The Wallapai Mining District Cerbat Mountains Mohave County Arizona

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By McCLELLAND G. DINGS

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A study of the geology and ore deposits

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THE WALLAPAI MINING DISTRICT, CERBAT MOUNTAINS, MOHAVE COUNTY, ARIZ.

By McClelland G. Dings

ABSTRACT

The Wallapai mining district is in Mohave County, northwestern Arizona, near the center of the Cerbat Mountains. The district is approximately 10 miles long and 4 miles wide. In the early days (1863–1900) miners sought silver, and to a less extent gold, in the oxidized parts of the fissure veins. Later, lead with a low silver content was mined, and still later the zinc and lead production became the most valuable, owing very largely to the combined output of the Golconda and Tennessee mines. From 1904 to 1948 the district had a recorded recovery of 54,760 tons of zinc and 35,736 tons of lead.

The rocks include granites, gneisses, schists, and amphibolite of pre-Cambrian age intruded by two younger masses of granite. The older of these two granite intrusions is in the northern part of the district and is named the "Chloride granite" in this report. It is probably of pre-Cambrian age. The other intrusion, the Ithaca Peak granite, is near the center of the district. In this report it is assigned a Mesozoic (?) age, although it had previously been designated as Tertiary (?). Gneissic granites predominate throughout the district. Dikes of pegmatite, rhyolite, and lamprophyre are abundant and widespread. Remnants of volcanic rocks of probable Tertiary and Quaternary age flank the Cerbat Mountains but are not present in the district.

The structural history has been complex. Most of the rocks, except the large Mesozoic (?) granite intrusion, are gneissoid or schistose. The prevailing schistosity strikes northeast, with steep dips either to the northwest or to the southeast. A large northeastward-trending fold occurs near Chloride; other, less prominent ones are indicated on the map. The veins occupy fissures in a very prominent and persistent northwestward-trending zone. Postmineral faulting offsetting the veins is rare and where present has resulted in only minor displacements.

The typical ore occurs in pyritic quartz veins and lodes formed at intermediate depths. Veins range considerably in thickness but average 3 to 4 feet. Only a few exceed a length of 1 mile. The oxidized zone, averaging 150 feet in depth, commonly contains cerargyrite, native gold, galena, and cerussite. The primary ore consists chiefly of sphalerite, galena, pyrite, and some chalcopyrite. The sulfides occur in irregular masses and in crudely banded forms in quartz gangue. Ore shoots vary greatly in size, but the smaller ones, averaging about a foot in thickness and 20 feet in length and breadth, predominate. Primary enriched zones are commonly, though not always, found at abrupt changes in the strike of the veins and also at the junctions of branch veins. Mineralization took place probably in the Mesozoic, and the solutions probably are genetically related to a granite intrusion exposed near the central part of the district.

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Wallapai (Hualpai) mining district is in Mohave County in the northwestern part of Arizona (fig. 45). It occupies the central part of the Cerbat Mountains, which extend north-northwestward from Kingman for about 30 miles. The Wallapai district is about 10 miles long and 4 miles wide, trending northwestward obliquely across the mountains. The district includes the mining camps of Chloride, Mineral Park, Cerbat, and Stockton as well as outlying and intermediate areas such as Union Basin, Todd Basin, C. O. D. Wash, and I. X. L. Wash. All the camps are practically deserted except Chloride, which has a population of about 620 (1943 estimate by local

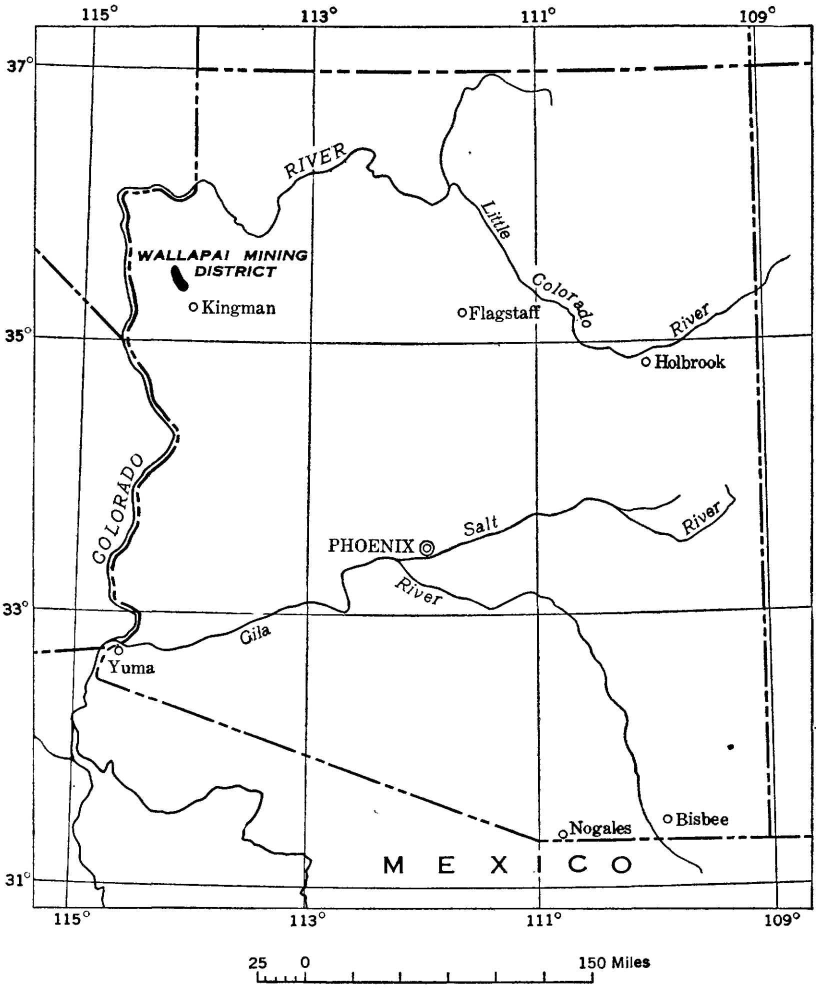

FIGURE 45.—Index map showing the location of the Wallapai mining district, Arizona.

postmaster). With the exception of those in the Stockton area, most of the mines are on the western slope of the mountains.

The nearest railroad station is at Kingman, reached from Chloride by a good paved road 24 miles long. Numerous dirt roads, generally in fair condition, extend to, or near, many of the mines.

TOPOGRAPHY

The topography is typical of eroded granite and gneiss masses in the more arid parts of the Southwest. The Cerbat Mountains rise sharply from the detritus-filled valleys bordering them on the east and west. The relief in the district amounts to about 3,500 feet; the lowest point is in Sacramento Valley in the southwestern part of the area, and the highest point is Cherums Peak (altitude 6,973 feet).

CLIMATE AND VEGETATION

The climate is arid, with mild winters and hot summers. The average temperature of the summer months is high, but the heat is allayed by cool nights, low humidity, and a more or less constant breeze. The annual precipitation is low. It is chiefly rain except in the higher mountains where snow falls in winter, but usually most of the snow melts within a short time. In summer the precipitation is largely concentrated in cloudbursts. Mining operations can be carried on throughout the year.

Vegetation is sparse and of the desert type, being confined largely to the valleys and lower slopes of the mountains. It consists chiefly of cacti, sage, yuccas, greasewood, soapweed, and a scanty growth of grasses. Scrub piñon or juniper is found in open groves and is particularly abundant in Mineral Park.

HISTORY AND PRODUCTION

Many of the mines were discovered between 1863 and 1900 by prospectors in quest of the silver and gold which occurred in the oxidized parts of the fissure veins, the silver commonly in very rich concentrations. Cerargyrite, argentite, galena, and some gold were the principal ore minerals recovered in the early days. Improvement in transportation facilities and milling methods led to the subsequent production of base-metal ores. At first, lead with a low silver content was mined, but later the production of zinc and lead exceeded in value that of all other metals in the district.

The value of the metals produced during the years 1904–48 (table 1) totals about $22,500,000. The value prior to 1904 is not known, but it probably amounted to at least five million dollars, for much high-grade silver ore, and to a less extent gold ore, is reported to have been mined in the early days.

TABLE 1.—*Production of gold, silver, copper, lead, and zinc in the Wallapai district, Mohave County, Ariz., 1904–48, in terms of recovered metals*

[Compiled by Metal Economics Branch, U. S. Bureau of Mines, Salt Lake City, Utah]

Year	Crude ore produced (dry tons)	Gold (oz.)	Silver (oz.)	Copper (lbs.)	Lead (lbs.)	Zinc (lbs.)	Value (dollars)
1904	1,531	1,592.42	64,335	1,480	6,036	----	----
1905	5,868	1,137.00	58,751	173	112,266	----	64,294
1906	9,946	2,772.00	125,331	114,502	904,390	----	----
1907	13,013	5,358.62	58,895	62,917	1,229,654	30,666	229,206
1908	2,179	1,193.13	29,931	11,920	249,328	505,133	76,313
1909	11,658	2,350.77	69,966	1,774	113,112	5,264,121	374,335
1910	1,109	424.33	48,509	20,341	235,368	----	47,908
1911	12,692	2,735.75	71,233	27,428	2,394,629	960,097	260,220
1912	4,472	1,461.87	43,761	7,828	1,350,920	799,219	174,362
1913	32,933	2,588.27	177,853	30,782	5,171,988	4,233,642	630,350
1914	22,492	1,205.41	88,951	18,297	3,708,102	4,932,108	472,695
1915	85,635	5,202.75	243,819	46,171	6,452,406	17,382,849	2,697,982
1916	104,658	6,106.90	229,237	190,807	5,825,791	17,024,626	3,007,298
1917	104,362	7,012.38	294,197	84,394	6,087,742	17,127,596	2,680,978
1918	4,739	987.82	42,098	91,596	533,462	82,853	130,558
1919	3,352	872.91	44,531	90,990	504,095	----	111,561
1920	2,399	682.81	37,500	11,160	338,623	----	84,133
1921	10,206	1,009.88	82,947	15,855	278,321	----	118,393
1922	3,453	553.94	42,099	22,638	84,142	----	61,234
1923	1,150	235.81	25,843	21,550	11,620	----	30,047
1924	388	165.30	5,027	6,460	172,088	----	21,398
1925	3,169	758.29	38,744	26,646	341,646	174,703	89,346
1926	10,056	2,034.39	75,470	80,728	697,805	1,669,266	281,469
1927	19,289	837.17	49,499	37,220	696,086	1,184,454	169,906
1928	995	198.45	10,770	10,450	43,791	150,319	23,617
1929	1,849	298.54	10,224	19,393	64,296	133,414	27,889
1930	342	103.06	4,181	2,411	37,640	35,104	7,620
1931	103	15.88	253	581	----	----	454
1932	236	193.55	3,553	2,333	17,500	----	5,675
1933	333	236.11	3,517	1,422	56,946	11,024	9,927
1934	1,057	223.69	4,718	2,737	11,514	10,698	11,973
1935	14,775	1,665.20	76,519	26,506	140,725	133,205	126,970
1936	36,185	5,782.00	193,763	107,859	1,681,478	1,047,960	491,334
1937	119,246	15,348.00	528,640	400,182	4,978,220	3,428,354	1,511,063
1938	109,810	15,027.00	560,518	311,163	4,007,239	3,319,812	1,262,478
1939	68,716	9,301.00	451,325	146,077	1,406,553	1,539,692	793,253
1940	76,317	8,135.00	284,760	224,221	4,607,480	8,589,000	1,284,039
1941	70,398	7,500.00	213,577	132,700	4,816,200	4,692,000	1,056,459
1942	70,533	5,406.00	157,112	136,800	3,312,600	4,487,700	956,787
1943	43,724	1,922.00	88,695	236,500	2,784,800	3,084,000	703,019
1944	33,579	895.00	57,856	1,005,200	1,567,000	2,091,000	571,903
1945	24,462	1,063.00	49,708	454,800	1,503,000	1,367,000	420,414
1946	34,899	730.00	38,229	390,500	737,000	971,000	318,495
1947	46,224	474.00	45,253	456,100	1,308,500	1,713,200	549,046
1948	51,734	694.00	32,059	621,400	891,100	1,344,700	526,501
Total	1,276,266	124,491.40	4,863,757	5,712,992	71,473,202	109,520,515	22,472,902

Zinc-lead production reached its peak in the years 1915–17, which coincided with large-scale production from the Tennessee and Golconda mines under the stimulus of high metal prices.

At the time the present investigation was being carried on in the district (early 1943), the Tennessee mine was producing and milling about 150 tons of crude ore per day averaging 7 percent zinc, 3.5 percent lead, and 17 to 25 ounces of silver per ton. A disastrous fire destroyed the Golconda mill in October 1917. Since then the Golconda has produced only intermittently and on a small scale, and the mine is now largely inaccessible on account of caving and the encroachment of water.

FIELD WORK AND ACKNOWLEDGMENTS

Field work for the present investigation was carried on from February to June 1943. Aerial photographs on a scale of about 1 inch equals 1,100 feet were used as base maps. The contour map on which plate 18 is based was made from the aerial photographs, after the field work was completed, by the Topographic Division of the United States Geological Survey.

It is a pleasure to acknowledge the wholehearted and able assistance rendered by Paul K. Sims, of the Geological Survey, during the field investigation. He performed a large share of the surface mapping and assisted in many other ways. Thanks are due G. E. Woodward and C. E. Needham, of the Salt Lake City office of the United States Bureau of Mines, who generously compiled much valuable statistical data on the district. Local assistance was freely given by people too numerous for specific acknowledgment. Those who were especially helpful include F. C. Cassidy, W. C. Wimer, W. J. Gardner, Frank Shuck, J. G. Blackwell, and Andrew Brown.

GEOLOGY

ROCK TYPES

The rocks exposed at the surface comprise pre-Cambrian crystalline rocks, chiefly of granitic composition, cut by large intrusions of Mesozoic (?) granite (the Ithaca Peak granite), especially one mass near the center of the area (pl. 18), and pre-Cambrian granite (Chloride granite) in the northern part of the area. Dikes of many rock types, probably related genetically to the Mesozoic (?) granite, are scattered throughout the area. Some are alined parallel to the prominent northwestward-trending system of fractures and veins, but others trend in different directions. Remnants of volcanic rocks of probable Tertiary and Quaternary age are found around the margins of the Cerbat Mountains but are not present in the mapped area.

Work in the area was done under the stress of war conditions; therefore it seemed inadvisable to devote much time to detailed petrographic studies of the various rock types. Also, little attempt was made to map the various types of pre-Cambrian crystalline rocks that form an intricate complex with each other and with the amphibolite and related schists and gneisses. The rock types delineated on the geologic map (pl. 18) are fairly well defined units that were selected to aid in structural interpretations or that appeared to be of sufficient size or possible genetic significance to warrant separate mapping. The units, with the exception of the dike rocks, shown on the geologic map are (1) amphibolite and related gneiss and schists; (2) undifferentiated granite, gneisses, and schists; (3) Chloride granite (new name); (4) Ithaca Peak granite (restricted name); and (5) gabbro. The first two units are considered to be of pre-Cambrian age. The Chloride granite is assigned tentatively to the pre-Cambrian, and the Ithaca Peak granite and gabbro are assigned tentatively to the Mesozoic. Three categories of dike rock are shown on the geologic map: intermediate to basic types, diabase, and rhyolite. All the dike rocks are younger than the Mesozoic (?) intrusions.

PRE-CAMBRIAN CRYSTALLINE ROCKS

AMPHIBOLITE AND RELATED GNEISS AND SCHISTS

One of the oldest rocks is a fine- to medium-grained dark-green to black amphibolite composed essentially of hornblende and plagioclase. In some places it appears to grade into hornblende schist, biotite schist, chlorite schist, or diorite gneiss. Locally it is epidotized, and it is very commonly cut along its schistosity by granite and granite pegmatite intrusions. The rock is particularly conspicuous in the area near Chloride; here it forms the bulk of the low hills near town and also occurs as conspicuous blocks in the granite slopes to the east. In the low hills southwest of Long Wash it is also present over a large area. It is widely distributed throughout the district, although in many places it is found in masses too small to be shown on the geologic map.

UNDIFFERENTIATED GRANITE, GNEISSES, AND SCHISTS

The rocks in this group are represented by many types which are not separated on the geologic map. However, this group has certain outstanding characteristics, the most important of which is that most of the exposed rocks are granite. Gneissic structure is widespread, and a large percentage of the rock is granite gneiss. Some of the rocks are distinct and separate intrusions, but others are probably differentiation facies of these intrusions. Still others may represent metamorphosed sedimentary beds.

The granite in this group of rocks varies considerably in color, texture, and mineral composition, although there are certain characteristics that are common to most outcrops. The variations, some of which are extreme, are widespread but generally of small areal extent. The rock is most commonly light-gray, medium-grained, gneissoid granite, containing a small amount of mafic minerals, chiefly biotite. It commonly weathers light buff, although in a few places weathered surfaces are reddish brown.

The extreme variation in color of the fresh granite is from white to almost black. The lighter shades are characteristic of the many irregular bodies of pegmatitic granite and alaskite, generally small, which contain little or no mafic minerals. Alaskite is particularly abundant in the hills about 1 mile northwest of Cerbat Wash. Dark, biotite-rich granites are most abundant in an irregular zone on the northeast side of the main mineralized belt.

Grain size is likewise variable. Fine-grained rocks, although less common than the medium-grained ones, are nevertheless much more abundant than coarse-grained types. Coarse-grained texture is generally confined to pegmatitic granite, alaskite, or biotite-rich granite, although the latter two may also show fine- to medium-grained textures. Porphyritic texture is not common, but a few facies show enough feldspar phenocrysts to class the rock as porphyritic granite. These bodies are generally of small areal extent and are more commonly found in the biotite-rich granite than in the other types.

Variations from the usual gneissoid structure in the granite are widespread. Some facies show little or no banding or mineral orientation, whereas others show pronounced banding and are more properly classed as granite gneiss. The gneissoid structure in most of the granite is indicated by streaks or thin bands of biotite 0.1 inch or less thick.

Several distinct types of gneisses and schists are irregularly distributed throughout the pre-Cambrian complex. The most common type of metamorphic rock is granite gneiss, which varies from place to place but most commonly consists of biotite-rich lenticles and bands 0.5 to 1 inch thick alternating with lighter, irregular lenticles and bands of mixed quartz and feldspar. Some of the gneiss is highly garnetiferous, particularly in the southwestern part of the mapped area, roughly centering around the junction of Charcoal and Cerbat Canyons. Typical injection gneiss, formed usually by injection of granite or granite pegmatite into biotite schist or hornblende schist, is commonly and widely distributed.

Diorite gneiss, hornblende schist, biotite schist, and chlorite schist are sparsely distributed throughout the area, usually in small bodies associated with, and grading into, amphibolite. For this reason most of these rocks were mapped with the amphibolite, but locally they are included with the undifferentiated granite and gneisses of pre-Cambrian age. Probably most, if not all, of these rocks are genetically related to the amphibolite.

PRE-CAMBRIAN(?) IGNEOUS ROCKS: CHLORIDE GRANITE

Schrader (1909, p. 53) has stated that the main part of the large mass of granite exposed north and northwest of Chloride much resembles the granite porphyry of the Mineral Park batholith, the Ithaca Peak granite of this report. Thomas (1949, p. 667), who likewise considered the granite near Chloride similar to the granite stock of Mineral Park, proposed the term "Ithaca Peak porphyry" for these two intrusives and tentatively assigned them to the Tertiary. The two granites, however, are quite different in their general appearance, alteration, and composition. The granite near Chloride is not nearly so altered as the granite in the Mineral Park district, and its prominent gneissic structure suggests that it may be older.

Because of this difference the name "Ithaca Peak" is here restricted to the granitic intrusive in the Mineral Park district, and the granite near Chloride, which is tentatively assigned to the pre-Cambrian, is here named the "Chloride granite."

The Chloride granite, which is well exposed north and northwest of Chloride (pl. 18), has intruded the amphibolite and older granite gneisses, forming a central band at the northeast end of a large fold in the pre-Cambrian crystalline rocks. Except near its borders, the intrusive body is fairly uniform, although it contains numerous inclusions of the older rocks. Some small, irregular masses and dikelike bodies extend beyond the limits shown on the geologic map. No attempt was made to map these smaller units. The Chloride granite weathers yellowish brown. Locally the rock breaks down easily and forms rounded hills, but most of it stands out as large blocky masses that are prominently jointed.

The rock is typically a light-gray, medium-grained, gneissoid granite. The gneissic structure, which in general conforms to the schistosity of the older folded rocks, in many places grades into a schist as the borders of the older rocks are approached. Microscopic examination discloses microcline, quartz, and biotite as the dominant minerals. The quartz is largely recrystallized. Biotite is the green variety, greatly frayed, fragmentary, and drawn out into bands. Accessory minerals are magnetite, apatite, and zircon. Locally the granite shows considerable variation in texture, ranging from fine to moderately coarse, and some facies are lacking in the typical gneissic structure. Near the border of the intrusion is a garnetiferous, light-gray or dull-white granite.

MESOZOIC (?) IGNEOUS ROCKS

ITHACA PEAK GRANITE

The name "Ithaca Peak" as used by Thomas is restricted by this writer to the granite of the Mineral Park district. The granite stock, near the center of the Mineral Park district, has intruded the pre-Cambrian granite, gneisses, and schists (pl. 18). Pegmatite, aplite, rhyolite, and many, if not all, of the diabase and intermediate- to basic-type dikes, as well as the veins in the district, are believed to be genetically related to this intrusion.

The main mass of the granite stock near Mineral Park weathers buff to reddish brown and generally forms a distinctive color contrast to most of the older rocks in this area, which weather to much lighter shades of buff and brown. Both Ithaca Peak and Turquoise Mountain are composed of the Ithaca Peak granite.

Unaltered specimens of the Ithaca Peak granite are rare. Those found show that the fresh rock is typically a light-gray, fine- to medium-grained, porphyritic granite. Microscopic examination of thin sections of the fresh rock shows that the phenocrysts are chiefly subhedrons of pink orthoclase commonly ranging from 2 to 5 millimeters in length. Phenocrystic quartz is much less abundant than the orthoclase and occurs as irregular grains commonly ranging from 0.15 to 0.25 millimeter in length. The groundmass consists chiefly of quartz and orthoclase. Biotite and rarely hornblende are the principal mafic minerals, and together they seldom constitute more than 7 percent of the rock. Other minerals found in small quantities include microcline, microperthite, oligoclase, sphene, magnetite, apatite, zircon, sericite, chlorite, and a clay mineral, probably kaolin.

Most of the rock of the stock contains only a few percent of phenocrysts and for that reason is classed as porphyritic granite. Locally, however, fine-grained facies contain abundant phenocrysts, and the rock is typical granite porphyry. Other differentiation facies are coarse-grained granite and granite pegmatite.

In many places it was difficult or impossible to locate the contact of this intrusive with the pre-Cambrian granites because of the alteration of the intrusive and the surrounding rocks, combined with the similarity of some of the differentiation facies of both the older and the younger granites.

Outlying bodies of the Ithaca Peak granite are particularly abundant from Mineral Park south into Stockton and Cerbat camps (pl. 18). Some extend beyond the southern border of the area mapped. They occur as dikes or, more commonly, as irregular elongated intrusive masses of diverse sizes, many too small to be shown on the geologic map. A few of the intrusives occur irregularly alined along northwestward-trending fissures. Some appear, in part at least, to have been intruded along the older schistosity planes. Dips of the outlying bodies are generally steep, the lowest recorded being 57° on the wide northeastward-trending dike a few miles southeast of Mineral Park. The direction of dip varies, but dips to the northeast, north, and northwest are the most numerous.

These outlying granite bodies are somewhat different from the main intrusive body exposed near Mineral Park. The rock is of finer grain size, and porphyritic texture is more common. Some of the rock grades into granite porphyry, although most of it is porphyritic granite. Badly altered feldspar phenocrysts are characteristic, and only rarely are parts of the rock found that are not intensely altered. The outlying granite bodies stand out in bold relief, particularly in the area near the Golconda mine and in the vicinity of Stockton. The bodies very commonly are intensely sheared, fractured, and silicified. The rock has weathered to brownish red, dark brown, or black, probably from alteration of finely disseminated pyrite.

In the northern part of the district a few narrow dikes and elongated bodies of granite, generally too small to be shown on the geologic map, are poorly exposed for short distances. Some may be genetically related to the Ithaca Peak granite, but no certainty exists as to this correlation.

The age of the intrusion is not known except that it is younger than the pre-Cambrian complex and older than the volcanic rocks of Tertiary (?) age. Schrader (1909, p. 30) states that it is very likely of late Jurassic or early Cretaceous age and of the same period of intrusion as the batholiths of California and western Nevada. Thomas (1949, p. 667) believes that his Ithaca Peak porphyry is of Tertiary (?) age on the "basis of close areal and structural relationships between the Mineral Park stock and the mineralization." However, on a later page (1949, p. 695) he makes the statement that "a direct genetic connection between the Ithaca Peak porphyry and these ore deposits does not seem reasonable, * * * owing to the time interval that elapsed between intrusion and mineralization." It is quite possible that the intrusion may be Tertiary in age, but the only direct evidence Thomas obtained is that the intrusion cuts rocks of pre-Cambrian age. Since no positive evidence is available in the Wallapai district to aid in dating the intrusion, it is still considered tentatively in this report as Mesozoic in age.

GABBRO

In the southern part of the mapped area, centering around Cerbat, are numerous small stocks and irregular bodies of gabbro (pl. 18). The largest of these, located 0.6 mile northeast of Cerbat, is about 1,500 feet in its longest dimension. Gently dipping gabbro or diabase sills are scattered throughout the district from the locality north of Chloride to the southern part of the mapped area. Many of these are too thin or discontinuous to be shown on the geologic map. The thickest and best-exposed sill is on the steep west slope of the Cerbat Mountains about 2 miles east of Chloride near the Redemption mine. The sill reaches a maximum thickness of about 60 feet north of the mine.

The gabbro is typically a greenish-black, medium-grained rock commonly having a pronounced diabasic texture. Chilled border facies and small dikes stemming from the larger gabbroic masses are typical diabase. Weathered surfaces are usually reddish to dark brown. Microscopic examination of thin sections shows that the dominant minerals are labradorite, olivine, augite, and hypersthene. The olivine has been slightly serpentinized. Other minerals present include biotite, a very small amount of green hornblende, apatite in long needles, magnetite, and calcite.

The diabase sills, as well as the diabase dikes to be described later, are all believed to be related to the smaller gabbro intrusives. Hernon (1938, p. 113) states that the diabase of the Cerbat Mountains closely resembles the diabase sills in the Grand Canyon series and in the Apache group of southeastern Arizona, which are regarded as pre-Cambrian in age. The exact age of the diabase in the Wallapai district is not known. The gabbro cuts the pre-Cambrian granites, gneisses, and schists but in turn is cut by mineralized quartz veins and rhyolite dikes.

DIKE ROCKS

Dikes of many lithologic types cut the rocks of the Wallapai district. They range in thickness from a few inches to 300 feet. Some extend only a few hundred feet or less, whereas others, notably the rhyolite dikes, extend for long distances. The most abundant dike rocks are granite pegmatites. Others, some of which are abundant locally, include porphyritic granite, aplite, and rhyolite. Also, there is a group of dikes of intermediate to basic composition, including such rock types as vogesite, minette, kersantite, camptonite, andesite, and diabase.

Only dikes that are 1 foot or more thick and appear to be fairly continuous are shown on the geologic map. Granite pegmatite dikes, although abundant, were not mapped because an excessive amount of time would have been required to outline these generally narrow and discontinuous bodies. Aplite dikes are not common and generally occur as short, very narrow bodies; hence they also are not delineated.

The age relationships between the various types of dike rocks are rarely indicated in the field. Many of the dikes, particularly some of the intermediate to basic types, are found only in the pre-Cambrian rocks far removed from outcrops of the Ithaca Peak granite. It is possible that some of these are older than that granite. Nevertheless, all the dikes shown on the geologic map are assigned an age younger than the Mesozoic (?) intrusives because of their lithologic similarities to other dikes definitely younger than these intrusives. All the dikes shown on the geologic map are likewise believed to be genetically related to the Ithaca Peak granite, even though some, particularly the rhyolites, may represent considerably younger intrusions.

Granite, porphyritic granite, and granite porphyry.—Dikes and somewhat irregularly shaped, elongated bodies of fine- to medium-grained, rarely aphanitic or coarse-grained granite occur at many places in the southern part of the mapped area. They are most commonly alined parallel to, or fill, the northwestward-trending fractures. These bodies are related to, and in places are definitely part of, the intrusive at Mineral Park, the Ithaca Peak granite, and are shown as part of this mass on the geologic map. Many of them change along their trends from typical tabular dikes to irregularly shaped, elongated intrusions or to irregular bodies. The typical dikes commonly range in thickness from 50 to 250 feet.

The rocks show many gradations in texture, commonly within short distances. Most of the rock is porphyritic granite, although some is granite, and only rarely is the grain size so small that the rock should be classed as granite porphyry. Orthoclase phenocrysts are much more common than quartz.

Granite pegmatite and aplite.—Most of the granite pegmatite dikes are less than 2 feet thick and seldom can be traced for more than a few hundred feet. Many appear to stem from highly irregular bodies of pegmatite a few hundred feet or less in longest dimension. The pegmatites are composed almost entirely of quartz and feldspar, though rarely other minerals, chiefly muscovite, may be present. They probably are genetically related to the Ithaca Peak granite.

Granite aplites, though widely distributed, are not abundant. They generally occur as narrow dikes ranging from a few inches to a foot in thickness. They are fine-grained, equigranular rocks consisting largely of quartz and feldspar.

Andesite, minette, vogesite, diabase, kersantite, and camptonite.—Andesite, minette, vogesite, and diabase are the most common rock types in the dikes of intermediate to basic composition, although some more nearly approach kersantite or camptonite. On the geologic map (pl. 18) the diabase dikes are shown distinct from the other dikes of intermediate to basic composition.

Alteration of these dikes commonly results in a greenish or brownish earthy appearance, but when fresh they are grayish to dark green. Porphyritic textures predominate. Partly because of their basic character these dikes weather easily and are poorly exposed, but they also seem to occur as less continuous bodies than the other dikes, particularly those consisting of rhyolite. On the geologic map (pl. 18), only the more continuous dikes of intermediate to basic composition are shown; there are many more that are too short to map.

Many of these dikes cut the pre-Cambrian rocks. They range from a few inches to 10 or more feet in thickness, but they average about 2 feet. In a few places they fill the vein fractures, but they seldom extend continuously along the veins for more than a few hundred feet. In every case where definite age relations could be obtained, the dikes are older than the veins.

Rhyolite.—Extending irregularly northward across much of the district is a network of rhyolite dikes (pl. 18), all believed to be of the same general age. The dikes are most abundant in a fairly obvious belt about 4 miles long that extends from a short distance south of Cerbat north to the southern edge of the main body of the stock at

Mineral Park. Rhyolite dikes are extremely rare, however, in the area northwest of the northern part of the Great White dike.

Many of these dikes trend northwest roughly parallel to the prominent vein system. The dips are generally steep, but some are as low as 50°; strike and dip commonly change within comparatively short distances. In places the rhyolite dikes cut, border, or trend parallel to the elongated bodies and dikes of the Ithaca Peak granite, a characteristic that is particularly conspicuous in the area north and northwest of the Oro Plata mine. Many of the dikes have numerous branches, some of which are too small to be indicated on the geologic map. The rock is characteristically white to light buff, aphanitic with occasional quartz phenocrysts, and in general greatly fractured.

The largest rhyolite dike, the one known locally as the "Great White dike," cuts the western part of the main mass of Ithaca Peak granite. It can be traced with little difficulty throughout most of the district, for a distance of about 6 miles, and it continues for an unknown distance to the northeast beyond the limits of the mapped area. This dike ranges in thickness from a few feet to as much as 100 feet but generally averages about 30 feet. In places it forms sharp ridges as much as 35 feet high, but more commonly it shows as a band of chalky white debris cutting irregularly across the other rocks. Schrader (1909, p. 92) states that this dike is an altered basic rock. However, microscopic examination of thin sections of the rock indicates a rhyolitic composition.

About 2 miles north of Cerbat, near the Oro Plata mine, is a prominent branch of the Great White dike that trends N. 10° E. and is locally known as the "Broncho dike." It can be readily traced to the northeast for a distance of 2 miles. It dips about 60° NW. and traverses or borders a wide dike of porphyritic granite related to the main Ithaca Peak granite. Hernon (1938, p. 113) states that the Broncho dike may be genetically related to the volcanic rocks of Tertiary (?) age in adjacent areas which are composed principally of rhyolite flows, tuffs, and agglomerates. Reconnaissance by the author in the volcanic area near Kingman failed to disclose any of the rhyolite dikes cutting or stemming from the volcanic beds.

All the rhyolite dikes in the Wallapai district, including the Great White dike and the Broncho dike, are believed by the author to be genetically related to the intrusion of the Ithaca Peak granite of Mesozoic (?) age. They cut this granite and its associated dikes but in turn are cut in a few places by mineralized veins that are believed to represent the last stage of the intrusion at Mineral Park. Thomas (1949, p. 668), however, assumes that the rhyolite dikes in the Wallapai district "were intruded in Tertiary times as part of the Tertiary volcanic system of the Basin and Range Province." His assignment of a probable Tertiary age to the Ithaca Peak granite, as opposed to a Mesozoic (?) age for this granite in the present report, would account for Thomas' assumption, as the dikes cut the stock at Mineral Park.

STRUCTURE

The Cerbat Mountains are in the Basin and Range geomorphic province only 20 miles west of the edge of the Colorado Plateau. The major geologic setting is shown on the geologic map by Schrader (1909, pl. 1), which is not duplicated in this report.

The structure of the rocks in the Wallapai district is complex. Gneissic and schistose structures are common, the prevailing schistosity striking northeast. Large and small folds in the schistosity generally have axes that strike northeast. In contrast faults, sheeting, and joints most commonly show a northwesterly strike.

SCHISTOSITY

The gneissic and schistose structure of the pre-Cambrian rocks in the Wallapai district strikes in general from N. 40° E. to N. 65° E. and dips steeply either to the northwest or to the southeast. Local variations are numerous, but the structure is unusually persistent throughout most of the district, and reconnaissance visits to a few other parts of the Cerbat Mountains disclosed essentially the same general structure.

FOLDS

Folds in the pre-Cambrian rocks occur on both a large and a small scale. The most prominent of these folds is near the town of Chloride (pl. 18), where the type of fold is reflected in the outcrop of pattern of the amphibolite. It is a large anticlinal fold, plunging northeast, only the northeast end of which is shown on the geologic map. To the southwest, beyond the limits of the mapped area, the fold is exposed for about a mile before it is concealed under the debris in Sacramento Valley. Much more of this fold is clearly shown on Thomas' geologic map (1949, p. 669, fig. 2), which covers an area extending about 3 miles west of the area mapped for this report. His map shows that the fold is several miles wide where it disappears under the alluvium of Sacramento Valley. North and northwest of Chloride a granite intrusive (Chloride granite) occupies a sill-like belt in the folded amphibolite.

FAULTS

The most outstanding structural feature of the district is the northwestward-trending fault fissures along which veins have formed (pl. 18). A few faults, generally of small displacement, crosscut and offset these mineralized faults. A large normal fault (Sacramento fault), which strikes northwest, is probably concealed under the alluvium of Sacramento Valley near, or west of, the border of the mapped area.

NORTHWEST FAULT FISSURES

From the southern end of the district northwest to the folded area near Chloride the fault fissures are very generally parallel in strike, the direction of strike being approximately at right angles to the regional schistosity. In the folded area near Chloride, however, the fissures conform to the general direction of schistosity. Here they change first to a more northerly strike, then follow the curvature in the strike of the rocks to the north and west around the axis of the fold so that in the extreme northwestern part of the mapped area the fissures strike nearly due west.

The dips of the faults are generally steep and may be either to the northeast or to the southwest, although northeasterly dips predominate. In places the faults are in conjugate systems. The fissures likewise show much branching and, in a few places, considerable "horsetailing." Gouge, breccia, and slickensided surfaces, as well as numerous tear faults in the walls, are present along some of the faults. The direction of the striations along the walls of the faults may be nearly horizontal, but a far greater number show dips down or diagonally down the dip of the fault surface. Most of these features suggest that shearing stress was important.

The age of the faulting that produced the northwest fault fissures is not known. The initial, and probably most intense, movement occurred after the gneissic and schistose foliation was developed in the pre-Cambrian complex and prior to the Mesozoic (?) intrusions. This is indicated by the fact that the faults cut the old (probably pre-Cambrian) gneissic and schistose structures and in turn are filled, or partly filled, in many places by the Mesozoic (?) dikes and veins. Brecciation of the veins and dikes in places indicates that some movement occurred at intervals throughout, and following, ore deposition. These later periods of movement, however, are believed by the author to have been very minor compared to the tectonic forces that formed the main northwestward-trending faults. It is likely that the major tectonic forces were active early in the Nevadian orogeny and that the minor period of movement occurred near the close of this orogeny.

TRANSVERSE FAULTS

Some faulting, believed to be still later than the brecciation of the veins and dikes that occupy the northwest fault fissures, occurred in a few places throughout the district. There is no evidence to indicate that this faulting was of major structural importance, for it most commonly is expressed by small crosscutting faults offsetting the dikes and veins a few feet or less. Several crosscutting faults, however, have greater displacements. One mile north of Mineral Park, about 1,400 feet northeast of the Eureka mine, a northwestward-trending fault has offset the Great White dike about 140 feet. About a mile east of Chloride is a northeastward-trending fault that is shown on the geologic map. The Payroll vein has apparently been offset about 600 feet by this fault, the South Georgia mine supposedly being on the offset part of the Payroll vein. This fault, however, may predate mineralization, according to data obtained on the inaccessible workings in the Payroll mine. Dr. J. G. Blackwell, of Chloride, stated in April 1943 that the Payroll vein turns abruptly to the southwest and follows the fault. He added that the vein is thick and shows no evidence of brecciation of the ore minerals along the fault.

SACRAMENTO FAULT

The large normal fault previously referred to as lying concealed beneath the alluvium in Sacramento Valley is based upon Thomas' mapping (1949, fig. 2) several miles west of Chloride and beyond the area mapped for this report. This fault has been aptly termed the "Sacramento fault." It strikes northwest and brings volcanic rocks of assumed Tertiary age on the southwest side in fault contact with rocks of pre-Cambrian age on the northeast side. The fault was traced by Thomas southeast to a point about 2½ miles west of Chloride; beyond this point he projects it southeastward under the alluvium for almost 4 miles to a point near the border of his mapped area. This fault is not shown on the geologic map (pl. 18) accompanying the present report, because its location under the alluvium is entirely too uncertain.

In discussing the Sacramento fault Thomas (1949, p. 671) states that it seems to be a boundary fault between Sacramento Valley and the Cerbat Range and that "vertical displacement on this fault and perhaps on allied faults that might be buried under an alluvial cover is believed to be responsible for the formation of the Cerbat Range, which is essentially an eastward-tilted block."

JOINTS

Jointing is pronounced throughout most of the district. In places it grades into sheeted and sheared zones, both generally of small areal extent. Commonly one of the joint systems is far better developed than the others, and on the geologic map accompanying this report only the attitudes of the most prominent joint systems are shown. The strike commonly ranges from N. 30° W. to N. 60° W., approximately parallel to the mineralized fissures. Dips are generally moderate to steep and may be either to the northeast or to the southwest. In a few places low-dipping fractures are fairly well developed, but they are not common. In general they have the same northwesterly strike as the other fractures and dip either to the northeast or to the southwest.

ORE DEPOSITS

TYPES OF DEPOSIT

The ore deposits are conveniently separated into three types. The first is represented by the vein deposits of the district, the second by a quartz-sulfide stockwork deposit, and the third by the Emerald Isle copper deposit. The vein deposits are overwhelmingly the most important in the district. The quartz-sulfide stockwork deposit contains some low-grade copper and molybdenum. The Emerald Isle copper deposit is quite different from all other deposits in the district and consists of a fissure vein and mineralized area of chrysocolla chiefly confined to alluvium.

VEIN DEPOSITS

GENERAL FEATURES AND DISTRIBUTION

The chief ore deposits of the Wallapai district occur in veins along fissures in all the rock types previously described. In some places the veins are along dikes of intermediate to basic composition, but they seldom extend continuously along these dikes for more than a few hundred feet. Other veins border or cut the rhyolite dikes, but generally such veins are poorly mineralized and of erratic extent and width. The most notable exception is the Eureka vein north of Mineral Park, where the mineralization was fairly rich. Wherever definite age relations could be observed, the veins are younger than the dikes. The source of the vein-forming solutions is believed to have been the magmatic reservoir of the granite stock (Ithaca Peak granite) centrally exposed about 1 mile south of Mineral Park (pl. 18). The veins in the district are classed as mesothermal deposits.

The veins range from a few inches to 33 feet in thickness but average 3 to 4 feet. In a few places the deposits are in lodes or vein zones, which rarely exceed a width of 50 feet. Most of the Silver Hill vein is of this type. Schrader (1909, p. 62) states that in the older workings of the Payroll mine a lode 100 feet wide was encountered. Vein widths reported in many of the mines are often exaggerated, as they frequently include considerable unmineralized wall rock between vein branches.

The veins show a strike length that varies from a hundred feet or less to almost 2 miles, but only the Victory, Tennessee, Clyde, Payroll, Emerson, Dutch Joe, South Washington, Rico, White Eagle, Banner, Summit, and Manzanita veins exceed a length of 1 mile. The aggregate length of the veins in the district as measured from plate 18 is about 85 miles. The veins commonly pinch and swell along both strike and dip. Numerous irregular branches, short spur veins, narrow parallel veins, and hydrothermally altered fissures are characteristic. About 2 miles southeast of Chloride, in the vicinity of the Twentieth Century and Midnight mines, the veins are unusually irregular and branching. This is the area in which the northwestward-trending veins deviate to a more northerly course.

VEIN DIPS AND TRENDS

Dips are commonly steep, only occasionally being less than 60°. Some veins show a moderate amount of reversal in dip as they are traced along strike or down dip. The dips shown on the geologic map (pl. 18) are, almost all of them, those obtained near the surface in shafts or prospect pits. In places the vein systems are conjugate, as noted by Schrader (1909, p. 50), but the conjugate arrangement is not nearly as common as suggested by its mention in brief descriptions of the district. Garrett (1938, p. 118) states that the progressive steepening of the dip of the veins to the northwest may indicate overthrusting stresses as the cause of the fissuring. However, detailed mapping does not support this conjecture.

Reference to plate 18 will show the prevailing northwesterly trend of the veins. Throughout the greater part of the district strikes range from N. 30° W. to N. 60° W. Near Chloride the average strike changes to a few degrees west of north, and still farther north and west a few veins trend nearly west. Throughout the main mineralized area southeast of Chloride the sparsity of eastward- or northeastward-trending veins is notable.

Plate 18 shows clearly that the veins occur in two main groups, one north and the other south of the main body of the stock of the Ithaca Peak granite. The total length of the mapped veins in each group is about equal. Veins of the northern group have more branches than those in the southern group. Likewise a statistical study of the direction of dip of the veins in the two groups shows differences. In both groups the total mapped lengths were measured separately for veins dipping to the northeast, to the southwest, and vertically, and the percentages of each were calculated. The results are as follows: northern group, 57 percent northeasterly dip, 25 percent southwesterly dip, and 18 percent vertical dip; southern group, 88 percent northeasterly dip, 11 percent southwesterly dip, and 1 percent vertical dip. In the northern group it is further notable that southwestward-dipping veins are almost entirely absent in the folded area north of Chloride.

RELATION OF VEINS TO COUNTRY ROCK

Some veins are separated from the wall rock by soft gouge bands a fraction of an inch to several feet in thickness. Gouge may be present on the hanging wall, on the footwall, on both walls, or irregularly traversing the veins. Many veins, however, are frozen to the walls. The type of wall rock has had little effect upon the character of the veins. In a few places, particularly near Chloride, some veins tend to split into branches as they pass laterally into large amphibolite blocks, but a short distance inside the block the veins generally assume their usual characteristics.

APPEARANCE AT OUTCROP

A few veins, notably the Payroll, Cerbat, and Manzanita, crop out over part of their lengths as prominent iron-stained quartz "ridges," but moderate to very careful observation is generally required to follow them. In tracing the veins on the surface by far the greatest aid is the many man-made excavations such as shafts, trenches, pits, and short adits. These are so numerous and in many areas so closely spaced that not all of them are shown on the geologic map (pl. 18). Probably there are at least a thousand prospects in the district. It is largely upon the data obtained from these workings that most of the veins are shown on the geologic map as solid, instead of broken, lines.

Vein outcrops commonly appear as brown, porous gossan or as pink to dark reddish-brown bodies composed chiefly of iron-stained quartz. Variations in depth of oxidation are so numerous that generalizations are difficult. The upper parts of the veins have been moderately oxidized to depths commonly ranging from about 75 to 200 feet. In some places unaltered pyrite is found within a few feet of the surface, yet Dr. J. G. Blackwell, of Chloride, stated in May 1943 that partially oxidized ore was found as deep as the 600-foot level of the Payroll mine. Complete oxidation seldom extends lower than 75 feet below the surface.

The depth to water level, although commonly 35 to 200 feet, ranges from 20 to 400 feet. In general this range coincides fairly well with the depth of the oxidized zone.

MINERALS

The vein minerals of the district fall into three general groups: oxidation products, products of downward sulfide enrichment, and primary (hypogene) minerals. In recent years, the primary ores have been the most worked for their base metals, but in the early years of mining in the district most attention was paid to the oxidized ores because of their precious-metal content.

The principal minerals of economic importance in the oxidized zone are cerargyrite, native silver, cerussite, and to a less extent native gold. Locally anglesite, azurite, malachite, mimetite, and vanadinite are common. Other minerals which are rare or occur as coatings include native copper, chalcanthite, covellite, cuprite, smithsonite, and manganese oxides. The most common gangue minerals are limonite and limonitic quartz. Calcite and particularly gypsum are rare.

The secondary sulfide enrichment products as determined by Bastin (1924, p. 35) are argentite, chalcocite, covellite, and proustite. He states that all except argentite are rare. Secondary enrichment in the vein deposits of the Wallapai district has not been important.

Excluding gangue minerals, the most abundant of the primary minerals are pyrite, sphalerite, galena, and chalcopyrite. Other minerals include arsenopyrite, proustite, molybdenite, and argentite. In addition to those listed Bastin has recognized tennantite, pearceite, and polybasite. Gangue minerals are quartz, calcite, manganiferous siderite, and rarely rhodochrosite.

Quartz, usually accompanied by varying amounts of pyrite, is by far the most abundant gangue mineral. Most of the quartz is fine-grained and milky to gray in color. Some is of the chalcedonic variety. In many places along the veins small vugs are lined with quartz crystals. In a few places the veins show a poorly defined comb structure, but the quartz is generally massive and commonly fractured and recemented by later quartz.

Sphalerite ranges in color from brown through reddish brown to black. It occurs most commonly in irregular masses or grains intimately associated with quartz and the other sulfides. The grain size varies greatly, but generally sizes of less than 0.3 inch predominate. The sphalerite also occurs as narrow bands or streaks. J. W. Sharpe, metallurgist for the Tennessee-Schuylkill Corp., stated in June 1943 that careful analyses of specimens of sphalerite collected in the Tennessee mine indicated the presence of a considerable amount of gold as well as minor amounts of silver. Sphalerite has been leached from the completely oxidized parts of the veins.

Galena occurs in fine to coarse grains; some is the very fine grained steel type, and some, commonly in the same ore shoot, is in cleavable masses as much as 3 inches in length. Practically all the galena, regardless of type, is silver bearing, and much of it is high in grade. J. W. Sharpe stated in June 1943 that the galena from the Tennessee mine contained most of the gold values produced in the mine. He believes that the pyrite in the Tennessee mine is practically, if not entirely, barren of gold. This is in contrast to Garrett's statement (1938, p. 119) that gold in this mine is obtained from pyrite. Additional analyses from the mine, and also for the district, would be needed to clarify these contradictory statements.

In many places unaltered galena is found at or near the surface; elsewhere it has altered to cerussite.

PARAGENESIS

The paragenesis of the principal hypogene minerals, as determined megascopically, is quartz, pyrite, arsenopyrite, sphalerite, galena, and chalcopyrite. Much of the ore shows a second generation of pyrite following galena. Quartz was introduced intermittently throughout the period of mineralization. A few veins show late calcite, manganiferous siderite, and—rarely—rhodochrosite.

Observations during this investigation coincide in general with Hernon's statements (1938, p. 115) regarding the main stages of mineralization. Fissures, some of them locally occupied by earlier dikes, were reopened; in the openings solutions deposited quartz, usually accompanied by pyrite. Many of the vein fissures were closed by this early stage of mineral deposition. Subsequent reopening permitted solutions to bring in the valuable constituents of the veins. A still later but minor reopening followed; in the voids thus formed quartz was deposited as narrow veinlets commonly cutting the earlier sulfides. A final movement produced gouge and quartz breccias, but the mineralization is believed to have ceased largely thoughn not entirely before this stage. The structure of the veins is irregularly massive or crudely banded by the arrangement of the sulfides.

ORE SHOOTS

The typical ore shoots in the unoxidized zone are complex assemblages of galena, sphalerite, and pyrite in quartz gangue. Chalcopyrite and arsenopyrite are not nearly as abundant, but a few of the mines, such as the Pinkham, Midnight, and Keystone, recovered a moderate amount of copper along with the other metals. Much of the vein matter is very low in grade. Narrow stringers and small irregular masses of the valuable minerals may persist throughout almost the entire length of the vein, but they are too small to be commercially valuable unless the gold or silver content is exceptionally high. However, few completely barren quartz veins occur in the district, and those which exist are short. Likewise, most of the veins have not been explored to sufficient depths to warrant condemnation based on the low base-metal content near the surface.

Ore shoots are generally small and as a rule range from 8 or 10 inches to 3 or 4 feet in thickness. The thickest shoot found measured 20 feet (Tennessee mine). Both the pitch lengths and the breadths of the shoots commonly measure about 10 to 50 feet. In the Tennessee mine (pl. 19) one ore shoot extends 400 feet horizontally and 700 feet vertically. An ore shoot in the Golconda mine is reported to have greatly exceeded in size any in the Tennessee, but the Golconda was not accessible for examination. The Tennessee and Golconda mines probably represent extreme cases, although the comparatively shallow depth reached in most of the other mines does not permit too broad a generalization. Commercial ore has been reported from the Tennessee and Golconda mines to depths of about 1,600 feet.

The character of the wall rock has had no apparent effect upon the localization of the ore bodies. Garrett (1938, p. 118) states that in the Tennessee mine ore shoots tend to occur where the vein has changed to a more westerly strike than normal. Later work in the mine supports this generalization. Schrader (1909, p. 51) states that many of the ore shoots coincide with intersections or forkings of the veins. Distinct vein intersections, however, are rare. Many of the forks are enriched, but many of them have lower-grade ore than average.

QUARTZ-SULFIDE STOCKWORK DEPOSIT

Centering around the main stock at Mineral Park is an area embracing several square miles of altered and fractured rock that contains many short and irregular sulfide-bearing quartz seams and veinlets that are distinct from the fissure veins found elsewhere. Mineralization of this type is chiefly confined within the Ithaca Peak granite but locally extends about 2,000 feet beyond into the older granites, gneisses, and schists. It is a poorly defined area with gradational and irregular borders and likewise much irregularity of mineralization within the main granite mass. Mineralization also extends into part of the large tongue of Ithaca Peak granite extending southeastward from the main stock to the Oro Plata mine. Most of the rhyolite dikes that cut the main stock are fractured and mineralized.

The veinlets occur most abundantly in highly fractured rock and form an intricate network generally with no persistent strike or dip. They are closely spaced and are rarely more than 6 inches apart. Thicknesses most commonly range from one-twentieth to one-half inch, although some veinlets are very thin seams and others reach a thickness of several inches.

The primary minerals are quartz, pyrite, chalcopyrite, bornite, molybdenite, galena, and sphalerite. Quartz and pyrite are by far the most abundant, and the amount of quartz greatly exceeds that of pyrite. Most of the quartz and sulfide minerals fill fractures, and only rarely are the sulfides disseminated in unbroken rock. For this reason the deposits are classed as a stockwork rather than as a disseminated deposit.

Locally chalcopyrite and molybdenite are associated with the quartz-pyrite veinlets as low-grade deposits. Rarely chalcopyrite occurs disseminated in small grains in the granite. Many veinlets of quartz and pyrite cut veinlets of quartz, pyrite, and molybdenite, although this relation was reversed in one specimen examined from the Gross molybdenite prospects. In general, however, most of the molybdenite formed at an early stage.

Small veinlets of galena, sphalerite, and pyrite in quartz gangue occur in a few places, notably on the northwest side of Ithaca Peak. No definite paragenetic relations could be established between these and the more common quartz-pyrite-chalcopyrite (or molybdenite) veinlets. The mode of occurrence and the intimate association of the two types suggest a close relationship, and both are probably of the same general period of mineralization as the prominent fissure veins of the district.

Much of the mineralized area, particularly around Ithaca Peak, has been so thoroughly silicified that the rocks have eroded into very rough forms. Hydrothermal alteration has produced abundant sericite, and much of the rock in the highly altered areas seems, in hand specimens, to consist almost entirely of sericite and quartz.

Oxidation and secondary enrichment have been widespread. Hydrous iron oxides are abundant on the higher peaks and also form the principal cementing material for some alluvial conglomerates. In Bismark Canyon, about half a mile east of the Gross ranch, is an alluvial conglomerate consisting of pebbles and cobbles cemented by hydrous iron oxides, cuprite, and malachite. Chalcanthite, azurite, malachite, covellite, native copper, and chalcocite are fairly widespread although generally not abundant. The Gross copper prospects are reported to have encountered considerable chalcocite and native copper.

EMERALD ISLE COPPER DEPOSIT

The Emerald Isle mine, located about a mile west of Mineral Park Wash, is the only known deposit of its type in the district. The ore mineral is chiefly chrysocolla contained in a fissure vein and filling spaces in alluvium of Quaternary age. It is described in detail under the heading "Emerald Isle mine."

GENESIS AND AGE

The vein and stockwork deposits are believed by the author to be genetically related to the Ithaca Peak granite. The granite, dikes, and mineralizing solutions are believed to have had a common source and were merely drawn off at different times. The time interval between the dikes and the mineralizing solutions in this area may have been fairly long, for the dikes and granite were locally brecciated prior to the introduction of the mineralizing solutions. The central position of the Ithaca Peak granite and the close association of the granite, dikes, and ore deposits strongly favor a genetic relation. The major structural control for their localization was established prior to the period of granite intrusion.

The vein and stockwork deposits are assigned a Mesozoic (?) age, for they are believed to be genetically related to the Ithaca Peak granite of that age. Schrader (1909, p. 48) likewise assumes a similar age and a genetic relationship of these ore deposits to the stock at Mineral Park; furthermore, he points out that they are quite different from the veins of the nearby Black Mountains that are of Tertiary age.

The Emerald Isle copper deposit is of Quaternary age. (See pp. 149–153.)

ZONING

The scanty information in the mine records and the exposed mine workings suggest that chalcopyrite and sphalerite increase relative to galena with depth in the mines of the district. However, exceptions are so numerous that this generalization should be very tentatively accepted. The best indication of increase in sphalerite with depth is found in the Tennessee vein (pl. 19). Here Garrett (1938, p. 118) has demonstrated an increase in sphalerite and a decrease in galena with depth from those parts of the mine for which reliable records have been kept. It should be remarked, however, that no records exist for a large part of the mine.

Indications of pronounced lateral zoning in the district are generally lacking. There is evidence, however, that copper and molybdenum are found in larger amounts in and nearer to the intrusive granite of the Mineral Park area than in the outlying parts of the district. Also, the chief values of the veins in the extreme southeastern and northwestern parts of the district were in silver, suggesting that silver was more characteristically formed at a considerable distance from the intrusive body. Garrett (1938, p. 118) notes horizontal zoning in the Tennessee vein (pl. 19), with a general increase in sphalerite and a decrease in galena and gold-bearing pyrite to the south.

PRODUCTION OF SELECTED MINES

Table 2 gives the production of gold, silver, copper, lead, and zinc from 1901 through 1948 of the more important mines in the district, as well as that of some of the smaller operations. Mines that have been small producers during this period may, however, have had a substantial production prior to the years for which accurate records were kept, particularly the old mines in which rich silver and gold ore was obtained from the oxidized parts of the veins.

It is notable that the combined output of the Tennessee-Schuylkill and Golconda mines has accounted for more than 90 percent of the total lead and zinc produced in the district from 1904 to 1948.

TABLE 2.—*Production of gold, silver, copper, lead, and zinc of selected mines in the Wallapai district, Mohave County, Ariz., cumulative from 1901 through 1948, in terms of recovered metals*

[Compiled by Metal Economics Branch, U. S. Bureau of Mines, Salt Lake City, Utah]

Mine	Gold (oz.)	Silver (oz.)	Copper (lbs.)	Lead (lbs.)	Zinc (lbs.)
Alpha (*m*)	292	35,499	22,265	16,476	------------
Altata and Altata Extension (*c*)	382	36,024	136,616	7,691	------------
Badger, Hercules, and Hercules group (*c*)	561	12,287	1,418	331,365	52,524
Banner group (*s*)	1,697	79,382	21,603	2,195,988	39,948
Blackfoot (*cer*)	158	11,886	19,617	104,565	144,369
Blue Bell (*s*)	469	50,954	44,274	182,001	------------
Cerbat (*cer*)	42	2,055	1,153	4,120	------------
Champion (*cer*)	982	23,689	14,931	825,993	335,391
C. O. D. (*s*)	1,550	151,263	23,924	348,872	23,188
Columbus-Monroe Doctrine (*cer*)	646	5,083	4,370	17,322	154,533
Copper Age (*c*)	3	1,062	266	24,575	------------
Distaff (*c*)	93	55,883	1,392	149,600	------------
Elkhart (*c*)	662	10,385	7,482	245,199	------------
Empire and Silver Union (*c*)	1	2,475	122	------------	------------
Eureka (*c*)	7	2,311	3,371	23,861	42,714
Flores (*cer*)	422	366	172	512	------------
George Washington (*m*)	114	11,059	15,777	34	------------
Golconda (*m*)	20,752	510,180	354,703	2,031,719	56,226,020
Golden Eagle and Bobtail (*m*)	1,777	25,845	890	40,076	------------
Golden Gem (*cer*)	2,478	8,243	3,365	14,980	------------
Hidden Treasure (*c*)	251	9,074	7,897	159,861	231,345
Idaho (*cer*)	280	5,285	4,742	9,348	51,900
Juno (*c*)	1,239	43,128	4,517	235,498	154,138
Keystone (*m*)	2,703	452,049	340,778	348,845	114,063
Little Chief (*s*)	391	68,351	2,070	111,825	------------
Lucky Boy (*c*)	1,923	40,438	230	8,140	------------
Mary Bell (*c*)	26	955	557	19,155	28,733
Midnight (*c*)	44	8,533	10,746	4,122	------------
Minnesota-Connor (*c*)	2,890	228,129	50,702	169,722	71,053
Mint (*m*)	222	15,265	------------	------------	------------
New London (*cer*)	13	3,268	1,558	136,699	31,243
Nighthawk group (*m*)	324	16,297	5,410	1,589	------------
Old Colony (*s*)	21	2,969	654	4,370	------------
Paymaster (*cer*)	99	25,090	------------	------------	------------
Payroll (*c*)	128	4,104	11,694	39,928	192,137
Pinkham (*c*)	56	14,695	55,136	3,133	------------
Rainbow (*c*)	2,400	34,982	4,748	313,271	22,426
Redemption (*c*)	21	4,042	11,449	------------	------------
Rico (*s*)	1,149	15,309	1,449	2,620	------------
Samoa and Samoan (*c*)	4,480	57,891	4,454	656,377	67,886
St. Louis (*cer*)	24	11,142	1,050	855,841	1,496
Silver Age (*c*)	24	3,550	------------	------------	------------
Silver Hill (*c*)	708	8,842	10,722	229,949	143,594
Tennessee and Schuylkill (*c*)	42,383	1,514,187	839,837	59,897,096	66,805,907
Towne (*c*)	144	6,286	2,108	5,516	------------
Vanderbilt (*cer*)	1,012	2,119	327	2,568	------------
Washington and Washington Extension (*m*)	58	2,205	1,610	1,700	------------

c, Chloride camp; *m*, Mineral Park camp; *cer*, Cerbat camp; *s*, Stockton camp.

FUTURE ECONOMIC IMPORTANCE OF THE DISTRICT

It is believed that the future economic importance of the district will lie chiefly in the base-metal content of the fissure veins. Most of the veins have not been explored sufficiently at depth to test the base-metal content and particularly the zinc content. On the basis of a geologic study of the veins in the district there is no reason for assuming that any of several other veins will not be as productive of lead and zinc as the Tennessee or Golconda veins. Future development work, particularly at greater depths, on the many miles of veins in the district may disclose several that will prove to be their equal or better.

DESCRIPTIONS OF MINES AND PROSPECTS

Several inherent difficulties were encountered in attempting to obtain data on the many mines in the district. Most of the mines were worked for the high-grade silver or gold in the shallow oxidized parts of the veins. Operations generally ceased when the lower-grade primary sulfides were reached. The principal work in most of the mines was done many years ago, and most of them are now largely or entirely inaccessible owing to caving or flooding. A few mines are partly accessible, but generally such a small part of the mine workings is disclosed, commonly in the oxidized zone or unproductive parts of the drifts and crosscuts, that it is not possible to obtain much tangible information concerning ore bodies or reserves. Mine maps and records are generally lacking, and many of those available are of such character as to make their reliability very dubious. Even past records of such large-scale operations as the Tennessee-Schuylkill and Golconda mines leave very much to be desired.

During Schrader's (1909, pp. 54–118) visit to the district in 1907, most of the workings were accessible and information was relatively fresh in the minds of people consulted, so that his data on most of the mines still remain by far the most reliable source of published information even though considerable additional work has probably been done in many of them. Bastin (1924) describes a few mines in some detail, whereas the only mine Thomas (1949, pp. 700–703) describes in any detail is the Emerald Isle mine. Garrett (1938, pp. 117–119) has described the Tennessee-Schuylkill mine, and during August and September 1943 engineers of the United States Bureau of Mines obtained assay data (Haury, 1947) on about 30 mines in the district from records and from a sampling of mine dumps and parts of all the accessible mines.

A few of the mines for which worthwhile new data have been assembled, in addition to material previously published, are described on the following pages. Most of these are mines that have been the leading producers of lead and zinc (table 2), although some, such as the Aurora and Emerald Isle mines and the Gross prospects, are briefly described because they contain minerals not commonly found in the district.

AURORA MINE

The Aurora mine is about a mile east-southeast of Chloride. The property consists of one unpatented claim (Aurora) leased by E. E. Vondriska from J. G. Blackwell, of Chloride. The mine was formerly worked on a small scale primarily for lead and silver in the oxidized zone, but it was being worked in 1943 for vanadium and lead. No ore had been shipped by Vondriska, but about 5 tons of vanadinite and

5 tons of lead ore were piled near the portal. The main workings consisted of a drift about 300 feet long bearing south along the vein. About 30 feet from the south end of the drift a winze 40 feet deep had been sunk on the vein.

The Aurora vein strikes north, is nearly vertical, and averages 4 feet in width. It can be traced southward from the mine for about 1,400 feet (pl. 18). About 275 feet south of the north end of the vein vanadinite crystals occur in open spaces in the wall rock of pre-Cambrian gneissoid granite along the west side of the vein. The crystal aggregates are erratically and sparingly exposed over an area about 15 feet long and 10 feet high. The vanadinite is associated with an iron-stained earthy material. This is the only occurrence of vanadinite observed or reported in the district.

CHAMPION MINE

The Champion mine is about a mile southwest of Cerbat camp on the western front of the range at an altitude of about 4,000 feet (pl. 18). This mine is reported to be one of the first discoveries in the district, worked in its early history chiefly for gold, silver, and lead. Table 2 shows that the mine has produced a substantial amount of zinc during its later operations. No reliable information could be obtained concerning the extent of the mine workings or the more recent operations. The mine was idle when visited, and all the workings were inaccessible.

The vein on which the mine is situated strikes about N. 50° W. and dips about 75° NE. It can be traced on the surface for a little more than 1,000 feet. A minette dike averaging about 6 feet in width lies alongside the southeastern part of the vein (pl. 18). Schrader (1909, p. 104, fig. 15) shows a section of the vein and dike sketched at the mine near the surface. Metallic sulfides observed on the mine dump include pyrite, galena, sphalerite, and a very minor amount of chalcopyrite; all are contained in quartz gangue.

EMERALD ISLE MINE

An unusual type of copper deposit is found at the Emerald Isle mine, located about a mile west of Mineral Park, Wash. The mine was idle when visited early in 1943 and again in 1950. It was worked at various times from 1917 to 1943, and late in 1943 the Emerald Isle Copper Co. resumed mining and began the erection of a 300-ton leaching plant, which was completed in 1944. Mining continued until June 1946. In 1947 the Lewin-Mathes Co. started operations on the property and continued work until June 1948. About 55,000 tons of copper was recovered from the ores during the period 1943–48.

Mining in the early days was carried on chiefly from underground workings, although work since 1943 has been done almost entirely from an open pit. The underground workings were inaccessible when visited. Two short shafts were sunk, and according to reports the main shaft is 90 feet deep, penetrating 80 feet of gravels and boulders and, at the bottom, 10 feet of bedrock. In the gravels near the bottom of the shaft a drift extends northeastward for about 300 feet, and another drift extends southwestward for about 1,100 feet. Until 1943 most of the surface work had been done in a small pit about 400 feet east of the main shaft. When visited in 1950, the open-cut work had been extended westward to the upper part of the old underground workings northeast of the main shaft.

The deposit consists of a fissure vein and an irregular area of mineralized alluvium bordering the vein chiefly on the east. The mineralization consists of bluish-green chrysocolla and shiny black copper pitch (probably an impure copper silicate).

The large open pit, which to date has yielded most of the copper ore, furnishes good exposures of the chrysocolla-bearing alluvium and also the upper part of the fissure vein. The mineralized alluvium consists of copper pitch and chrysocolla coating particles and filling interstices in the various-sized outwash material of the valley. Except for a few mineralized fissures, striking northeast, and the vein near the shaft, the walls of the open pit show the individual copper-bearing bodies as concentrations of the chrysocolla and copper-pitch cement in irregular lenses and pods ranging from a few inches to several feet across. The outlines of a few of the lenses are clearly controlled by the bedding of the debris. Boundaries of the mineralized parts are commonly sharp. In places the finer-grained gravels and grits are uniformly dull green, which may in part be due to material other than copper. The richer parts are the typical bluish green of chrysocolla.

The gangue consists of alluvial material ranging from sand and grit to boulders as much as 4 feet long. The debris is commonly subangular to angular and composed of rocks from the pre-Cambrian crystalline complex as well as from the Mesozoic (?) granite. Granites of various types predominate to a great extent, although a minor amount of volcanic material is present. The material in the pit is fairly well cemented.

The upper part of the vein is exposed on the west side of the open pit. Here it is several feet wide and cuts the mineralized alluvium. The vein strikes about N. 30° E. and is vertical. The minerals are the same in the vein as in the open pit, but in richer concentrations. The vein walls are irregular but distinct. Part of the vein is banded.

During Thomas' work in the district (1949, pp. 701–703) he was able to observe the underground relations of the vein to bedrock. These relations were of much importance to him in interpreting the origin of the deposit. He states:

* * * In its uppermost portions the vein is vertical or dips steeply north, but dips of 45 degrees north have been reported in some of the lower workings. The vein ranges from 3 to 12 feet in width. Alluvium occupies both walls at and near the surface. At depths as little as 25 feet, however, bedrock occurs in the footwall, and alluvium occurs in the hanging wall. * * *

Where bedrock was observed in the footwall the vein filling still consisted of cemented alluvial detritus. The nature of the vein where bedrock occurs in both walls is not known. Specimens of granite porphyry from the footwall are leached and thoroughly altered, and tiny irregular veinlets of chrysocolla occur in the rock. In thin section the principal minerals are seen to be abundant clay mineral, sericite, and brown chlorite.

The age of the deposit is Quaternary, because the mineralization passes into and is contained chiefly in alluvium that is assigned to the Quaternary. Thomas (1949, pp. 702–703), who believes that the chrysocolla is of primary rather than secondary origin, gives his reasons as follows:

It has been suggested that the mineralization was by solutions derived from the weathering of the "porphyry copper" deposit of the Mineral Park district. This would involve gravitative transfer of the solutions and localized deposition of chrysocolla around and within a strong fissure vein and associated fractures. Such solutions could exist, but the concentration of copper in them would be negligible, and there are no plausible reasons to explain the concentration and deposition of the copper at this particular location and within a vein.

On the other hand, solutions ascending along fissures and spreading out into the alluvium provide a simple and logical source for the copper. Assuming this to have happened, the question arises as to the nature of the chrysocolla. This mineral is usually supergene and is a secondary product of various primary copper-bearing minerals. In the Emerald Isle deposit, however, the following points suggest that the chrysocolla is primary:

(1) There are no relict grains of sulfides, or any minerals, which might have served as a primary source of the copper. It might be assumed that replacement or solution of such primary minerals was complete, but at least a few specks should have been preserved here and there.

(2) The texture of the chrysocolla, both in vein and blanket, is delicately banded and crustified, which suggests that formation was by open space filling and not replacement. If the chrysocolla is supergene the logical source of the copper would be at some higher level. If there were primary mineralization above, however, furnishing the source of copper solutions, there should have been primary mineralization at the present levels, at least in the vein. This would have to be leached completely away, before the solution of overlying material, in order to explain the lack of relict primary minerals and replacement textures. Such a sequence does not seem feasible.

(3) Some of the veinlets pinch out upward. The chrysocolla filling apparently was deposited by ascending solutions. Perhaps the veinlets could be explained by lateral secretion, but the primary source material would still be missing.

From the above considerations it is concluded that the mineralization has resulted from deposition of chrysocolla by ascending hypogene solutions that rose along one large and many small fissures and spread out into the adjacent alluvium. The conclusion is supported by the fact that the deposit was formed under essentially surface conditions. The main fissure and some of the associated minor fractures undoubtedly reached the original surface. In such an environment ascending hypogene solutions would be under the same pressures and could very easily have the same temperatures as the supergene solutions that deposit chrysocolla. And there is no reason why copper and silica could not be present in the proper amounts to form chrysocolla from such hypogene solutions.

Thomas' theory of a primary origin for the chrysocolla of the Emerald Isle deposit is disputed by Searls (1950), who states in part:

Rather than to have unchallenged in the record the rather startling suggestion that this chrysocolla "resulted from deposition by ascending hypogene solutions that rose along one large and many small fissures and spread out into the adjacent alluvium," the writer begs leave to contribute the following:

Churn drilling by the Calumet and Arizona Company and development by many individuals and groups (some listed by Schrader), have demonstrated these many years that important, although probably non-commercial, amounts of disseminated copper are contained in "The Broncho" or mineralized belt associated with the granite-porphyry intrusions of Mineral Park, and covered by Mr. Thomas as the "Ithaca Peak disseminated sulphide deposit."

The higher elevation of this belt and the present occurrence of soluble copper in the run-off from it, through Mineral Park wash (to the extent that copper has been and is still recovered from it, by precipitation on scrap in certain seasons), has convinced many geologists that Emerald Isle chrysocolla originally derived from the sulphides connected with this mineralization a mile or more distant.

This writer shared the skepticism of Mr. Thomas as to likelihood of the transfer, and still more of the localization, of the (circa) ten thousand tons of copper now known to exist in the secondary ore of Emerald Isle, from the Mineral Park disseminations; the more so as on the basis of present topography, higher bedrock separates the discharge of Mineral Park wash and the Emerald Isle deposit, a mile to the north of it. No chrysocolla deposits are known to exist in the bottom of the Gila conglomerate in the area currently receiving the waters of Mineral Park wash.

Equally unacceptable is the theory that the "vein" at Emerald Isle was the source of primary ore. The "vein" is one of a series of post-Gila faults that step down the pediment of the Cerbat Range and develop the graben of the Sacramento Valley, where the Gila and other agglomerate is very deep. Several of these faults are nearly parallel; and while only two are indicated by the topography, seismic work discloses others, successively stepping the bedrock down to the west and deepening the overburden on the basal layer.

As has been pointed out by several engineers, the "vein" ceases to be a vein below the depth at which it ceases to have the Gila conglomerate on one wall. Below its dip shift, the fault is unmineralized. Whatever the source of the copper, the emplacement of the chrysocolla (and copper pitch) in its present position has been brought about by a process equivalent to that, under which the African and Australian laterites accumulate. Acid copper-bearing solutions have at certain seasons over a long period of years trickled along the bedrock of this area and, as the rainy season yielded moisture to the pull of the sun, have been raised by capillary action into the lower layers of the gravel. Banding in the distribution suggests that certain of the layers contained a little calcium carbonate—as caliche—but not enough to exhaust the acid supply. Not only at the intersection of the "vein," but also at other small slips and irregularities in the conglomerate, the capillary action and perhaps osmosis has sucked the green water higher along these avenues of better circulation and, as Thomas says, the "veinlets pinch out upward" and "the chrysocolla filling apparently was deposited by ascending solutions." They ascend, however, only from the top of bedrock.

As this conclusion, amply supported—in the writer's judgment—by observation in the present workings, leaves unanswered the ultimate source of the copper, Mr. Arthur Storke and the writer, last year, in behalf of Climax Molybdenum Company and Newmont Mining Corporation, conducted geophysical surveys over the area, using a method that detects disseminated sulphides—whether of iron or copper. Briefly, the work resulted in the discovery of a large mass of "protore," lying adjacent to and east of the chrysocolla deposit. This rock carries from 1% to 2½% sulphide, and is too low in copper content to warrant drilling. At one small area, this remnant of a "porphyry copper" actually emerges east of the cover, and presents the gossan of a disseminated body of pyrite carrying perhaps 0.2% Cu.

There is little doubt that this dissemination (extending over several hundred acres) constitutes the roots or protore of a more important—and possibly at one time commercial—"porphyry," of which the secondary enrichment occurred, as elsewhere in Arizona, in pre-Gila time. Despite its destruction, the verdure deriving from its wasting chalcocite still adorns the residues of its former cap and enclosing host rocks.

GOLCONDA MINE

The Golconda mine, which has been the second-largest producer of zinc in the district (table 2), is located in Todd Basin about 1.5 miles north of Cerbat. The mine was worked at various times and by numerous operators between the years 1910 and 1942, and Schrader (1909, p. 100) reports mining prior to his visit to the district in 1906–7. In May 1943 Bulwark Mines, Inc., of Kingman, Ariz., obtained a 10-year lease from Pontiac Mines, Inc., of Los Angeles, Calif., on 20 claims distributed around and including the Golconda mine. E. E. Bollinger, of Kingman, is president of Bulwark Mines, Inc.

The mine was idle when visited. Almost the entire production dates from 1908 to 1917, but by far the greatest amount of zinc was produced between 1914 and 1917. In October 1917 a fire destroyed the mill and most of the other surface equipment. Only a few intermittent and very small scale attempts to resume operations have been made since the fire. The main shaft has caved, and most of the other workings are inaccessible owing to caving or flooding.

Reliable information on the underground workings is scant. The main shaft is on the Golconda, or Prosperity, vein at an altitude of about 4,375 feet. It is inclined to the northeast and is reported to have reached a depth below the surface of 1,400 feet, following down, or approximately down, the dip of the vein. The mine has 12 levels, and drifts along the vein are commonly about 600 to 1,400 feet long, roughly the same distance northwest and southeast of the shaft. The 600-foot level, however, extends northwestward from the main shaft along the vein, intersecting the surface at a point about 2,400 feet beyond the shaft. Southeast of the shaft this level is reported to extend for 400 feet. No drifts are reported between the 1,200-foot level and the bottom of the shaft (1,400-foot level).

The Golconda vein strikes northwest and dips to the northeast (pl. 18). The angle of dip varies, but it is reported to average about 65° in the underground workings. The vein pinches and swells, ranging in thickness from 2 to 7 feet. On the surface the vein can be traced, chiefly by small prospect pits, for about 4,000 feet. Near its northwest end it splits into several branches, two of which form approximately parallel prongs and have opposing dips. The Oro Plata mine is located on the southwest prong. A branch, about 1,700 feet long, trending in a more northerly direction, is known as the Primrose vein.

The country rock is chiefly the pre-Cambrian complex, mostly granite. Numerous small, irregular bodies of the Ithaca Peak granite, too small to be shown on the geologic map, are exposed on the surface in the area along and adjacent to the trend of the vein.

The principal metallic minerals, as determined chiefly from material on the mine dumps, are sphalerite, galena, pyrite, and chalcopyrite, contained in a milky quartz gangue. Much of the sphalerite is dark brown to almost black. Sphalerite is greatly in excess of galena. This is in marked contrast to the Tennessee-Schuylkill mine, which has produced about the same amount of zinc as the Golconda mine (table 2) yet has produced almost as much lead as zinc.

Information of a general nature indicates that the best ore shoots on the Golconda vein were found northward from the main shaft for about 1,000 feet. Most of the ore has been removed from the surface to the 600-foot level. Reports vary greatly regarding the grade and quantity of ore left in the workings below the 1,000-foot level.

About 500 feet southeast of the shaft on the 700-foot level a crosscut to the southwest connects with the mine workings along the Tubb, or Middle Golconda, vein. One of the higher levels in the Golconda mine also is reported to be connected by a crosscut to the Tubb vein. The Tubb vein roughly parallels the Golconda vein and, like it, dips to the northeast. On the surface the Tubb vein is 350 to 600 feet distant from the Golconda vein. Four levels, with a total of about 3,500 feet of drifts, are reported on the Tubb vein.

GROSS COPPER PROSPECTS

A low-grade deposit of chalcocite occurs on the Gross ranch near the western border of the main exposure of the Ithaca Peak granite south of Mineral Park. The inaccessible mine workings are reported to consist of a 200-foot shaft and two drifts, each about 600 feet long. One drift is to the east, and the other is to the northeast. The workings were driven in 1926 by the C. and A. Mining Co. No ore has been shipped. Material on the mine dump shows malachite, azurite, and specks of chalcocite disseminated in minor quantities in pyritized and silicified granite. Several veinlets of chalcocite 0.05 to 0.2 inch thick were observed, and one such veinlet is reported to have been 2 inches thick. A few specks or paper-thin stringers of molybdenite also were seen. Native copper, occurring as small leaf forms, is reported to be present in minor quantities but was not observed during the visit to the prospect.

GROSS MOLYBDENITE PROSPECTS

In Bismark Canyon, 1,400 feet east of the Gross ranch house, two adits have been driven to explore a low-grade molybdenite deposit (pl. 18). The work was done about 1926 by the C. and A. Mining Co., but no ore has been shipped. The adit on the north side of the canyon bears almost due north for about 800 feet. Molybdenite occurs most commonly in specks and small stringers in quartz veinlets that cut the Ithaca Peak granite. The veinlets are 0.02 to 1.5 inches thick, but thicknesses of 0.5 inch or less predominate. Some molybdenite occurs in small disseminated specks in the granite or as paper-thin stringers with little or no quartz.

The adit on the south side of the wash is inaccessible but is reported to bear a little east of south. Near its south end a crosscut to the east encounters a rhyolite dike about 20 feet wide in nearby exposures. The material on the dump shows numerous narrow molybdenite-bearing quartz veinlets and stringers of pyrite cutting the rhyolite. The minerals extend into the granite in the same manner that was noted where they are exposed in the adit on the north side of the wash.

HIDDEN TREASURE MINE

The Hidden Treasure mine is nearly 2 miles southeast of Chloride on the lower western slope of the mountains (pl. 18). The property consists of five claims along and bordering the Hidden Treasure vein held by Frank H. Grannis, of Chloride. The mine has been worked intermittently for many years by numerous operators. Schrader (1909, p. 72) reports mining operations prior to his visit to the district in 1907. The mine has produced, in addition to gold, silver, and copper (table 2), a little more than 115 tons of metallic zinc and nearly 80 tons of metallic lead during the period of recorded production from 1901 to 1948.

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The mine workings, which were partly accessible when the mine was visited, include several shafts, three crosscutting adits bearing northeast, and three levels vertically spaced about 50 feet apart. Drifts total about 3,000 feet.

The Hidden Treasure vein, on which the mine is located, has an average strike of about N. 50° W. and dips steeply to the northeast. It is correlated with the vein on which the Emerson mine is located (pl. 18). The vein pinches and swells to thicknesses ranging from 0.5 to 15 feet. Many branches and spur veins are disclosed in the underground workings of the Hidden Treasure mine. Crosscuts indicate several thin veins, some of which are probably branches of the main vein, trending about parallel to it. These smaller veins or branches, with few exceptions, could not be traced on the surface.

The country rock is the pre-Cambrian complex of granite, gneiss, schist, and amphibolite. In numerous places the country rock adjoining the vein is greatly altered to sericite or impregnated with pyrite for distances ranging from a fraction of an inch to several feet. Locally seams or thin zones of gouge an inch or two thick border the quartz veins.

The metallic sulfides, which are in a quartz gangue, include pyrite, sphalerite, galena, and minor quantities of chalcopyrite. Ore shoots that were observed in the underground workings are generally small bodies only a few feet long and a foot or less thick consisting of an intimate mixture of the various metallic sulfides and little or no quartz.

KEYSTONE MINE

The Keystone mine is in Mineral Park at an altitude of about 4,375 feet. Schrader (1909, p. 82) states that it was located in 1870 and that its surface ores were very rich in gold and silver, by reason of which it became the first important producer in the district. The mine, consisting of three patented claims, has changed ownership many times and, when visited, was reported to be owned by the Beach Estate. It was then idle, and water filled the underground workings and the shaft to a depth of about 50 feet below the surface. Table 2 indicates that the greatest values have been in silver and gold, although the mine has also produced substantial amounts of copper, lead, and zinc.

The mine was developed by a shaft, reported to be about 400 feet deep, and four levels at 150, 200, 300, and 400 feet. Drifting on the 150-foot level is reported to have reached a distance of 850 feet northwest of the main shaft and 450 feet southeast of it. On the 300-foot level drifts extend about 275 feet both northwest and southeast of the shaft. On the 400-foot level is about 125 feet of drifting, mostly to the northwest. The greater part of the ore above the 300-foot level is reported to have been worked out.

The vein on which the mine is located strikes northwest and dips to the northeast at angles ranging from about 65° to 80°. About 800 feet northwest of the shaft the vein splits into two main branches; the southern branch dips prevailingly to the southwest at a steep angle and near its west end cuts a wide rhyolite dike. Another vein about parallel to the main vein is reported to lie approximately 100 feet northeast of the Keystone shaft, although no evidence could be found of this vein in surface outcroppings northwest of the shaft.

Vein matter on the mine dump is milky quartz with abundant pyrite and lesser amounts of sphalerite, chalcopyrite, and galena. Argentite, although reported to be present in the ore, was not found.

PAYROLL MINE

The Payroll mine is about 1.5 miles east of Chloride, near the head of Payroll Gulch, at an altitude of about 4,500 feet. The property, which includes the patented Payroll and Black Prince claims, is held by the Thomas B. Scott Estate. The property is an old one, having been located in 1887, and much of the early work consisted of shallow diggings along the Payroll vein chiefly for high-grade gold ore. Considerable mining had been done prior to Schrader's (1909, p. 62) visit to the district in 1907, as he reports three shafts, about 400 feet of drifts, over 600 feet of tunnels, and some crosscuts and stopes. The main shaft was 225 feet deep. The mine was idle and the workings were inaccessible when visited by the writer in 1943. The main shaft is now reported to be a little more than 600 feet deep. The mine was developed by four main levels, the 50-, 200-, 400-, and 600-foot levels. Drifting and stoping from these levels has extended chiefly southeastward along the vein, the maximum distance from the shaft being 500 feet on the 600-foot level. The total length of all drifts is reported to be about 2,000 feet.

Production from the mine during the period 1901–48, as given in table 2, shows that during these years the mine was essentially a producer of zinc, although the early, unrecorded production may have been mostly in gold and silver.

The country rock consists of many types of the pre-Cambrian complex, although light-gray, fine-grained granite, dark, medium-grained biotite granite, hornblende schist, and amphibolite predominate. A diabase dike, not shown on the geologic map, is poorly exposed for a short distance along the northeast side of the vein near the main shaft. It could not be found in its projected position on the northwest side of the gulch, and it apparently has been cut off by the northeastward-trending fault shown on plate 18.

The Payroll vein strikes N. 30°–35° W. and dips steeply to the northeast. It commonly ranges in thickness from about 4 to 12 feet, though Schrader (1909, p. 62) reports a maximum thickness of nearly 100 feet. The vein can be traced by persistent croppings southeastward to a point about 1,000 feet beyond the Mary Bell mine, but past this point it is poorly exposed and correlations are somewhat questionable. The total length of the vein is about 6,700 feet. Northwest of the main shaft of the Payroll mine the vein has been offset by a fault. (See p. 138.)

The vein filling, as determined chiefly from material on the mine dump, is sphalerite, galena, pyrite, and chalcopyrite in a gangue of quartz. Cerussite, although not observed, has been reported as occurring in moderate amounts in the oxidized parts of the vein.

TENNESSEE-SCHUYLKILL MINE

The Tennessee-Schuylkill mine is 1 mile east of Chloride at the western foot of the Cerbat Mountains, at an altitude of about 4,200 feet. It is an old mine and has been worked intermittently by numerous operators for at least the past 50 to 60 years. During most of World War II the mine was operated by the Tennessee-Schuylkill Corp., and it was the only large mining operation in progress in the district. A mill located near the Tennessee shaft was running at a capacity of about 150 tons of crude ore per day, averaging 6 to 8 percent zinc, 3.5 percent lead, and 17 to 25 ounces of silver per ton.

The mine has been the largest producer of lead and zinc in the district (table 2). It has produced almost as much lead as zinc and, in addition, has yielded substantial values in gold and silver. This and the Golconda are the only two mines that have yielded a total production valued in excess of $1,000,000.

The Tennessee-Schuylkill mine is on the northern part of the Tennessee vein (pl. 18). The main, or Tennessee, shaft is about 1,400 feet deep. The Schuylkill shaft, about 1,450 feet to the north, is about 800 feet deep but is caved, so that the only access to the mine is by the Tennessee shaft. For many years the Schuylkill and Tennessee mines were operated as separate mines. Plate 19 is a longitudinal section along the vein showing the extent of the workings. The section has been compiled from data of various sources and may be inaccurate in part because past records are scanty and underground workings are inaccessible in most of the Schuylkill workings and also in a very large part of the Tennessee workings. It will be noted that only a small amount of stoping and drifting has been done below the 1,400-foot level. Also, very little work has been done south of the Tennessee shaft, although most of the work in progress when the mine was visited in 1943 was confined to stopes off the 900-foot level south of the shaft.

The Tennessee vein is about 6,000 feet long and strikes N. 8° W. Dips are steep, averaging 85° E. in the Tennessee and Schuylkill workings. One reversal of dip, 50 feet north of the Tennessee shaft between the 900- and 1,250-foot levels, is to 87° W. Garrett (1938, p. 118) notes that ore shoots in the mine tend to occur where the vein changes to a more westerly strike. In common with many other veins in the district, the Tennessee vein shows considerable pinching and swelling along both strike and dip. In the Tennessee workings thicknesses range from 1 to 22 feet; the average is about 8 feet. Spurs, irregular branches, and small parallel veins are characteristic. In a few places enrichment is found at the junction of branch and spur veins with the main vein. Other junctions show lower-grade ore than average.

Gouge, locally accompanied by brecciated vein material, is common along the hanging wall and footwall of the vein as well as irregularly traversing the vein. Alteration of the wall rock, with the formation of sericite and pyrite, extends a few inches to several feet from the vein. The composition of the wall rock has not influenced the vein as regards either width or mineral composition. Throughout the entire length of the vein the country rock is a complex of amphibolite, pegmatite, granite, gneiss, and schist.

The hypogene metallic minerals are chiefly sphalerite, galena, and pyrite with minor amounts of arsenopyrite and chalcopyrite. They commonly occur intimately associated in a gangue of milky quartz. In a few places a crude compositional banding of moderately pure sphalerite, galena, or pyrite is present, the bands seldom exceeding a few inches in width.

Supergene minerals are anglesite, cerussite, cerargyrite, native gold, and—rarely—native silver. The supergene ores are now of little importance, although the precious metals were of chief interest in the earlier period of mining in the higher oxidized zone.

Plate 19 indicates that those ore shoots about which information was obtainable pitch to the north. The ore shoots likewise show an increase of sphalerite over galena southward. The ore shoot south of the Schuylkill shaft has a stope length of about 400 feet along the 800-foot level (pl. 19) and a pitch length of about 1,000 feet between the 300- and 1,000-foot levels. An even larger ore shoot has probably been mined out in the ground a few hundred feet north of the Tennessee shaft, but no records of it are available and the workings are largely inaccessible. The four main ore shoots were projected to the surface, and an attempt was made to determine any special characteristics of outcrops at these places that might aid in predicting ore shoots in the southern part of the vein. However, no special thickness, gossan, brecciation, or other indications of possible ore shoots were evident.

OTHER MINES AND PROSPECTS ON THE TENNESSEE VEIN

The Elkhart mine, at the extreme north end of the Tennessee vein, is an old mine that has been idle for many years. The total production from this mine from 1901 through 1948, as shown in table 2, has been small. The mine workings, now inaccessible, are reported to consist of three shafts, six levels (the lowest 500 feet deep), drifts totaling about 2,600 feet, numerous stopes, and several crosscuts.

The Silver Age mine, near the extreme south end of the vein, was primarily a silver mine (table 2). The silver was probably derived in large part from silver chloride (cerargyrite) found in the oxidized zone. Accurate data concerning the inaccessible mine workings could not be obtained. It is reported that the shaft is about 150 to 200 feet deep and that drifts and stopes extend northward from the shaft for some 200 or 300 feet. The vein material on the mine dump is partly oxidized, chiefly to iron hydroxides. Pyrite is the most abundant primary sulfide. Minor amounts of galena and sphalerite, together with sparse chalcopyrite, are associated with the pyrite in quartz gangue.

Several shafts have been driven and numerous pits and trenches have been dug along the Tennessee vein from the Silver Age shaft to the Tennessee shaft. The deepest of these is the Johnny Bull shaft (pl. 18), which is reported to be 88 feet deep. No drifting or stoping from this shaft is known.

Diamond drilling on the southern part of the Tennessee vein was carried out by the United States Bureau of Mines (Tainter, 1947) during the period from September 16 to December 8, 1943. The exploratory work consisted of eight drill holes on the Johnny Bull and Silver Knight claims, between 750 and 2,450 feet south of the Tennessee shaft. The holes were distributed along the vein at intervals ranging from 200 to about 375 feet. All holes were drilled from the surface and inclined toward the vein. Four were drilled from the west side of the vein outcroppings and the other four from the east side. Depths below the surface at which the vein was intersected ranged from about 100 to 350 feet, the deepest corresponding approximately in altitude to the 400-foot level in the Tennessee mine.

All holes intersected the vein, but the vein filling in seven of the eight cores was barren of ore minerals or was so low in grade as to be of little or no economic interest. The only hole that showed a substantial amount of the ore minerals was hole 8, located about 1,900 feet south of the Tennessee shaft. This hole intersected the vein about 100 feet below the surface, at an approximate altitude of 4,100 feet. A 3.5-foot interval of sphalerite, galena, and pyrite in quartz gangue assayed 7.6 percent zinc, 0.1 percent lead, and 0.03 percent copper.

This intersection might suggest that the top of an ore body was penetrated, but the Bureau of Mines engineers believed that the extensive drilling necessary to determine the existence of an ore shoot in the vicinity of hole 8 was not warranted.

TURQUOISE MINES

Deposits of turquoise are restricted to the Ithaca Peak granite and occur most abundantly in the southern half of the main intrusive body south of Mineral Park, particularly on Ithaca and Turquoise Peaks. Many small and shallow workings have explored these deposits, and only the larger ones are shown on plate 18. Some of the diggings are very old, having been started by the Aztec Indians. Very little work has been done on the deposits for many years.

Turquoise occurs typically in veinlets and small lenses in silicified, sericitized, and kaolinized porphyritic granite. Turquoise most commonly fills cavities in quartz veinlets, although some is in altered granite. Other minerals sparsely associated with turquoise in a few places are malachite, chrysocolla, and hydrous iron oxides. Sterrett (1908, pp. 847–852) describes some of the individual deposits in this area.

The features of the deposits suggest a secondary origin by supergene processes similar to those given by Paige (1912) for the origin of turquoise in the Burro Mountains of New Mexico.

LIST OF REFERENCES

The literature pertaining to the district is not extensive. The list given below includes the chief publications. Of these, Schrader's report on districts in Mohave County furnishes the most extensive description of the Wallapai district, and it is of particular value in furnishing descriptions of many of the mines. Thomas' manuscript contributes much information, particularly his detailed descriptions of the minerals and their paragenetic relationships. He includes a small-scale geologic map that covers an area extending from Mineral Park northwestward for several miles beyond Chloride. Most of the references are brief summaries of the geology and ore deposits, probably taken in part from Schrader's previous work.

Bastin, E. S., 1924, Origin of certain rich silver ores near Chloride and Kingman, Ariz.: U. S. Geol. Surv. Bull. 750, pp. 17–39.

Darton, N. H., 1925, A résumé of Arizona geology: Ariz. Bureau Mines Bull. 119, p. 180.

Dings, M. G., 1950, Wallapai mining district, Mohave County, Ariz.: Arizona Bur. Mines Bull. 156, pt. 1, pp. 138–142.

Elsing, M. J., and Heineman, E. S., 1936, Arizona metal production: Ariz. Bur. Mines Bull. 140, pp. 73–95.

Garrett, S. K., 1938, Tennessee-Schuylkill mine: Ariz. Bur. Mines Bull. 145, pp. 117–119.

HAURY, P. S., 1947, Examination of zinc-lead mines in the Wallapai mining district, Mohave County, Ariz.: U. S. Bur. Mines Rep. Inv. 4101.

HERNON, R. M., 1938, Cerbat Mountains: Ariz. Bur. Mines Bull. 145, pp. 110–117.

LINDGREN, WALDEMAR, 1933, Mineral deposits, pp. 578–579, New York, McGraw-Hill Book Co.

MASON, R. T., 1917, Mining in northwestern Arizona, pp. 627–628, Min. and Sci. Press.

MCKNIGHT, E. T., 1933, Mesothermal silver-lead-zinc deposits: Ore deposits of the Western States (Lindgren volume), pp. 592–593, Am. Inst. Min. Met. Eng.

NOLAN, T. B., and others, 1936, Mineral resources of the region around Boulder Dam: U. S. Geol. Surv. Bull. 871, pp. 18–19.

PAIGE, SIDNEY, 1912, The origin of turquoise in the Burro Mountains, N. Mex.: Econ. Geology, vol. 7, no. 4, pp. 382–392.

SCHRADER, F. C., 1909, Mineral deposits of the Cerbat Range, Black Mountains, and Grand Wash Cliffs, Mohave County, Ariz.: U. S. Geol. Surv. Bull. 397.

SCHRADER, F. C., 1917, Geology and ore deposits of Mohave County, Ariz.: Am. Inst. Min. Eng. Trans., vol. 56, pp. 195–236.

SEARLS, FRED, JR., 1950, Discussion and communications: The Emerald Isle mine: Econ. Geology, vol. 45, pp. 175–176.

STERRETT, D. B., 1908, Precious stones: Mineral Resources U. S., 1908, pt. 2, pp. 847–852.

TAINTER, S. L., 1947, Johnny Bull-Silver Knight lead-zinc property, Cerbat Mountains, Mohave County, Ariz.: U. S. Bur. Mines Rept. Inv. 3998.

THOMAS, B. E., 1949, Ore deposits of the Wallapai district, Ariz.: Econ. Geology, vol. 44, pp. 663–705.

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