 50 feet wide, and has a 15-foot face. From the north end of the cut the drift extends to a depth of 45 feet, and from the drift a series of overhead stopes of unknown depth descend down the bedding planes to the northeast. The shaft is at the south end of the cut. It inclines 40° SW. and is timbered. The tunnel, starting 50 feet below the open cut, is driven eastward and contains several winzes.

The deposit occurs in a north-south metamorphosed mineralized zone in the crystalline limestone near its contact with the intrusive diorite on the south. The zone is about 100 feet in width and 800 feet in length. It lies approximately conformable with the limestone, which on the north dips 60° W. but on the south curves to the east. On the west at a point about 50 feet from the open cut the limestones are unaltered. The mineralized zone is composed principally of garnet and silicated limestone with quartz and calcite. It contains much actinolite with other metamorphic minerals and the ore minerals, which are chiefly sphalerite and chalcopyrite. Some of the sulphide ore is well embedded in quartz. In the open cut the ore was largely a mixture of earthy limonite, malachite, azurite, and sphalerite, contained in an 8-foot bed of a siliceous garnetiferous gangue that overlies the white crystalline limestone. Ore from the dump of the 200-foot shaft is largely chalcopyrite but contains also oxidized copper and iron minerals.

SILVER BELL MINE.

The Silver Bell mine is in the southwestern part of the camp, at an elevation of about 5,220 feet, and almost joins the Belmont mine on the northeast. It is the next claim after the Belmont that was patented prior to 1889. Subsequent to the patenting considerable very rich oxidized lead-silver surface ore was taken out, mostly by "chloriders." The Duquesne Co. purchased the mine from a St. Louis owner about 1901 but has not yet developed it. The deposit occurs in a garnet zone contained in highly metamorphosed crystalline limestone. The limestone dips to the southwest and, as at the Holland mine, is cut transversely by a sheeting that dips to the northeast. The mineralized zone trends N. 40° W. and dips 45 or 50° SW., conformably with the limestone. It is separated from the zone of the Belmont mine by several hundred feet of intervening white crystalline limestone. The Holland mine, however, is in alignment with its trend, and it may connect with the zone near the Holland mine. Garnet is abundant in the zone, which is stained or mottled with various shades of red, green, and brown by iron and copper carbonates.

The deposit is opened by a 60-foot shaft which inclines 50°-60° SW. and shows the ore-bearing portion of the zone to be at least 16 feet in width. The oxidized ores extend to a depth of 30 or 40 feet, but sulphides, especially chalcopyrite, begin to appear very near the surface, and in the lower part of the shaft the ore is unoxidized and contains appreciable quantities of copper sulphide.

EMPIRE MINE.

The Empire mine is in the southwestern part of the camp, about 900 feet north of the Silver Bell mine. It is one of the oldest properties in the camp, having been patented by Capt. O'Connor in 1874. It was worked considerably, mostly by "chloriders," in the middle eighties and produced much high-grade lead-silver ore. The Duquesne Co. acquired it in 1905 and has done some work on it.

The mine is opened to a depth of only 60 feet. It is on a mineralized garnet zone in the crystalline limestone close to the quartz monzonite contact. The zone is locally regarded as the one on which the Silver Bell is located. The croppings southeast of the mine are prominent and in the top of a small hill they are craggy. They are composed chiefly of a mixture of garnet and quartz. The deposits carry mainly lead-silver ore with some copper. The ore minerals—galena, chalcopyrite, and pyrite—are contained in a gangue composed of green garnet and silicated limestone with much associated quartz, pyroxene, tremolite, and iron oxide. The garnet whose analysis is given on page 328 is from this mine.

POOLE GROUP.

The Poole group comprises seven claims, most of them in the northeastern part of the camp. The claims are the Kansas, the Texas (formerly the St. Louis), the New York (formerly the Ohio), the Maine (formerly the Ella), the Cincinnati, the Georgia (formerly the Columbia), and the California (formerly the Grasshopper). The deposits were discovered and located about 1878 by the Allen brothers and others. At one time, it is said, the property was bonded for $24,000.

New York mine.—The New York mine is in the northwestern part of the camp, nearly half a mile west-northwest of Washington, on the north side of Washington Gulch, at an elevation of about 5,500 feet. The claim extends from the gulch northeastward across the ridge and the Nogales road. The history of the New York is about the same as that of the Kansas mine, next described, except that the original owners in the early days took out and shipped from it a considerable quantity of good-grade lead-silver ore. The workings extend to a depth of more than 200 feet but are about all caved. A large stope is outlined on the surface by sunken ground back from the head frame of a shaft.

The ore contains principally chalcopyrite with sphalerite, in garnetiferous crystalline limestone. The zone of mineralization extends northeastward. The garnet zone is not developed here as at the Empire and most of the other mines. The claim and most of the hill it crosses to the northeast of the mine seemingly contain a large body of ore.

Kansas mine.—The Kansas mine, in the northwest corner of the camp, adjoins the New York claim on the northwest and parallels it, extending from Washington Gulch northeastward across the ridge and the Nogales road. It is opened on the road about a mile northwest of Washington, at an elevation of about 5,700 feet.

As copper was not in demand, but little development work was done on it immediately after discovery. The mine was later bonded to the Pride of the West Co., which in 1905 took out several thousand tons of ore. In 1906 it was acquired by the present owner, the Duquesne Co., which has done little else on it than to take out a few carloads of ore. It is opened by a 200-foot inclined shaft and several hundred feet of drifts and stopes.

The deposit is contained in a 10-foot garnetiferous zone in crystalline limestone. It lies 700 feet from the contact of the limestones with the intrusive quartz monzonite on the northwest, the intervening sediments being mostly unaltered, and it is about 200 feet from the limestone and quartzite contact. According to Crosby[1]—

> The main ore body is veinlike in form but without walls, and clearly a replacement in the limestone, with many isolated bunches or pockets of ore from 3 inches to 3 feet or more in diameter and usually parallel to the main ore body and the bedding of the limestone. The garnet ledge is not developed here, but a feature of special mineralogical interest is found in the pseudomorphic cavities due to the oxidation of the pyrite.

Above the water level the ore was about all oxidized and consisted of limonite, cerusite, malachite, and azurite in the earthy form, with much greenish-yellow lead-copper sulphate. Below the water line the ore contains pyrite, galena, chalcopyrite, and sphalerite, with some silver in a gangue that is mainly quartz.

The ore is of low grade, but there seems to be a very large body of it, and it is not so basic as the ore in most of the other mines.

Maine mine.—The Maine mine is about a quarter of a mile southwest of the New York mine, on a southern tributary of Washington Gulch, at an elevation of about 5,800 feet. The claim was relocated by M. W. Thompson and others in the eighties and subsequently deeded to Chalmer B. Coughlin, who in 1907 worked it with fair results. It was later worked successively by lessees, whose ore shipments, besides containing lead and silver, were credited with 9 per cent in copper by the El Paso smelter, the copper being reported to occur free in the ore.

In 1901 the mine was sold to a New Jersey company, the present owner. This company has driven a 150-foot tunnel, mostly in the quartz monzonite and vein material, but has not yet reached the limestone contact.

POCAHONTAS MINE.

The Pocahontas mine is in the northeastern part of the camp just northeast of Washington. It was located about 1880 by David Harshaw, W. C. Davis, and others and produced in the eighties a very large amount of ore, which was treated in a smelter built for the purpose on the San Rafael ranch, on Santa Cruz River, 6 miles to the east. It is among the properties first purchased by the Duquesne Co. in 1889. The mine is on the limestone and granite porphyry contact. It contained a large body of silver-bearing lead carbonate ore that extended from the surface to a depth of 50 feet, where it gave way to a soft decomposed conglomerate or breccia-like formation in which no ore to speak of has yet been found.

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[1] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, p. 643, 1906.

TIBBETTS MINE.

The Tibbetts mine is about one-eighth of a mile east of Washington, and the claim adjoins that of the Pocahontas on the north. It is on the granite porphyry and limestone contact, but except for local silicification of the limestone and the occurrence of specularite there is no indication that the deposits are contact metamorphic.

The mine is owned by M. M. Trickey and partners, of Washington, and has been worked since 1884. A shipment of 12 tons of ore from it made in 1902 or 1903 is said to have assayed 30 per cent in lead, 31 ounces to the ton in silver, and a little gold and copper. In June, 1909, there was on the dump 50 tons of cerusite ore that was said to average 8 per cent in lead and 10 ounces to the ton in silver. This ore was obtained from the tunnel level 60 feet below the surface. There was also about 100 tons of galena ore that was said to average 18 per cent in lead and 20 ounces to the ton in silver; this ore, however, contains from 18 to 20 per cent of zinc, for which it is penalized by the smelter.

The mine is developed to a depth of 200 feet by tunnels and drifts, stopes, winzes, and upraises, aggregating about 1,600 feet of work, most of which is shown in figure 46. The tunnel runs S. 26° E. into the hill a distance of 144 feet. A 60-foot upraise to the surface is 129 feet from the mouth, and 8 feet in front of it drifts are turned both east and west. The west drift runs S. 75° W. for 120 feet to a 15-foot inclined winze which descends to the north. The east drift is 63 feet long and bears N. 60° E. At its end a hoist station is located, from which an irregular winze inclining eastward is sunk to a depth of 136 feet on a vein that dips 80° N. At 78 feet below the collar of the winze a drift 36 feet long extends to the west. At 116 feet below the tunnel level a platform covers the winze, which continues 20 feet below it. A short drift to the west, one 25 feet to the north, and another 15 feet to the east are run from this level.

The tunnel and most of the other workings lie in the granite porphyry, which in the upper part of the oxidized zone is altered and micaceous, but at the face of the tunnel the porphyry is in fault contact with the Paleozoic sedimentary rocks on the south, here represented by siliceous altered limestone and quartzite. The contact is marked by a red clay breccia. At about 70 feet and 114 feet in from the mouth of the tunnel are two faults that dip 70° and 87° SSW. The zone of the second fault is composed of flinty quartz fragments in a red clay matrix. The upraise is in reddish altered granite porphyry.

The face of the west drift, which is in limestone, also contains a fault that dips 80° NW., with granite porphyry on the hanging-wall side of the winze below the drift. Along this fault contact occurs from 3 to 6 inches of reddish iron-stained gouge containing galena, a little malachite, and some specularite. The east drift lies in a sheet of soft reddish gouge and breccia in which some pockets of galena and cerusite were found. The drift at about 90 feet in from the mouth followed a siliceous iron-stained streak in the clay in which was found some ore that assayed 67 per cent in lead and 93 ounces to the ton in silver, but the streak became lost about 20 feet from the winze. The winze is sunk on a limestone footwall in soft red clay that contains quartz and some bowlder-like masses of galena.

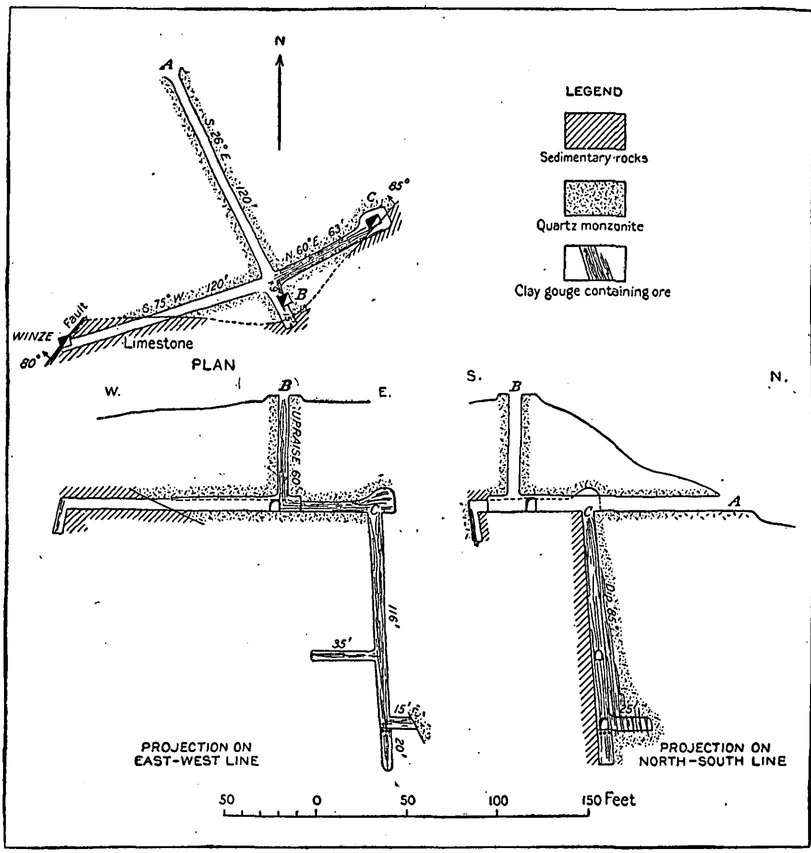

FIGURE 46.—Plan and projections of Tibbetts mine.

On the 116-foot level the footwall dips north-northeast, and granite porphyry was cut 15 feet east of the winze, which dips to the northeast at low angles. A 25-foot drift driven to the north is all in soft red material, apparently ground-up granite porphyry along a fault zone. Most of the galena ore was found as bowlders in this zone, largely following short disconnected ferruginous streaks. Mixed with the galena was more or less pyrite and chalcopyrite. Some ore occurs also in a very miarolitic and partly spherulitic phase of the granite porphyry.

COUGHLIN LEDGE.

The prospect known as the Coughlin Ledge lies southwest of the Pride of the West mine, principally between that mine and the Duquesne Gulch. It is on a 30-foot zone of dense flinty, cherty mineral-bearing quartzite or silicated garnetiferous limestone. It dips steeply to the northwest, and a quartz monzonite dike forms the footwall and limestone the hanging wall, the conditions being just the reverse of those in the Pride of the West mine. The dike seems to be the Pride of the West dike, or at least to be connected with it.

At Duquesne Gulch the zone and dike seemingly pass into the quartz monzonite area and are largely covered with wash material and débris. Croppings which occur at intervals, however, on its trend indicate that the zone continues southwestward in the quartz monzonite to the vicinity of the O'Connor camp or to the northwest of it, half a mile distant. This is the only observed instance of a zone of mineralization extending from the limestone into the quartz monzonite or igneous rock.

O'CONNOR PROSPECT.

Capt. O'Connor owns a group of claims a quarter of a mile west of the Belmont mine, just west of the limestone area, in the quartz monzonite, which is cut by masses of granite porphyry. The rocks have been much disturbed and fractured. They contain a large amount of mineral-bearing drusy quartz in veins and stringers that trend in all directions. The more prominent strike about east.

BROOKS PROSPECT.

The Brooks prospect is a mile west of the Belmont mine, on a vertical shear plane that trends N. 55° W. in the quartz monzonite. The rock along the plane is impregnated with chalcopyrite and pyrite, some of which is coated with chalcocite. The minerals also fill small seams in the rock. The prospect is opened by a shaft and tunnel.

GOLD LEDGE PROSPECT.

About 1¼ miles southeast of Duquesne, in a gulch just south of bench mark 5021, is an 8-foot dike of red rhyolite in quartzite and quartzite conglomerate. The rhyolite is cut by northeast vertical fissures, some of which contain a little iron-stained drusy quartz that is said to carry gold. No work has been done on the deposit.

BENTON MINE.

The Benton mine is 2¼ miles south of Duquesne and about three-fourths of a mile north-northeast of post 113 of the international boundary. It belongs to Dennis Coughlin and partners, of Duquesne. A party of four men was working on it in 1909. The property was known in the early eighties but was not located or worked until January, 1908. It comprises five claims lying in a north-south direction.

The country rock is quartz monzonite, which is cut by granite porphyry, diorite, and aplitic granite, the two last-named rocks cropping out on the hill above the tunnel. The granite porphyry occurs mainly in a 60-foot north-south dike. It is impregnated with pyrite, chalcopyrite, and a little molybdenite, and its contact with quartz monzonite is marked by a sericitic zone a few feet in width.

The developments consist principally of a 165-foot tunnel that trends N. 20° W. and is mainly in the quartz monzonite but toward the face passes through the granite porphyry, which at this point is 50 feet wide and is so highly and uniformly impregnated with pyrite and chalcopyrite that it forms a body of low-grade ore. The rock in the east side of the dike, in which the minerals are a little more concentrated than elsewhere, is said to average 2 per cent in copper. The croppings of the dike are iron stained and contain, in small fissures, little bodies or lenses of limonite, azurite, and malachite that are said to average about 14 per cent in copper and from $6 to $8 to the ton in gold.

ALFONSO VILLY PROSPECT.

The Alfonso Villy prospect, named for the owner, is a quarter of a mile east-northeast of international-boundary post 114. It is on a vertical quartz vein in the quartz monzonite. The vein is 6 feet wide, strikes N. 70° W., and contains seams of pyrite and chalcopyrite coated with chalcocite and covellite. These minerals also occur in small fissures in the adjoining quartz monzonite. The vein is opened by several shallow shafts.

LINE BOY MINE.

The Line Boy mine, owned by Capt. O'Connor, is just north of post 113 of the international boundary. The country rock is the gray quartz monzonite which is intruded by a small stocklike mass of granite porphyry that trends north and is about 300 feet wide. The locality of the mine is seemingly a focal point for several leads. From the mass of granite porphyry near the middle of the claim a 10-foot dike extends to the west-northwest and dips steeply to the north. Much white mica is developed in the quartz monzonite near the contact.

The metallic minerals pyrite, chalcopyrite, and molybdenite,[1] with a little bornite and films of chalcocite, are particularly abundant

[1] The occurrence of the molybdenite is described more fully in U. S. Geol. Survey Bull. 430, pp. 161–162.

along the contact of the two rocks and are concentrated in joint planes and fissures, locally with a little associated quartz in small stringers and veins, and the adjoining quartz monzonite is partly impregnated with them. Along the hanging-wall side of the dike occurs a sheet of specularite 3 feet wide, shown in the tunnel drift.

The prospect is opened by three shafts and a tunnel, two of the shafts, each 50 feet deep, being at the top of the hill and the third, 80 feet deep, at the north base of the hill. The tunnel is 65 feet long and follows the north or hanging-wall side of the dike.

In August, 1910,[1] development work is reported to have encountered, in a 120-foot tunnel, a 6-foot vein of ore carrying from 11 to 24 per cent in copper. The ore contains principally chalcopyrite, with 15 to 20 per cent of bornite.

PLACER DEPOSITS.

Placer gold occurs in the Patagonia district in the Quaternary stream gravels in the piedmont portion of Mowry Wash and its tributaries, being present on the main wash at the east border of Guajolote Flat about 1½ miles southwest of Mowry, on a south-side tributary gulch about 1¼ miles south-southwest of Mowry, and on two north-side parallel tributary gulches about 1½ miles southeast of Mowry.

The production is small, as the deposits are worked only by Mexicans when in need of money. The average earnings are about 75 cents a day for each man. The placers at the Guajolote locality were being worked by dry washing at the time of visit. The deposits at this place seem to be about 5 feet thick. The known production in 1908 was 2 ounces of gold. In 1906, when, after the closing of the Mowry mine, many unemployed men were in the country, the production was about $200.

NOGALES DISTRICT.

LOCATION AND GENERAL FEATURES.

The Nogales district lies in the southwestern part of the area, on the Sonoran border (Pl. I, in pocket). It adjoins the Palmetto and Patagonia districts on the west and extends from the international boundary 10 miles northward to Sonoita Creek, and from Nogales Wash on the west to Santa Cruz River on the southeast. Nogales is at its southwest corner and Calabasas at its northwest corner. At the international boundary it has a width of 10 miles. Nogales is a port of entry between the United States and Mexico, and the principal supply point for northern Sonora and the adjoining region

[1] Letter from Capt. Stephen O'Connor.

of Arizona. Calabasas is on the Benson-Nogales and Tucson-Nogales branch lines of the Southern Pacific Co., and the Pioneer smelter is located a few miles to the north.

Most of the country is less than 4,000 feet in elevation. The topography in general is rough, the surface being scored by deep gulches or shallow canyons. The highest point is Mount Benedict, near the center of the western part, which rises to 4,500 feet. The surface, especially on the east and north, is mostly underlain by a sheet of Quaternary gravels and wash.

GEOLOGY.

The oldest formation is the quartz monzonite of Mount Benedict, which, beginning at the south base of the mountain and occupying a belt about 2 miles wide, extends northwestward for 5 miles to a point within 1½ miles of Calabasas. Croppings of what seems to be this same rock by the roadside along Santa Cruz River in the vicinity of Yerba Buena Canyon, about 6 miles northeast of Nogales, indicate that beneath the gravels and lavas it underlies a considerable portion of the Santa Cruz Valley in this direction and probably connects with the Patagonia Mountain area of this rock on the east. It is a granitoid rock very similar to the quartz monzonite of the Washington-Duquesne camp, described on page 327, except that it is coarser grained, being locally called "bull" granite, and it contains a little more of the dark silicates, especially biotite. As seen on the north slope of Mount Benedict, the rock mass is sliced by a dominant sheeting that dips steeply to the west and by a secondary sheeting that dips to the northwest. It is also traversed by a system of east-west fissures in which the ore deposits at Mount Benedict occur. It is intruded by dikes of aplite, granite porphyry, diorite, and lamprophyric and diabasic rocks, with which the ore deposits are mostly associated. The granite porphyry forms the summit of Mount Benedict and the crests of the highest ridges, notably on the west and the south.

The formation next younger than the quartz monzonite is quartz diorite, which occupies a semicircular area on the south, extending from Nogales eastward along the international boundary for 2 miles and seemingly forming but the northern portion of a large area of the same rock, most of which lies on the Mexican side of the line. East of Nogales it forms a steep hillside, and in the northeastern part of the town, east of the courthouse, the reservoirs of the municipal water supply are excavated in it. It is a dark iron-gray fine-grained rock, composed principally of oligoclase-andesine in prisms, biotite and hornblende in short prismatic laths in about equal amount, and some associated augite, but the rock is low in dark silicates. Some orthoclase and considerable magnetite are also present.

The formation next younger than the diorite consists of the reddish bedded volcanic tuffs which, as shown on Plate II (in pocket), occupy an irregular area of about 3 square miles in the vicinity of Nogales, extending several miles northward down Nogales Wash and northeastward up the Proto Canyon road. The tuffs are in many places covered by the Quaternary gravels and are generally best exposed in the bottoms and sides of the drainage ways. Their general structure is indicated in section *E–F*, Plate III (in pocket). In the southwestern part of the district, at Nogales, as shown in Plate VI, *B*, the beds overlap the diorite on the hillside already mentioned. In the northern part of the town the courthouse stands upon the contact between the diorite and the tuffs.

At 3 miles east of Nogales and one-third of a mile north of the Mexican line black basalt, occurring in a small north-south area, shown on Plate II, intrudes the Quaternary gravels.

LODE DEPOSITS.

The lode deposits occur principally in the middle of the western part of the district in the quartz monzonite area, mainly at Mount Benedict, about 4 miles north of Nogales, and 2½ miles northwest of Mount Benedict, at the Reagan camp. The Mount Benedict deposits are principally gold-bearing, and those of the Reagan camp carry wolframite.

MOUNT BENEDICT.

The deposits at Mount Benedict occur in east-west veins in the quartz monzonite in the vicinity of intrusive quartz diorite or allied rocks, to which they seem to owe their origin. The gold occurs associated with white pyrite, chalcopyrite, and lead minerals, principally cerusite and galena. The presence of a streak of lead carbonate in the vein is regarded as an indication of gold, generally ranging from 2 to 3 ounces to the ton.

The deposits at the time of visit in 1909 were opened principally at the Dura, Uncle Sam, Lion, and Columbia mines. Late in 1911 it was reported that the Float Gold Amalgamating Co. had located an additional group of claims on which it was working a force of 20 men and operating a Nissen 10-stamp mill with good results.

DURA MINE.

The Dura, also known as the International and as the Old Contest mine, is 4½ miles north-northeast of Nogales, on a ridge on the east-southeast slope of Mount Benedict, at an elevation of about 4,050 feet. Some mining was done here on the XXX claim in the early days—in the forties, it is said—by Mexicans, who smelted the ore in a plant near the Buena Vista mine and left much good ore on the dump. The property comprises three claims, the Dura, XXX, and Yankee Girl. It formerly belonged to Mr. Litchliter but is now owned by J. C. Gleason, of Cortland, Ariz. The known production in recent years is several thousand dollars. Seven tons of ore shipped to the Selby smelter averaged, it is said, 35 ounces in gold to the ton; three cars shipped in 1903 averaged $600 in gold to the car, and 8 tons shipped by Mr. Litchliter about 1895 netted $50 to the ton. From a small streak in the hanging-wall side of the vein was taken a mortar full of ore, which, it is said, contained $1,600 in gold. But little work was done on the property between 1905 and 1910.

The mine is on a fault fissure vein which strikes west-northwest in the quartz monzonite and is seemingly the same vein as that of the Uncle Sam mine, described below. At the surface the vein dips to the south, but in depth, as shown in the tunnel below, it dips steeply to the north. The vein as shown in the tunnel is about 2 feet in maximum width; the filling consists of quartz and crushed, altered, and partly silicified country rock, with which is associated a dark dioritic pyrite-bearing dike rock and a little black calcite or spar. The vein is locally brecciated and crudely banded with quartz stringers that contain some ore and together with the ore impregnate and replace the rock.

The vein contains gold, silver, and lead but is worked for the gold. Ore on the dump at the shaft looks well, and the vein in the tunnel shows also considerable indications of copper, the minerals seen being malachite, pyrite, chalcopyrite, galena, cerusite, and stibnite. A little wolframite is also reported. With these minerals are associated the gold and silver. The order of the metals in value in the ore is gold, lead, silver. Five per cent of the value of the metal content is said to be in free gold and the rest chiefly in lead and silver. Some of the ore shipped is said to have carried 60 per cent in lead.

The mine is developed by about 1,000 feet of work, including two shafts and a 270-foot tunnel which extends westward into the east slope of the ridge and contains a 40-foot winze and stopes.

UNCLE SAM MINE.

The Uncle Sam mine is just across the gulch, 300 feet east of the Dura mine. It is owned by W. C. Ellis, of Nogales, and is opened by shafts and drifts, the deepest shaft having a reported depth of 345 feet. The material on the large dump is thoroughly oxidized and mineralized. The mine is in the quartz monzonite and seems to be on the same vein as the Dura mine, but the shaft and apparently also the vein trend N. 75° E., though the dip continues steep (75°) to the north, as at the Dura mine. The vein is said to contain 4 inches of ore-bearing quartz on the hanging wall and 6 inches on the footwall. The ore carries lead, gold, and a little silver.

In the gulch between these two mines the quartz monzonite is intruded by dioritic, aplitic, and dark basic dikes, some of which are apparently lamprophyric. To some of the dikes the deposits of the two mines probably owe their origin.

LION MINE.

The Lion mine is on the east slope of Mount Benedict, on the north side of its main gulch. The principal openings are 80 feet above the gulch at an elevation of about 4,050 feet. The mine is reported to have produced and shipped some ore. It is owned by George Norbeth, of Nogales, and is opened by shafts, cuts, winzes, and tunnels extending through a vertical range of 100 feet. The vein lies in the quartz monzonite country rock and dips steeply but variably to the north. It is 3½ feet in width and is composed mainly of quartz and crushed and altered quartz monzonite but contains considerable azurite, malachite, and bunches of galena, with which are associated gold and some silver. The deposit is being worked for its gold content. Much of the ore is stained yellow with what is probably lead-copper sulphate.

The deposit probably owes its origin to a dark siliceous pyritic fine-grained, slightly porphyritic quartz diorite which occurs in intrusive masses and dikes just northeast of the mine.

COLUMBIA MINE.

The Columbia mine is on the northwestern slope of Mount Benedict, at an elevation of about 4,040 feet. It is developed by about 500 feet of work, which includes an 80-foot shaft, a 300-foot tunnel, and a winze. It has produced some fair-grade ore, mostly from the winze. The country rock is quartz monzonite. In one part of the workings it contains a large body of massive quartz which, together with the quartz monzonite, is cut by dark-greenish diorite that is traversed by calcite veinlets.

The deposits occur in two east-west veins about 250 feet apart, of which the north or principal vein strikes N. 80° E. and dips 50° S. in the quartz monzonite and quartz. It consists in part of massive quartz, crushed, sheared, altered quartz monzonite, and dark intrusive diorite. It is 4 feet in maximum width, but the portion worked is only about 1¾ feet wide and consists principally of banded quartz and mineralized rock. The vein is opened by a 40-foot open cut and the 80-foot shaft.

The south vein strikes N. 80° W. and dips 60° S. in hard quartz monzonite. It is about 1½ feet in maximum width and consists principally of banded quartz containing galena, pyrite, chalcopyrite, and some malachite stain.

REAGAN CAMP.

The Reagan camp, in which the deposits contain tungsten minerals,[1] is in the low northwest end of the quartz monzonite area of Mount Benedict, 3 miles north-northwest of the Mount Benedict ore deposits, 2½ miles south-southeast of Calabasas, and a quarter of a mile east of the railroad. The main property, which includes the Reagan mine and a group of prospects extending southward from the mine for about a mile in a belt half a mile wide, is owned by E. G. Peck and Reagan Bros., of Nogales. The deposits are opened principally by shafts to a depth of 30 feet. The presence of wolframite was first noted here about 1906, and a few prospect holes sunk at that time led to mild excitement. At the time of visit the owners had shipped from the mine about 1,000 pounds of ore which, they stated, assayed more than 50 per cent tungstic acid, and about 400 pounds of ore of the same grade still lay on the ground, together with several hundred pounds of lower-grade material.

The quartz monzonite country rock is similar to that at Mount Benedict but seemingly a little coarser, and it is locally porphyritic, with some feldspar crystals half an inch in longer dimension. It is extensively cut by a conjugate system of dikes of two types, one basic and the other acidic. The basic dikes are the more important so far as the ore deposits are concerned. They consist of a greenish-black fine-grained lamprophyre composed mainly of an undetermined plagioclase with index of refraction less than Canada balsam and hornblende in long, needle-like crystals, with considerable magnetite and a little quartz. The rock is largely altered to chlorite and contains some secondary epidote and hematite, the latter probably being derived from the magnetite. It is traversed by veinlets of calcite. Some phases of the rock are coarsely porphyritic with the weathered surfaces pitted, the casts being coated with iron oxide or filled with calcite. The contact of this rock with the quartz monzonite is very sharp, the quartz monzonite being but little changed beyond a band a fraction of an inch wide, in which much epidote and a chloritic mineral are developed from both the feldspars and the ferromagnesian minerals. For a quarter of an inch from the contact the intrusive rock is very dense, fine grained, and black. Beyond this band is a belt of varying width, dependent on the size of the dike, containing rock that is much epidotized and chloritized, and beyond this belt the rock is unaltered. The lamprophyre dikes are mostly

[1] For a more extended description of these deposits see Hill, J. M., Note on the occurrence of tungsten minerals near Calabasas, Ariz.: U. S. Geol. Survey Bull. 430, pp. 164–166, 1910.

from 2 to 4 feet in width, and none of them exceed 6 feet. They are generally persistent, some having been traced for 2,000 feet. They occur in two sets which differ slightly in age. The dikes of the older set strike N. 75° W. and dip steeply to the north; those of the younger set strike N. 25° W. and are vertical or dip steeply to the west.

The ore deposits occur in narrow veins in the lamprophyre dikes and in the adjoining quartz monzonite, the association between the deposits and the dikes being apparently very intimate. The veins range from a few inches to 2 feet in width, but most of them are less than 10 inches. The larger veins are generally lean in values. Locally the walls and gouge are iron stained. The vein filling is principally quartz with a little associated finely crystalline calcite. The veins show beautiful comb structure and are well banded, bands of quartz alternating with those of wolframite. The usual order from the wall inward is first quartz, then wolframite. Here and there this order is reversed, and it may be that in places the deposition of the two minerals was more or less simultaneous, as wolframite crystals are seen in some of the quartz layers and quartz in some of the wolframite. Postmineral movement is shown by the gouge-covered wall, but the veins were not much crushed by this disturbance. In a number of places the quartz is cemented to the wall by a thin layer of greenish siliceous material, which is very dense, like a silicified shale, and is seemingly the intrusive rock that has been altered by the solutions which formed the veins.

The only metallic minerals occurring in the belt are wolframite, a reddish-black heavy mineral with metallic luster and brownish streak, and a little scheelite. The wolframite is in part fairly well crystallized but mostly massive. In the crystallized form, in the larger veins, the crystals apparently grew into an open space that later became filled with white vitreous quartz. Near the surface the wolframite is partly altered to iron oxide, which shows the form of the original crystal. The wolframite seems to lie in pockets and shoots in the larger quartz veins and to be more concentrated where these veins pinch. In the smaller veins the deposition of wolframite was apparently more general, as bands or shoots about one-eighth of an inch in width are fairly continuous along some of these veins, the largest shoot seen being about 4 by 3 feet in dimensions along a 6-inch vein.

At the Reagan mine, which is on a group of three veins that beginning on the west are spaced respectively 60 and 30 feet apart, in much altered and weathered quartz monzonite, the veins occur chiefly in the north-south or younger set of fissures. They strike N. 25° W., parallel with the younger dikes, and have a nearly vertical dip.

They offset by a throw of a few feet two of the older east-west dikes.

The two outside veins are small and well banded and contain minor amounts of wolframite. The "tungsten" ore is usually next to the wall rock, and the vein has a central band of comby quartz, showing that the ore minerals were deposited mainly during the early stages of fissure filling. The middle vein ranges from 1 to 2 feet in width and consists largely of quartz in which occur pockets and stringers of wolframite. The deposition seems to have been repeated, as the banding from the wall inward is quartz (0.2 inch), wolframite (0.3 inch), quartz (0.25 inch), wolframite (0.1 inch), and quartz. The banding is not at all regular, however, wolframite locally filling the entire space inside of the first quartz bands. Scheelite occurs as minute crystals in the quartz near the bands of wolframite.

The veins seem to narrow or pinch and grow leaner as they go down, but as observations were confined almost entirely to the surface—the principal opening at the mine, a 30-foot shaft, not being enterable and but few prospects being visited—no generalization can be attempted as to the probable occurrence of ore at greater depth. The general geologic conditions are favorable.

PLACER DEPOSITS.

Gold placer deposits occur in the northeastern part of the district on Guebabi Canyon, which drains into Santa Cruz River from the northeast at a point about 6 miles north of Nogales. The canyon extends southwestward through a large area which is commonly known as the Guebabi district but which, except along the canyon, is barren of ore deposits. For lack of time the locality could not be visited in this examination, but along the course of the stream gold placers of considerable extent are reported to occur in the Quaternary gravels. Here are said to be the oldest and largest placer mines in this part of the country. The placers produced considerable gold in early days and are being worked to a moderate extent at the present time.

SAN CAYETANO DISTRICT.

LOCATION.

The San Cayetano district is in the southwestern part of the area, almost adjoining the Nogales district on the north and the Tyndall district on the west. It is elliptical in outline and is practically coextensive with the San Cayetano Mountains. It has a length of 6 miles and a width of 3 miles. It extends from Josephine Canyon on the north nearly to Sonoita Creek on the south. The nearest railroad shipping point is Calabasas, 3 miles to the south.

TOPOGRAPHY AND GEOLOGY.

The topography is rough, mostly of the type resulting from the erosion of volcanic rocks in a mountainous region. The periphery of the district lies at a general elevation of about 4,000 feet, from which the surface rises to about 6,000 feet along the middle part of the crest. The mines are near the central part of the district on each side of the range and are reached by wagon roads and trails.

The geologic structure is monoclinal, the rocks dipping to the east. The formations, except a small north-south area of sedimentary rocks on the middle south slope of the range at an elevation of about 5,000 feet (Pl. II, in pocket), are all igneous. The sedimentary rocks are composed mainly of thin-bedded red and green quartzites and hornfels, which are regarded as of Paleozoic age. They dip 40° E. and are underlain by intrusive quartz diorite, and overlain by rhyolite. On the west the lower and middle slopes of the mountains are occupied by the quartz diorite rising to an elevation of about 5,000 feet, and on the east bedded volcanic tuffs rise to about the same elevation, while the intervening belt, composing the upper slopes, crest, and axis of the range, consists of rhyolite.

The quartz monzonite is a greenish-black intrusive rock of Mesozoic age. It is composed mainly of labradorite or a related basic plagioclase, with some orthoclase, brown biotite, hornblende, a small amount of quartz, and accessory magnetite and apatite.

The rhyolite, which overlies the diorite on the east, is dark greenish and generally vitreous. It is composed mainly of a felsitic to glassy groundmass of quartz and orthoclase with a little biotite and acidic plagioclase and has in places a few small phenocrysts, especially of quartz and orthoclase. It belongs to the Tertiary lavas elsewhere described. Both the rhyolite and the diorite are intruded by quartz monzonite porphyry, a light-gray, coarsely porphyritic rock in which quartz, plagioclase, orthoclase, and hornblende can be distinguished in hand specimens, some of the crystals being about a quarter of an inch in longer axis. The groundmass is microgranular and is apparently composed of quartz and feldspar. The phenocrysts, which are unequal in size, are, in the order of their abundance, andesine, orthoclase, hornblende, quartz, and biotite. Secondary minerals are calcite, chlorite, and epidote, and the rock contains a little accessory magnetite.

The tuffs which cap the rhyolite on the east occur in cream-white to yellow beds and are rhyolitic. At and beyond the base of the mountains and the eastern limit of the district they are capped by a younger blackish scoriaceous andesite.

ORE DEPOSITS.

Quartz-calcite veins, containing pyrite, chalcopyrite, tetrahedrite, and chalcocite as the principal metallic constituents, are the only ore deposits thus far exposed in the San Cayetano district. These veins occur in the rhyolite, in which they stand nearly vertical, and in the quartz diorite, in which the dip is rather flat and about parallel with the sheeting structure of the rock. All the veins occur in the immediate vicinity of intrusive masses of quartz monzonite porphyry. In the two places where there are openings in these mountains considerable shearing is evident along the veins, which were deposited from solution, as is indicated by their banded structure.

Neither of the prospects appears very promising. The Tubutana vein, in the quartz diorite, is apparently pinching in depth, and the rich surface ores containing horn silver will probably not continue to any great depth. The deposit in rhyolite, at the Wise prospect, is much larger, but here the metals are so sparingly disseminated through the mass of country rock as to be of but little present value.

TUBUTANA MINE.

The Tubutana mine is located on the west slope of the San Cayetano Mountains, a little south of the center, at an elevation of 4,250 feet. It is said to be an old Mexican mine, but nothing is known of its ownership prior to 1901, when it was located by Mr. Brownfield, of Patagonia. In 1904 it came into the possession of San Francisco men who organized the San Cayetano Mining Co. This company continued work until the earthquake in 1906. Later Mr. Cane, who had been the superintendent, is reported to have shipped 9 tons of ore to the El Paso smelter. Mr. Brownfield is also said to have shipped in the later part of 1901 some ore that averaged well in silver.

The mine is developed by an incline, reported to be about 40 feet deep, sunk on the ore. The dump, however, is large and indicates considerable underground work. Parts of a whim remain at the entrance to the mine.

The general country rock is a dark greenish-gray holocrystalline quartz diorite. It is cut south and southwest of the mine by a dike of quartz monzonite porphyry similar to that at the Wise prospect. It is sheeted with the structure, dipping into the mountains at an angle of 32° S. 75° E. At 500 feet above the incline the diorite is capped by rhyolite dipping parallel with the structure in the diorite.

The ore deposits occur in a quartz vein that parallels the structure of the mountains and the inclosing diorite. The cropping of this vein is about 2 feet wide, but the vein is only 8 inches in width at 20 feet down in the incline and is reported to pinch out at a depth of 40 feet. Water stands within 25 feet of the collar of the shaft. For about a foot on each side of the vein the diorite is much altered and is cut by parallel veinlets of quartz and gray to pinkish calcite. These veinlets as well as the larger vein contain the ore minerals pyrite, chalcopyrite, and tetrahedrite, which appear directly at the surface with minor amounts of limonite, malachite, cuprite, and azurite. The silver content is apparently associated with the tetrahedrite.

WISE PROSPECT.

The Wise prospect is on the east slope of the San Cayetano Mountains near its middle point, at an elevation of about 4,600 feet. It is 5 miles north-northeast of Calabasas, from which a wagon road, now out of repair, ascends the canyon to a point about 500 feet below the lower workings. This property has been relocated many times since the late sixties, but little work was done on it before 1889, when it came into the possession of the present owner, J. E. Wise, of Calabasas. It is opened by about 110 feet of tunnels, but no ore has been shipped from it.

The country rock is greenish-gray dense rhyolite, which is locally porphyritic and which is cut by a dike of quartz monzonite porphyry that strikes N. 70° W. and dips 85° S. On the south or hanging-wall side of this dike the rhyolite is considerably sheared, crushed, and altered for a distance of 4 feet. In this sheared belt occur veinlets of quartz as much as 8 inches in width which carry ore containing pyrite, chalcopyrite, chalcocite, and bornite, said to assay $10 to the ton in silver and copper. The vein in general is banded. In several places bands of quartz are separated by a band of the metallic minerals. Small stringers and films of quartz and metallic minerals occur also in the banded crushed claylike gouge on the south side of the dike at the tunnels.

In a belt extending 150 feet north of the dike the rhyolite is considerably altered and is traversed by quartz veins ranging from a small fraction of an inch to 8 or 9 inches in width. Some of these veins are composed of pure-white quartz; others contain also a little pyrite and chalcopyrite.

Sulphides are found directly at the surface accompanied by oxidized minerals in small amounts, hematite and limonite films being the most conspicuous locally, with a small amount of malachite and cuprite. In some of the more open cracks occurs a very soft black mineral which is finely divided, contains principally copper and sulphur, and corresponds to chalcocite.

NONMETALLIFEROUS MINERAL RESOURCES.

BUILDING MATERIALS.

The principal nonmetalliferous mineral resources of the area here discussed are building materials, chiefly building stone and the raw materials limestone, clay or shale, and sand suitable for the manufacture of brick, lime, mortar, and cement. Owing to the slight demand they have been little exploited, but they seem in general to be plentiful in many parts of the area.

The building stones most easily available are volcanic tuffs, limestone, and sandstone. Where stone of greater resistance than these is required for footings or abutments it may be had from the areas of granite or granitoid rocks, quartz monzonite, quartz diorite, and perhaps from the harder bedded nontuffaceous volcanic rocks.

The principal occurrences of the volcanic tuffs, as described on pages 73 and 350, are in the area extending from Nogales several miles north; in a similar area of 8 or 10 square miles, about 5 miles north-northeast of Calabasas, in the lower east slope of the San Cayetano Mountains and the adjoining lowland on the east; and in the north slope of the Grosvenor Hills 1½ miles southwest of Salero. Some tuffs also occur on the east slope of the south end of the Santa Rita Mountains and in the Patagonia Mountains near the town of Harshaw, where they have been used largely in building.

At Nogales the tuff occurs in gently inclined beds 6 inches to 8 feet in thickness and is more or less extensively quarried for local use in various ways. The county courthouse, a substantial structure, and many of the best and most modern residences and business structures are built of it. At Salero this rock is used for pavements and flooring.

Limestone suitable for flux, for the burning of lime, and seemingly for building purposes occurs in nearly all the Paleozoic stone areas shown on the geologic map (Pl. II). It has been quarried to some extent on the north, near the Andrade ranch and the California mine. Here the rock is a white crystalline limestone or marble. In the Empire Mountains the limestone is dark or black and of variegated shades. Lime was formerly burned from the limestone in the northern part of the area and near the center, where a limekiln of much service still stands at the north end of the Canelo Hills, and lime is now burned for local use at Mowry by the Mowry Mines Co. from the limestone at that locality.

In connection with limestone may also be mentioned the calcareous deposit known as caliche, which in other portions of this southwestern desert country where limestone is not readily available is used for flux with good results. Caliche occurs locally in well-developed deposits, underlying portions of the bajada at the base of the mountains, as seen, for example, at Tiptop Mountain, Bulldozer Hill, and other foothills.

It is probable that some of the quartzites associated with the Paleozoic limestone beds, especially the Carboniferous, may also be found useful for building.

The sandstone occurs principally in the Mesozoic formations in the northern part of the area, mostly in heavy reddish beds.

Deposits of unsorted Quaternary sand and gravel occupy more than half the area and occur in almost inexhaustible amount on the floors of the valleys and on piedmont slopes. They are generally coarse near the mountains and finer toward the middle of the valleys. Deposits of sorted sand suitable for use in mortar and plaster occur along Sonoita Creek and Santa Cruz River.

Clay suitable for adobe is found in almost all the valleys, and some along Santa Cruz River is said to make a fine red brick. The chief source of brick material, however, will probably be found in the clay shales of the Carboniferous and perhaps older formations. On the northeast, between Tucson and Benson, a good pottery clay is reported to occur. Abundant limestone and shale, seemingly suitable for the manufacture of hydraulic and other cement, occur in the Paleozoic formations, especially the Carboniferous. It is also probable that much of the volcanic tuff in the Nogales and other districts may be suitable for cement, for which similar deposits in southern Europe and in western America, as on the Los Angeles Aqueduct,[1] are extensively used.

COAL OR LIGNITE.

Deposits of lignite are reported[2] to occur in the western part of the Whetstone Mountains, whose western base lies within the northern part of the area but whose formations seem largely to underlie the wide Cienega Valley. The coal occurs in a 40-foot zone in a formation of inclined sandstone and shale or slate which is apparently Mesozoic and with which it is conformable. The zone is said to have a known horizontal extent of nearly half a mile. At one point it was opened by a 40-foot shaft by R. R. Richardson, but the coal, which was of low grade, was not found to improve perceptibly in this depth. The shale here on being rubbed or pounded with a hammer is said to give off a petroleum odor, but no oil seepage has been reported. Associated with the deposit are reported to be plentiful remains of petrified trees, some being about 100 feet in length.

[1] Lippincott, J. B., Tufa cement, as manufactured and used on the Los Angeles Aqueduct: Am. Soc. Civil Eng. Proc., vol. 38, No. 8, pp. 1191–1216, 1912.

[2] Oral communication from A. J. Stockton and R. R. Richardson, of Patagonia.

At a neighboring locality Fairlee & Jenson, of Benson, in early times discovered and opened two small coal beds that likewise occur conformably in sandstone and shale which incline at an angle of 22°. Here the beds are about 8 feet apart and the coal is said to be of good grade. It was used with good results on the forge in sharpening miners' tools on the ground, but as the largest bed does not much exceed 4 inches in width, the ground, after being developed by about 1,000 feet of work in the hope that the beds would be found to widen in depth, was relinquished. At this locality are said to occur both plant and animal fossils.

ONYX.

On several claims in the Greaterville district efforts have recently been made to develop "onyx" deposits, but it is thought that the deposits are too calcareous to be of commercial value. Recently the Onyx Mining Co. is said to have developed here a large deposit of chalcedony.

OPAL.

So-called opal or opaline silica occurs in the Grosvenor Hills 2 miles southwest of Salero. It is mostly amber-brown or yellowish brown and occurs mainly in a 6-inch vein in the andesite and rhyolite. With it are associated considerable chalcedony and hyalite, which occur also in stalactitic and stalagmitic forms on the joint and sheeting planes of the rocks. It seems doubtful whether the deposits will prove to be of commercial value.

ALUNITE.

Alunite, a hydrous potassium-aluminum sulphate, occurs generally as an alteration product in the Palmetto district at the Three R group of mines, 5 miles south of Patagonia. It occurs in the wall rock of the Evening Star prospect as a replacement of the orthoclase feldspar in altered granite porphyry, as shown in Plate XIX, *A*. The zone of alteration of the porphyry extends at least several feet back from the vein and perhaps many times this distance. Its width was not investigated in this work.

The rock in this vicinity is a medium to coarse grained gray granite porphyry. It was at one time probably pegmatite but has been dynamically altered. It is composed in part of what seems to represent a fine-grained groundmass of orthoclase and quartz, in which rest many larger phenocrysts of the same minerals. The phenocrysts constitute more than two-thirds of the volume of the rock. Pyrite and chalcopyrite are present in both the orthoclase and the quartz, and apatite and zircon are present as accessories. The rock, moreover, is highly altered, principally by sericitization and some kaolinization.

The alunite-bearing portion of the rock, however, is pink instead of gray. It has been alunitized instead of sericitized, the feldspar being almost if not completely replaced by pink alunite, so that the rock consists chiefly of quartz and alunite with a little pyrite and chalcopyrite.

The rock in its present deformed and altered state presents a sort of graphic structure. It shows a general parallel pegmatitic arrangement of the minerals, quartz and mostly alunite alternating with each other in elongated crude lenslike bodies or discontinuous bands with irregular outline. These bands vary from about 0.1 to 0.4 inch in width. They are traversed at nearly right angles by a very close lamination or schistose structure, which amounts almost to cleavage and which is most conspicuous in the quartz. In the former feldspar areas the structure has been dimmed or largely effaced by the replacing aggregates of alunite, which is in part pseudomorphic after the orthoclase. In or paralleling this schistose structure in the alunite or areas of the former feldspar phenocrysts occur also numerous veinlets of alunite having comb structure, by which a single crystal area is commonly sliced into 6 or 8 or even 10 to 12 sections. The veinlets show bilateral symmetry, with the comb structure locally interlocking. They are composed of slender elongated crystals which are apparently made up of numerous smaller, almost cryptocrystalline aggregate forms, or successive zonelike stages of growth. The veinlets that extend into the adjoining quartz are usually less well developed.

Owing to the recent activity in the potash industry and the recognition of alunite as a possible source of potash, the interest in this occurrence centers chiefly in its potash content. The rock from the Evening Star prospect, according to E. S. Larsen, who examined it microscopically and who is familiar with the occurrence of alunite-bearing rocks in other fields, contains by estimate about 30 per cent of alunite, and therefore carries 3 or 4 per cent of potash (K_2O).

This occurrence alone, here observed only incidentally, is not to be regarded as of commercial value but serves to call attention to the presence of alunite in this part of the area and suggests that very likely other deposits of the mineral may occur in the granite porphyry, which in the Three R belt alone occupies an area of about 9 square miles. This early suggestion of wider distribution of the deposits is borne out by later and more extensive examination of the camp by Probert,[1] who states that "the alunite is found not only in the vicinity

[1] Probert, F. R., The Three R mine, Patagonia district, Ariz.: Min. and Sci. Press, vol. 109, No. 5, p. 175, 1914.

of the chalcocite ore bodies, but in altered pyritized areas, where the rocks have been more or less cleaved."

The porphyry area would commend itself for prospecting in case a practical process is discovered for the reduction of alunite to soluble potash salts. A study of the alunite problem by the United States Geological Survey indicates that the mineral may at some future time become an important source of alumina for use in the manufacture of the metal aluminum.

The occurrence of the alunite in the granite porphyry, a post-Paleozoic hypabyssal or plutonic intrusive rock, is unusual, for most of the known occurrences of alunite, especially in the western United States, are in Tertiary volcanic rocks.[1] The alunite here described seemed to the writer at the time of his visit to have been formed chiefly by the metasomatic replacement of the orthoclase feldspar in the granite porphyry, a process accomplished by hydrothermal solutions that ascended the fissure after the intrusion of the granite porphyry or the rhyolite near by on the east. The solutions probably contained sulphuric acid, and the process was attended by some silicification. The deposition apparently took place in two periods, or else during the period of deposition the rock was crushed and sheared, and later the veinlets traversing the earlier alunite bodies were deposited in the fractures.

However, Ransome[2] and others have shown that alunite may be formed by very different processes, among which is the action on feldspar, as held by De Launay, or on sericite away from free oxygen, as held by Lindgren,[3] of downward-percolating meteoric waters charged with sulphuric acid by the oxidation of pyrite. Probert,[4] whose observations cover later developments in the mine, also favors the meteoric origin of the alunite and states that "the close relation-

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[1] Cross, Whitman, On alunite and diaspore from the Rosita Hills, Colo.: Am. Jour. Sci., 3d ser., vol. 41, pp. 466–475, 1891.

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Ransome, F. L., The geology and ore deposits of Goldfield, Nev.: U. S. Geol. Survey Prof. Paper 66, pp. 129–139, 193, 1909.

Butler, B. S., and Gale, H. S., Alunite, a newly discovered deposit near Marysvale, Utah: U. S. Geol. Survey Bull. 511, pp. 61–63, 1912.

Larsen, E. S., Alunite in the San Cristobal quadrangle, Colo.: U. S. Geol. Survey Bull. 530, pp. 179–183, 1912.

[2] Ransome, F. L., op. cit.

[3] Lindgren, Waldemar, The copper deposits of the Clifton-Morenci district, Ariz.: U. S. Geol. Survey Prof. Paper 43, pp. 119–120, 169, 193–194, 1905.

[4] Probert, F. R., op. cit.

ship between chalcocitization and oxygenation of sulphides suggests a later (or posthydrothermal) origin of the alunite. I attribute it to the sulphurous waters of the oxidized zone." He refers to alunite as a common associate of enriched copper ore and its occurrence in pyritized altered porphyry at other mines. In the locality here described the pyritic and highly sericitized character of the weathered porphyry admirably fulfills the conditions requisite for the formation of the alunite by the meteoric process.

In prospecting for alunite, as suggested by Butler and Gale,[1] it is well to examine (1) the general so-called kaolin and talc deposits and also those of jarosite, associated with the feldspathic rocks in the oxidized zone; (2) phases of the Tertiary volcanic rocks containing potassium and aluminum silicates in places where, as along fissures, they have suffered propylitic alteration by hydrothermal solutions and contain pyrite or chalcopyrite; (3) supposed spar, talc, or kaolin veins, especially in or near Tertiary volcanic rocks, whether or not associated with metallic veins.

Butler and Gale[2] give the following simple field test for the mineral alunite, suggested by W. T. Schaller:

> Boil the powdered sample with water or with hydrochloric acid for several minutes. After allowing the powder to settle pour off the liquid and repeat the operation to insure the removal of all soluble sulphates. Dry the powder and heat to a dull red. Again boil in water, and after settling pour off some of the clear liquid. To this add a small fragment or a solution of barium chloride. If the mineral is alunite a heavy white precipitate will form. To be sure that the water used in this test does not contain sulphates in solution it should be tested with barium chloride, and if it gives a marked precipitate it can not be used. For this test all that is required that is not included in a miner's or prospector's outfit is a little barium chloride, which can be carried in a small bottle or cartridge.

WATER SUPPLY.

Water is not scarce in this region, as it is in many parts of the southwest desert country. During the rainy season there is in general an abundance of running water, which in most of the streams continues for some time after the rains in early April, and at a few places water is permanent in the larger streams, but in the dry season of the year the supply for the most part is obtainable from springs only.

Springs are numerous in the upper part of the Santa Rita and Empire mountains, and the locations of some of them are shown on Plates I and II. Wells sunk almost anywhere in the canyon bottoms obtain water at shallow depths. Basins or reservoirs of ground water occur on the upper part of the Santa Cruz and its tributaries, as at

[1] Op cit., pp. 61–63. [2] Idem, p. 63.

Guajolote Flat and elsewhere, and in the detritus-filled valleys the ranchers seem to obtain from shallow wells all the water they need, generally raising it by windmills.

Water is encountered in nearly all the mines of the quadrangle, in most of them at depths of about 200 feet, and in many places surface water accumulates at shallow depths. In the region of the McCleary ranch, at the northwest base of the Santa Rita Mountains, the ground-water level stands 50 feet below the surface.

The Halfway well, located just beyond the north border of the area mapped, about midway between Tucson and Helvetia, in the plains portion of the Santa Cruz Valley, is 220 feet deep. Here water was encountered at a depth of 212 feet and rose to 180 feet below the surface. It is now pumped by windmill or gasoline engine.

Santa Cruz River flows on the surface in the southeastern part of the area for about 6 miles of its course north of the boundary, and also in the southwestern part, from the boundary to a point a little beyond the mouth of Guebabi Canyon, 10 miles to the northwest.

Most of the water in Sonoita Creek comes from three large springs on the flanks of the Canelo Hills. Two of the springs are opposite Old Fort Crittenden, and the third is three-fourths of a mile west of the Pennsylvania ranch. The latter, Monkey Spring, discharges about 3 cubic feet a second.[1] Two miles south of the Pennsylvania ranch the creek sinks below the surface, but it reappears just below Patagonia, whence it continues as a surface stream through the box-canyon portions of its course for a distance of 8 miles.

Cienega Creek, in the northeastern part of the area, is a permanent stream throughout most of its 15-mile course, extending from the Cottonwood ranch northward through the canyon to a point beyond the Empire Mountains. Some of the head tributaries of this stream, in Gardner and Sawmill canyons, heading in the Old Baldy portion of the Santa Rita Range, are perennial streams except in periods of drought covering several years. Practically the same is true of the streams in Madera and Stone Cabin canyons, on the west side of the range.

The following table[2] gives the depth of run-off of Santa Cruz River when distributed over the drainage area of 2,100 square miles above the gaging station at Tucson, together with the approximate rainfall, the ratio between these quantities being the proportion of precipitation which reaches Tucson as surface flow. Practically all the rainfall evaporates or escapes by underground channels, and the latter amount is probably quite as insignificant as the run-off. By

[1] Oral communication from Mr. Ashburn.

[2] Smith, G. E. P., Ground-water supply and irrigation in the Rillito Valley; Univ. Arizona Agr. Exper. Sta. Bull. 64, p. 117, 1910.

estimate a very large part of the precipitation is confined to about three-sevenths of the drainage basin, or 900 square miles, in the southwestern two-thirds of the area.

Depth and percentage of run-off of the Santa Cruz drainage basin.

Year.	River discharge.	Rainfall.	Run-off.	
			Depth.	Percentage of rainfall.
	Acre-feet.	*Inches.*	*Inch.*	
1906	14,670	15	0.13	0.9
1907	29,780	17	.26	1.5
1908	15,130	18	.13	.7
1909	15,820	13	.14	1.1

Owing to evaporation and dissipation of the water in the deposits of the valley fill, the best localities for the development of water-supply projects of the drainage area are near the source, along the mountains. Along the river between Calabasas and the international boundary there are said to be excellent opportunities for the development of small streams by underflow ditches.[1]

At the mouth of Yerba Buena Canyon, where a gaging station has been maintained since 1906 by the United States Geological Survey, a dam site and irrigation project has been surveyed which would irrigate a large part of this section of the valley, but owing to its proximity to the international boundary and the possibility that Mexico might impair the water supply it does not seem certain at present whether the project will be consummated.

At Agua Caliente, near the middle of the west border of the area, southwest of Pete Mountain, occurs a fine warm perennial spring which is said to have been frequented from the time of the earliest settlement of Arizona for the medicinal qualities of its waters.[2] The water issues from the red shale and sandstone through the overlying Quaternary sand and gravels. It wells up with considerable force in the bottom of a shallow bowl-shaped reservoir, 10 to 12 feet in diameter and several feet deep, whence it flows over the rim in a fairly rapid clear stream about a foot wide and 2 inches in depth. The water is nearly milk-warm and is perfectly palatable, especially when cooled. Some of the water is used for stock and a small amount for irrigation, but most of it flows through a bathing pool 150 feet long, after which it soon sinks beneath the surface a short distance down the arroyo. The spring, owing to its perennial character, is a boon to the stock industry in times of drought, when neighboring

[1] Smith, G. E. P., op. cit., p. 200.
[2] Report of the Governor of Arizona for 1895.

springs dry up and stock from long distances come here for water. The temperature of the spring is said to vary less than half a degree the year around, and from this fact its source is regarded to be deep-seated, probably near or associated with heated but gradually cooling volcanic rocks.

Two strong streams of cool palatable water also issue from the Paleozoic rocks in the northeastern part of the quadrangle, of which one supplies the Andrade ranch and the other flows from a shallow tunnel at the California mine.

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