Historic Mining Camps and Jurassic Calderas

By BRENDA HOUSER

With a paper on the GREATERVILLE PLACER DISTRICT

By LESLIE COX

ARIZONA GEOLOGICAL SOCIETY FALL FIELD TRIP, 1992

Arizona Geological Society
P. O. Box 40952
Tucson, AZ 85717

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[1]This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards or with the North American Stratigraphic Code. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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HISTORIC MINING CAMPS AND JURASSIC CALDERAS, SOUTHEASTERN ARIZONA

Brenda B. Houser
U.S. Geological Survey

Introduction

Initially, this field trip had only one topic - historic mining camps in southeastern Arizona. As I started working on the road log, however, the spatial coincidence of mining districts with some of the Jurassic calderas proposed by Lipman and Hagstrum (1992) became clear. Lipman and Hagstrum noted that in some cases mineralization was apparently genetically related to the calderas so it seemed reasonable, both logistically and conceptually, to combine the two topics in one field trip. Although detailed studies of Jurassic silicic volcanics and plutons have been done to the west of the field trip area (for example the Mount Wrightson Formation in the Santa Rita Mountains (Riggs and Busby-Spera, 1990); similar studies in southeastern Arizona are in the early stages. Ken Hon is presently mapping in the area of the proposed Montezuma Caldera and, at stops 6 and 7, will present an overview of his work in progress. During reconnaissance investigations in the Courtland-Gleeson district, Lipman and Hon found exposures showing that Paleozoic limestone blocks are completely engulfed in unsheared Jurassic tuff (stop 10), which is the key evidence supporting the interpretation that the blocks are a caldera collapse breccia. In previous detailed mapping in the area, Gilluly (1956) and Drewes (1981) had interpreted the limestone blocks and tuff to be thrust fault breccia. In both these areas, Montezuma Pass and Courtland-Gleeson, some of the exotic limestone blocks have been mineralized.

The field trip route and stops are shown in figure 1. The first day's route is from Tucson to Bisbee by way of Patagonia, Lochiel, and Montezuma Pass. The second day we will travel back to Tucson through the Courtland-Gleeson mining camp, Pearce, and Arimetco's plant at Johnson.

The guidebook has three parts; (1) the road log, (2) a paper on the Greaterville placer district contributed by Leslie Cox, and (3) an appendix consisting of 10 reproduced articles pertaining to various subjects of the field trip. There are a number of important dates in the history of mining in Arizona. They are listed below;

1853 Gadsden Purchase. Prior to this, the land south of the Gila River was part of Sonora, Mexico.
1861 Beginning of the Civil War. All the Federal troops were withdrawn from Arizona, making it unsafe to be out alone or in

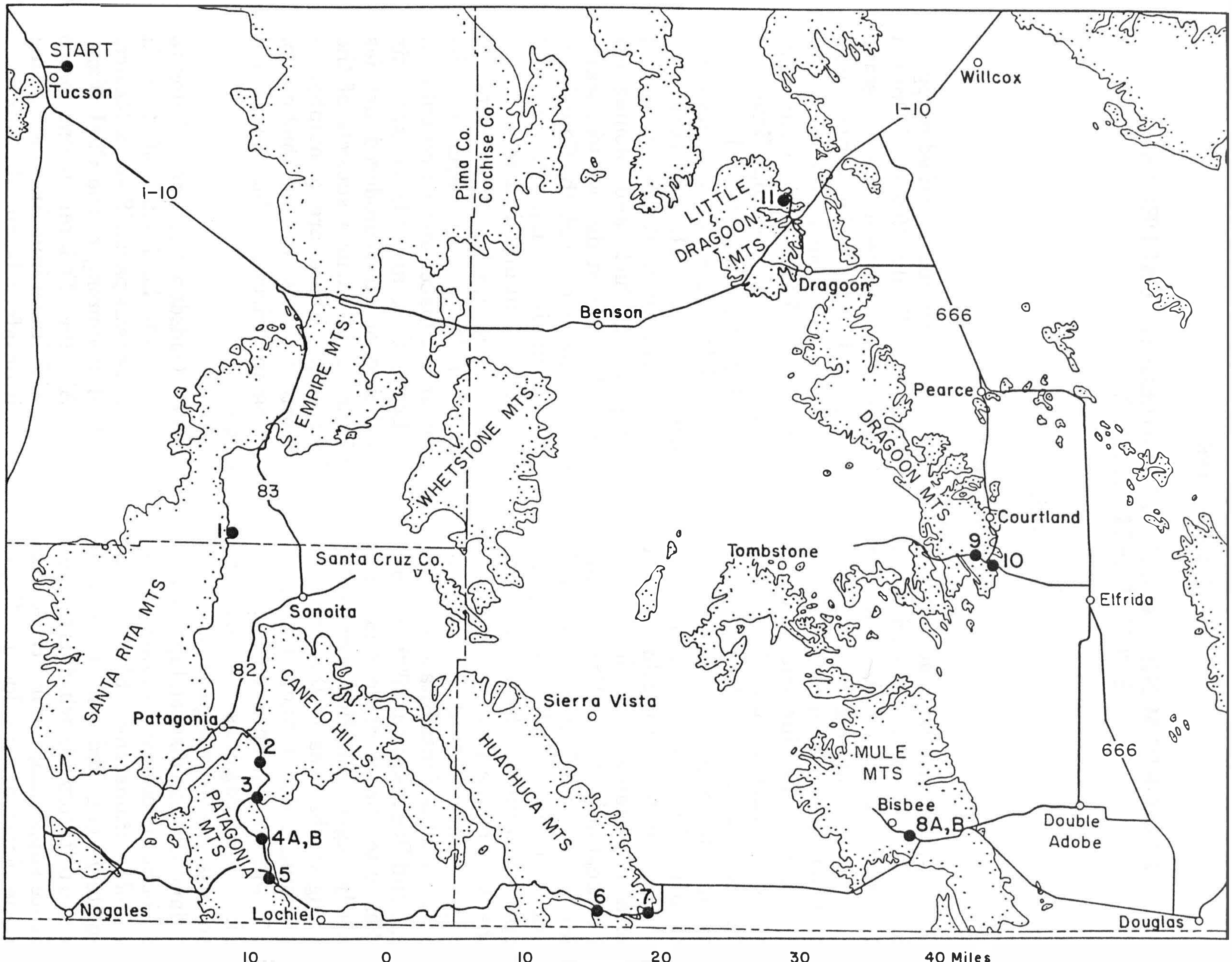


Figure 1.--Map showing field trip route and stops.

small groups because of Apache raids. Pumpelly's account of the hazards of being a miner in Arizona at this time is excellent (Wallace, 1965).

1872 Apache Peace Commission under Vincent Colyer. This first Apache peace made existence a little less precarious for miners, but there was still the threat of Apache raids until about 1876.

1881-83 Railroads were built in Arizona. Because of shipping costs before this, ore had to be worth at least $100 per ton to be worth mining.

1893 Demonetization of silver. Prior to this time, the price of silver was about 1$ per ounce. Afterwards, the price dropped sharply.

1914-17 World War I. Sharp upswing in metal prices.

1921 Collapse of metals prices.

A word of caution - in reviewing references and preparing the road log, I noticed a number of discrepancies among reference texts as to dates and versions of events. Because this road log is not intended to be a scholarly historical treatise, I chose the date or version that I knew to be correct, or that seemed to be the most likely, or that was the concensus of several sources. I did not search newspaper files or court records to resolve discrepancies.

Road Log

Day 1

Mileage	Comments
0.0	Depart from U of A flex-permit parking lot at the southeast corner of Euclid and E. 4th St. Go south on Euclid to E. 6th St. (0.2)
0.2	Junction of Euclid and E. 6th St. Turn right (west) on E. 6th St. (name changes to St. Marys west of the RR tracks). (1.4)
1.6	Junction of St. Marys and I-10. Take I-10 East to Route 83 (exit 281 - Sonoita Road). (23.4)
25.0	Junction of I-10 and Route 83. Take Rt. 83 south toward Sonoita. (6.0)
31.0	The Empire mining district is to the southeast in the Empire Mountains. Schrader's (1915) and Tenney's (1929) discussions of the history and production of the mines in the Empire district are in the guidebook appendix following the road log (Schrader, app. 8; Tenney, app. 9). Deposits of argentiferous lead and copper ores were first discovered in the Empire district in the late 1870's, but mining became economically feasible only after the railroad was built in the early 1880's. The principal camps in the district were California camp, Total Wreck, and Copper camp.

The highest and most rugged part of the Empire Mountains consists of generally southeastward dipping Paleozoic carbonate rocks and quartzite that have been intruded by early and late Laramide age granitoid plutons. Precambrian granitoid rocks are exposed on the north flank of the Empire Mountains. Sedimentary rocks of the Lower Cretaceous Bisbee Group surround the Empire Mountains and overlap both the Paleozoic and Precambrian rocks (Finnell, 1974; Drewes, 1980).

The mineralization of the Empire district is probably genetically associated with intrusion of the Laramide age granitoid rocks into the Paleozoic carbonate rocks. The mineral deposits are chiefly oxidized silver-lead and copper minerals contained in vein and replacement deposits. Some mines in the district produced small amounts of gold.

For a time, Total Wreck was the leading silver bullion producer in the Territory. The name Total Wreck came from the description of the site of the first silver mining claims in the Empire Mountains, given by John T. Dillon who discovered the deposits in 1879. He said the site was "a big ledge, but a total wreck, the whole hillside being covered with big boulders of quartz which have broken off the ledge and rolled down" (Granger, 1960). By 1883 the camp had 200 inhabitants and the Tucson Weekly Star reported that there were five saloons, three general stores, a butcher shop, a shoemaker shop, and from eight to ten Chinese laundries. The mine was closed in 1884 after producing about $500,000 in silver bullion. In 1926 the mill tailing pile was leased and more than 1,000 tons of low-grade material was shipped as flux (Tenney, 1929). (6.1)

37.1 Road to Rosemont Junction, 2.5 mi to the southwest. Rosemont camp, the site of the Rosemont Mining and Smelting Company, was a thriving village in the Helvetia district in the 1880's and 1890's. There were about 150 residents, a school, a hotel, and some stores (Sherman and Sherman, 1969). The claims and smelter were acquired by Lewisohn Brothers of New York City in 1896. Subsequently, the mines were worked on an exploratory basis until 1907, when finally, they were closed and the smelter was shut down. After that, Rosemont was more or less deserted (Schrader, 1915). (5.1)

42.2 Junction of Rt. 83 and Greaterville Road. (3.7)

45.9 Junction of Rt. 83 and Gardner Canyon Road (FR 92). Turn right on Gardner Canyon Road. (0.8)

Plan on leaving about half the vehicles here (particularly those with low clearance) and car-pooling the rest of the way to Kentucky Camp.

46.7 Junction FR 92 and FR 163. Take 163 to the right. (0.9)

47.5 Road to the left goes to an abbey. Continue straight. (1.1)

48.7 Junction of FR 163 and FR 4060 to the right. Go straight on FR 163. (1.1)

49.8 Junction of FR 163 and FR 162 to the right. Go straight on FR 163. (0.2)

50.0 Junction FR 163 and FR 4113. Take FR 4113 to the right. (0.2)

50.2 Wire gate. (0.9)
51.1 Go left at Y-intersection. (0.1)
51.2 Park at locked gate and walk about 0.2 mi down the hill to Kentucky Camp.

STOP 1 KENTUCKY CAMP AND GREATERVILLE PLACER DISTRICT
Leaders: Mary Farrell, U.S. Forest Service and Leslie Cox, U.S. Geological Survey

The adobe structures at Kentucky Camp were built in 1904 in conjunction with an engineering project to bring water from the Santa Rita Mountains to the placer workings in Kentucky Gulch. The site plan is shown in figure 2. They are in much better shape than adobe structures of equivalent vintage at other mining camps because they were kept in repair by a rancher until the 1960's. The buildings presently are being stabilized by the Forest Service for possible restoration some time in the future. The structural soundness of some of the walls is being monitored by strain gauges. Please don't remove any artifacts.

The geologic setting and the source of the Greaterville placer deposits are discussed by Cox in her paper in this guidebook after the road log. A summary of the U.S. Forest Service stabilization work at Kentucky Camp is given in appendix 10. Schrader's (1915) and Tenney's (1929) discussions of the Greaterville district are in the appendix also (app. 8, 9).

Placer gold was discovered on the east side of the Santa Ritas in 1874 and a moderate-sized gold rush ensued. By 1878 there were about 400 Mexicans and nearly 100 Americans in the new community of Greaterville. There were several dance halls, saloons, and stores; and the jail was a round hole dug in the ground into which prisoners were lowered by rope (Sherman and Sherman, 1969).

The Greaterville placer district suffered from a problem common to many southwestern placer deposits - lack of water. Placers were worked by rocker and long tom; water was brought 4 mi from Gardner Canyon in canvas and goatskin bags on burros with the Mexicans charging about 3 cents a gallon for it.

Between 1881 and 1886, the camp gradually declined as the richer gravels were worked out and attacks by Indians continued to be a threat. There was a revival of interest in the Greaterville placers between 1900 and 1905 when there were several attempts to bring water in by ditch and pipeline. The center for one of these operations was Kentucky Camp in Kentucky Gulch (app. 10). From 1905 to about 1930, various companies attempted to work the gravels with a steam shovel, drag-lines, and a dredge; all failed because of insufficient water and poor sampling (Tenney, 1929).

Return to Rt. 83. (5.3 mi)
56.5 Turn right (south) toward Sonoita. (4.1)
60.6 Junction of Rt. 83 and Rt. 82 in Sonoita. Turn right on Rt. 82 toward

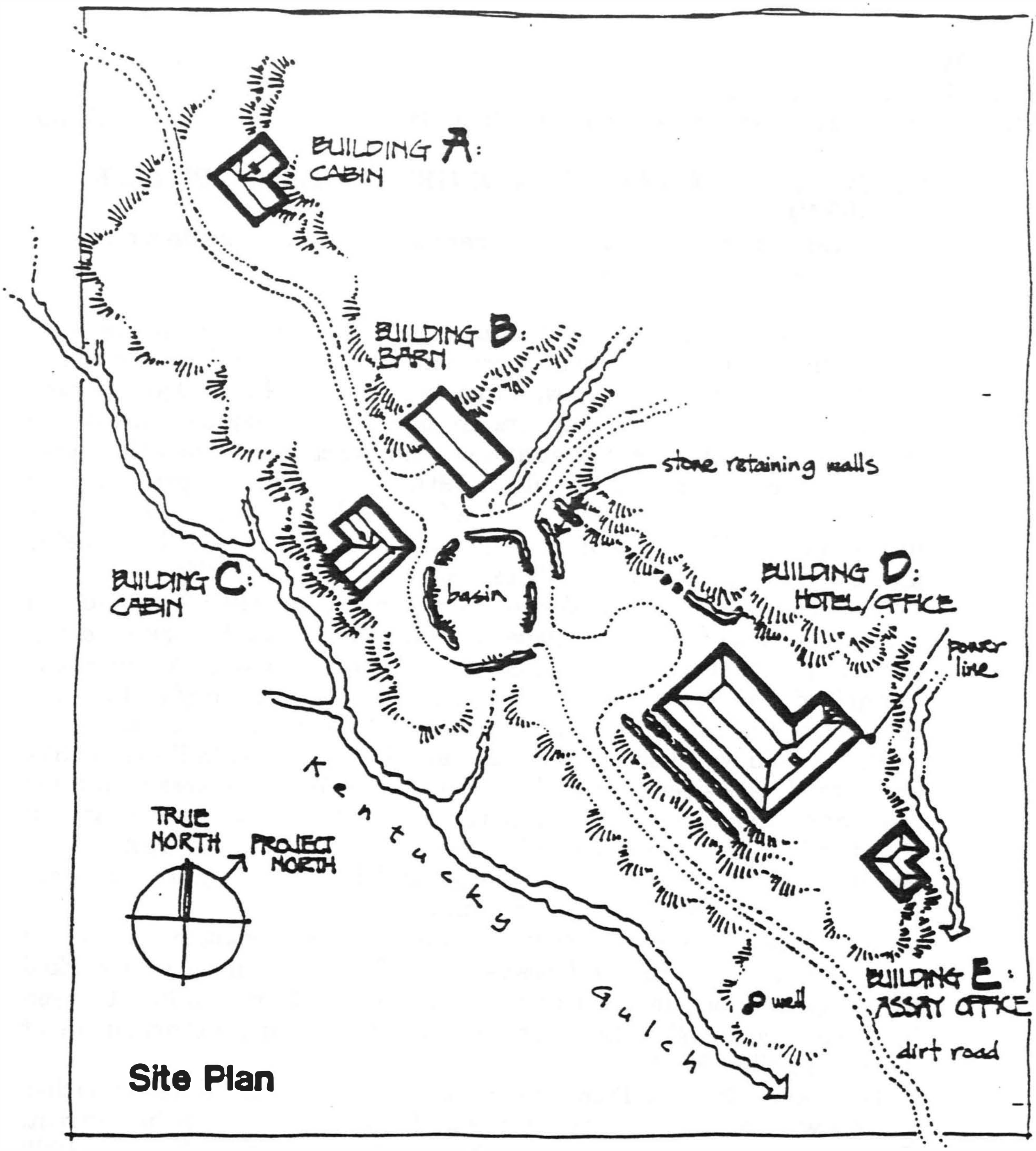


Figure 2.--Map showing Kentucky Camp site plan. Prepared by U.S. Forest Service.

Patagonia. Sonoita was established in 1882 on the newly built railroad line. The name comes from the Tohono O'Odham word meaning "place where corn will grow" (Granger, 1960). (2.9)

63.5 The site of Fort Crittenden is about 0.2 mi north of the road. Camp (Fort) Crittenden was established March 4, 1867 on a hill overlooking the old site of Fort Buchanan. It was named for Gen. Thomas Leonidas Crittenden, military commander for southern Arizona 1867-1868. The camp was abandoned in the summer of 1872 because of unhealthy conditions, probably malaria (Granger, 1960). (0.6)

64.1 The former site of Fort Buchanan is near here about 0.1 mi north of the road. In 1856, Major Enoch Steen was ordered to set up a permanent military post in Tucson to protect the settlers of southern Arizona. Steen was unimpressed with the "miserable huts" he found in Tucson and the lack of grass and grain in the area for horses, so instead, he chose a site for the post (called Camp Moore) 60 mi to the south up the Santa Cruz River Valley. When his superiors in Santa Fe ordered him to relocate the post closer to Tucson, Steen replied that in the Sonoita Valley he was protecting miners and ranchers, whereas in Tucson he would be protecting only "whiskey peddlers". Nevertheless, another site for the post was chosen 20 mi to the northeast of Camp Moore and construction on Fort Buchanan was begun in the summer of 1857 (although Tucson residents pointed out in a petition that the new site was even farther from Tucson than the old site had been).

Morale was low at Fort Buchanan because of poor accomodations, lack of troop rotation, Apache raids, and the prevalence of malaria that had its source in nearby swamps. The fort was abandoned July 21, 1861 when the soldiers were withdrawn to help repel the Confederates on the Rio Grande (Wagoner, 1975). (8.8)

72.9 Junction of Rt. 82 and road to Harshaw and Lochiel at the Patagonia post office just west of Sonoita Creek. Turn left, go 1 block and turn left again on McKeown Ave.

Patagonia was established in 1896 when Rollen Rice Richardson decided to move the town of Crittenden about 3 mi south to a marshy area that he owned at the present site of Patagonia. Richardson, a rancher, had previously owned much of the land in the area and had bought out the squatters at old Camp Crittenden. Richardson had wanted to call the town Rollen, but the residents of the new town chose the name Patagonia from the name of the mountains to the south. Because the petition for a post office had to be signed by the residents, Richardson had little say in the matter of the town name (Granger, 1960).

In 1909, Patagonia was an active mining center with about 200 residents. Two daily passenger and mail trains stopped there, and daily stage and mail service was maintained between Patagonia, Harshaw, Mowry, Washington, and Duquesne (Schrader, 1915). Nowadays, ranchers, retirees, hunters, and bird watchers provide much of the economic base for Patagonia.

The Harshaw district is in the northeastern quarter of the Patagonia Mountains and extends about 7 mi south of the town of Patagonia (fig. 3). The principal camps of the district were Harshaw, World's Fair, Wieland, Elevation, Standard, and Thunder. Schrader's (1915) and Tenney's (1929) descriptions of the Harshaw district are in appendixes 8 and 9.

Figure 4 shows the geology of the trip route through the Harshaw and Patagonia districts (Simons, 1974). The eastern two-thirds of the Harshaw district is underlain by lower Paleocene silicic to intermediate volcanic rocks intruded by upper Paleocene granitoid stocks at Red Mountain and Saddle Mountain. The western one-third, which includes much of the mineralized area, is underlain by granitoid stocks and chiefly silicic volcanic rocks of Mesozoic age. A small exposure of Paleozoic carbonate rocks and limestone and conglomerate of the Lower Cretaceous Bisbee Group extends up into the southern part of the district (Drewes, 1980).

The north-northwest-trending Harshaw Creek fault forms part of the boundary between the eastern and western terranes. Simons (1974) presented evidence that the Harshaw Creek fault has at least 4 mi of left-lateral displacement.

Early mines in the Harshaw district produced large amounts of high-grade lead-silver ore. The ore is usually contained in vein deposits in Mesozoic granitoid and silicic volcanic rocks that have been intruded by younger rocks (Schrader, 1915). (3.3)

76.2 According to local tradition, the smaller rock on the northwest side of the big rock on the left side of the road broke off during the 1887 earthquake (Robert Lenon, oral commun., 1992). (1.9)

78.1 Park in wide pullouts on either side of the road.

STOP 2 RED MOUNTAIN OVERVIEW
Leader: Robert Lenon, Mining Engineer, Ret.

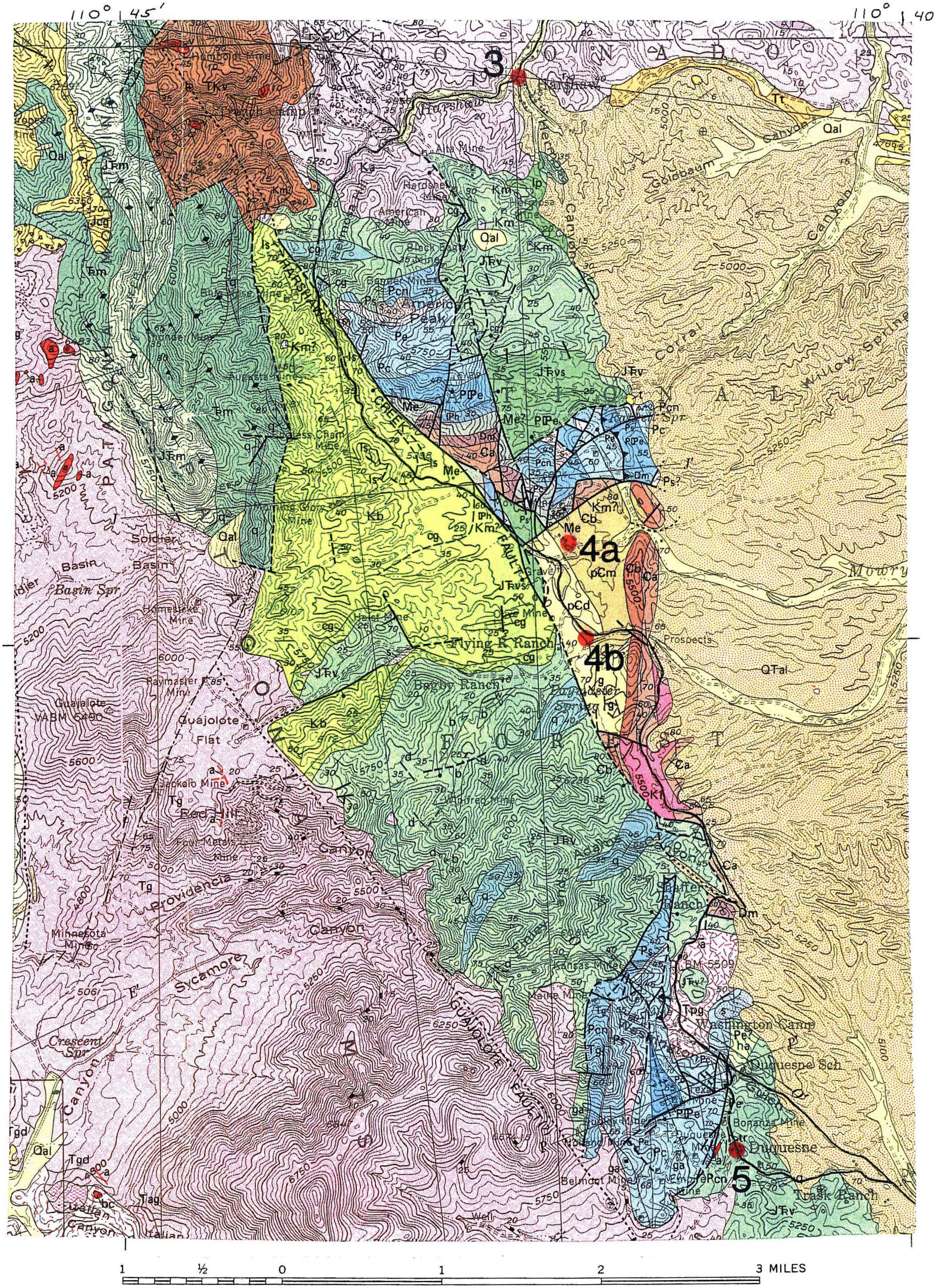
Quinlan's (1986) description of the geology and alteration of the Red Mountain porphyry copper deposit is in appendix 7. Red Mountain is composed of three Cretaceous through early Tertiary volcanic sequences that have undergone various degrees of alteration associated with the formation of a porphyry copper deposit. Simons (1974) described the upper sequence as white, light-gray, yellowish-gray, or pale-red, massive, very fine grained to sparsely porphyritic, silicic flow breccia and tuff. It forms most of the upper part of the mountain and is as thick as 2,400 ft. These rocks are locally cliff-forming and outcrops are stained with iron oxide. Alteration to quartz, kaolinite, sericite, and limonite is common. alteration to alunite and zunyite is locally common. Schrader (1915) reported that the tuff is profusely impregnated with pyrite, chalcopyrite, and chalcocite disseminated in crystals and grains. Drewes (1980) gave the age of the rock as Paleocene(?).

Figure 3.--Map showing Harshaw and Patagonia mining districts (from Schrader, 1915).

Figure 4.--Geologic map of the Patagonia Mountains in the vicinity of the Harshaw, Washington, and Duquesne mining camps (from Simons, 1974) showing field trip stops 3, 4, and 5. Scale is 1:48.000. Contour interval is 80 ft along the western edge of the map and 50 ft in the rest of the map.

List of map units

Qal	Younger alluvium and talus, Quaternary
QTal	Older alluvium, Quaternary and Tertiary
Tt	Biotite rhyolite tuff, Miocene and Oligocene
Tg	Biotite-hornblende granodiorite, Paleocene
Tbg	Biotite quartz monzonite, Paleocene
Tgd	Syenodiorite of mangerite, Paleocene
a	aplite
Tpg	Porphyritic biotite granodiorite, Paleocene
TKv	Tuff, Paleocene or Upper Cretaceous
v	volcanic breccia
Ka	Trachyandesite or doreite, Upper Cretaceous
r	rhyolite or latite
Kl	Biotite quartz latite, Upper Cretaceous
Kb	Bisbee Group, Lower Cretaceous
cg	conglomerate
Jcg	granite of Comoro Canyon, Jurassic
JTR m	Monzonite porphyry, Jurassic or Triassic
JTR v	Silicic volcanic rocks, Jurassic or Triassic
cg	limestone or conglomerate
q	quartzite
JTR vs	Volcanic and sedimentary rocks, Jurassic or Triassic
T m	Mount Wrightson Formation, Triassic
q	quartzite
Naco Group, Permian and Pennsylvanian	
Pcn	Concha Limestone
Ps	Scherrer Formation
Pe	Epitaph Dolomite
Pc	Colina Limestone
PIPe	Earp Formation
IPh	Horquilla Limestone
Me	Escabrosa Limestone, Upper and Lower Mississippian
Dm	Martin Limestone, Upper Devonian
€a	Abrigo Limestone, Upper and Middle Cambrian
€b	Bolsa Quartzite

110° 45'
110° 40'
3
4a
4b
5
Duquesne
Washington Camp
Flying R Ranch
Bagby Ranch
Red Hill
Guajolote Flat
Soldier Basin
Providencia
Canyon
Sycamore
Mowry
Corral
Willow Spring
Goldbaum
Trask Ranch
Duquesne Sch
Bonanza Mine
Belmont Mine
Kansas Mine
Holland Mine
Minnesota Mine
Homestake Mine
Hale Mine
Winifred Mine
American Peak
Alta Mine
Crescent Spr
Italian Canyon
Guajolote VABM 5890
Prospects
FAULT
CREEK
Qal
QTal
Kb
JTrv
Tg
1 ½ 0 1 2 3 MILES

The middle volcanic sequence is andesite and trachyandesite about 3,000 ft thick that crops out on the flanks of Red Mountain. This sequence was dated at 72 Ma (Simons, 1974). Hornfels bands occur at the base (Quinlan, 1986).

Rocks of the lower sequence are chiefly latitic volcanic conglomerate and breccia, and silicified tuff and flows(?) interlayered with and cut by latite sills and dikes (Quinlan, 1986). This sequence is exposed on the south side of Red Mountain in Alum Canyon. It correlates with the Upper Cretaceous silicic volcanics of Simons (1974).

The rocks of Red Mountain dip to the east at about 15 and are cut by porphyritic granitic dikes and small intrusive bodies of Laramide age.

Return to cars and continue south on Harshaw Road. (0.5)

78.6 End of pavement. Junction of Harshaw Road (FR 49) with FR 58. Take FR 49 to the right. (0.3)

78.9 This was the patented mill site for the American Mine. In the 1882 patent survey, the large sycamore tree by the creek on the right side of the road was surveyed in and was described as being about 3 ft in diameter. In the course of resurveying in 1972, the same tree was identified and had grown to 4 ft in diameter (Robert Lenon, oral commun., 1992). (1.9)

80.8 Park along road at Harshaw town site.

STOP 3 HARSHAW TOWN SITE AND CEMETERY
Leader: Robert Lenon, Mining Engineer, Ret.

The town was named for David Tecumseh Harshaw who started grazing cattle in the area in 1874. He located and developed mines here and by 1880, Harshaw was a flourishing mining camp with several stores and mostly stone buildings (Granger, 1960). The town grew to a population of about 600 and finally peaked near 2000. It was the metropolis for about thirty-five mines in a 40 square mile area.

The Hermosa Mill, a 20-stamp mill and the largest mill in the territory, was crushing about 75 tons of ore a day. About 150 men were employed in the mines. It wasn't long, however, before the mines were worked out. Mining was suspended in 1881, and the mill was sold and moved in 1885. The coming of the railroad to the Sonoita Valley in 1887 caused a brief revival of mining, but the supply point shifted to Patagonia and Harshaw once again declined. The post office was closed in 1903 and by 1909 only a few families remained.

The mines that used Harshaw as a hub produced over a million tons of ore valued at more than $40 million. Zinc, lead, copper, and manganese ore made up most of the deposits, but more than 9 million ounces of silver and 4,000 ounces of gold were recovered also.

There are some very nice wrought iron crosses in the Harshaw cemetery.

Return to cars and continue south on Harshaw Road. (0.8)

81.6 Flux Canyon Road (FR 812) on the right goes to Trench Camp town site and the World's Fair Mine. The Trench Mine is one of the oldest mines in Arizona, dating back to the Spanish. It was still being worked up to 1964 by ASARCO.

The adobe ruin on the left was the Hardshell store (Robert Lenon, oral commun., 1992). Ore was discovered in Hardshell Gulch in 1879 by Jose Andrade and David Harshaw, and the claim was bought in 1880 by Rollen R. Richardson (Granger, 1960). Continue straight on the Harshaw Road (FR 49). (0.8)

82.4 Contact between Cretaceous trachyandesite to the north and Triassic or Jurassic silicic volcanics to the south (fig. 4). Lipman and Hagstrum (1992) suggested that part of the thick pile of Triassic or Jurassic silicic volcanic rocks in the Patagonia Mountains may be caldera fill on the basis of Simons' (1972) description of these rocks. Simons described sections of rhyolite, tuff, and welded tuff several thousand feet thick that contain blocks of sandstone, quartzite, and Paleozoic limestone breccia as much as half a mile long. The larger blocks are shown on Simons' map (1974). (0.4)

82.8 Contact between silicic volcanic rocks on the north and a large block of brecciated Paleozoic limestone on the south (fig. 4). The approximate contact can be traced up the hill to the east for about 0.4 mi, but is nowhere exposed. The lack of exposure of the tuff-limestone contact may indicate that the tuff is not welded adjacent to the limestone. This tends to support the possibility that the limestone block is part of a caldera-fill megabreccia because the megabreccia blocks that collapse into intra-caldera tuff are cold and, thus, prevent the adjacent tuff from welding (Kenneth Hon, U.S. Geological Survey, oral commun., 1992). (0.1)

82.9 Southern contact of the brecciated limestone block and silicic volcanics. (0.1)

83.0 We are now in the Patagonia district, which takes in the southern part of the Patagonia Mountains on down to the international border (fig. 3). (See Schrader (1915) and Tenney (1929) for descriptions of the Patagonia district; app. 8, 9.) Schrader reported that Mowry, Washington, and Duquesne were good sized settlements in the district with telephone lines, and daily stage and mail service. Both Mowry and Washington had concentrating mills and smelters.

The field trip route is through the eastern part of the Patagonia district (fig. 4). The rocks here consist of an eastern belt that includes exposures of Precambrian crystalline rocks overlain by Cambrian sedimentary rocks south of the Mowry mine; Paleozoic carbonate and clastic rocks; Triassic or Jurassic silicic volcanic rocks, plugs, and dikes; and the Lower Cretaceous Bisbee Formation. The Harshaw Creek fault cuts diagonally through the eastern belt.

The western belt is a large intrusive body of biotite-hornblende granodiorite composition dated at 58 Ma (Simons, 1974; Drewes, 1980). A small stock of porphyritic biotite granodiorite was emplaced probably at the same time in the vicinity of Washington Camp.

The mineral deposits of the Patagonia district are mostly silver and lead with some copper and occur as veins and as contact metamorphic deposits. Some of the mineral deposits are spatially and probably genetically related to the granodiorite intrusives. Others, however, farther removed from the Tertiary intrusive contacts may be genetically related to the volcanism and hydrothermal systems associated with the proposed Triassic or Jurassic caldera. (0.1)

83.1 A German named Herman Bender was murdered near here in the early 1940's by his two companions as they were returning from an evening of drinking. The murderers threw his body down the shaft of the Blue Nose Mine about a quarter of a mile up the hill to the right (Robert Lenon, oral commun., 1992).

Cross Harshaw Creek fault (fig. 4). We will be traveling over exposures of the Bisbee Group for the next 1.9 mi. Simons (1972) described the Bisbee here as siltstone and mudstone with intercalations of limestone, sandstone, epiclastic volcanic sandstone and siltstone, and conglomerate. He estimated that the total thickness is more than 3,000 ft and noted that the Bisbee in the Patagonia Mountains contains considerably more volcanic material than elsewhere, chiefly in the form of reworked volcanic ash in the matrix of the clastic rocks. (1.2)

84.2 The Morning Glory Mine, which is about 0.5 mi up the small valley on the right, produced high-sulfide silver-copper-zinc ore. During the rainy season, sulfate-rich water from the mine flows down the valley and mixes with the stream on the left side of the road, which drains carbonate bedrock on the ridge to the east. At the confluence of the two streams, a soapy gray-white precipitate forms and white froth is rafted along the stream surface (Robert Lenon, oral commun., 1992). X-ray diffraction analysis confirms Lenon's suggestion that the precipitate and froth are gypsum. (0.7)

84.8 Guajolote (turkey) Flat Road to the right. The flat was named for the Guajolote mine, located in 1880. Continue straight on Harshaw Road. (0.7)

85.5 Take the Mowry Road (FR 214) to the left. Go about 0.1 mi, turn left, and park alongside the road to the mine.

STOP 4A MOWRY TOWN SITE AND MINE

Leaders: Robert Lenon, Mining Engineer, Ret. and Spencer Titley, Dept. of Geosciences, U. of A.

The town site is near the junction of the mine road with the road we turned in on. The superintendent's house and the store were on the low ridge southwest of the junction; the school, rooming house, office, and caretakers house were northeast of the junction. The location of the cemetery is not known. It may have been on a low hill to the south about halfway between the mine and the smelter (Robert Lenon, oral commun., 1992).

Notice that most of the oak trees are fairly small and all are about the same size. The original oaks were probably cut down to make charcoal for the smelter, and thus most of the present trees are second growth.

The Mowry Mine, first called the Corral Viejo Mine, was known to the Jesuits and was worked by Mexicans in the early 1850's. It was relocated by a Mexican herder and prospector in 1858 who sold it to some officers at Fort Buchanan for a pony and other miscellaneous items. The officers named the property the Patagonia mine for reasons that are not known. The mine was bought by Sylvester Mowry in 1859 after he resigned his commission as a first lieutenant at Fort Buchanan. Mowry is reported to have purchased the mine for $25,000 and to have put about $175,000 into subsequent improvements and equipment. Mowry operated the mine for about three and one-half years, employed 120 men, and shipped about $1,500,000 of ore to San Francisco, London, and Europe through Guaymas, Mexico (Schrader, 1915; Greeley, 1987).

On the orders of Colonel James H. Carleton, Mowry was arrested and his mine confiscated in June, 1862 based on the charge of being a Confederate sympathizer and having sold percussion caps to the Rebel army. He was found guilty of aiding and abetting the enemy by a military board of inquiry and was ordered to be confined at Fort Yuma. Mowry was acquitted of the charges against him, and released from Fort Yuma in November, 1862 but in the meantime, the government receiver for the mines had made the property unworkable by extensive and deliberate damage to the equipment (Granger, 1960). In December, 1862 Mowry filed damage claims of more than $1 million against Carleton and others, and tried to get the Federal Government to relinquish his property. His mine was sold at public auction in July, 1864 for only $2,000. Although Mowry was eventually awarded $40,000 in 1868, it was inadequate to reopen the mine and he died in 1871 while in London trying to raise capital (Wagoner, 1975).

Because of Apache raids prior to 1872 and the inaccessibility of the area until the railroad to Patagonia was completed in 1883, there was little production from any of the mines in the Patagonia Mountains between 1864 and 1883. The coming of the railroad was not a great stimulus for the Mowry Mine, however, because it was 14 mi from the connection. The Mowry passed through a number of hands and was intermittently worked between 1890 and 1907. In 1918, the workings above the water level were reopened and developed. Small shipments of both new ore and ore from old stope fills were made until the working shaft caved in 1928 (Tenney, 1929).

Return to the Harshaw Road and continue to the south. (0.7)

86.2 Park alongside the road.

STOP 4B MOWRY SMELTER SITE
Leader: Robert Lenon, Mining Engineer, Ret.

This was the site of the smelter for the Mowry mine and of a village named Commission. There were reported to be fifteen houses here in 1864 (Granger, 1960).

Return to vehicles and continue south on Harshaw Road. (0.3)

86.5 Along the creek on the left side of the road there was a placer mining camp. Note the disturbed gravel indicative of placer workings (Robert Lennon, oral commun., 1992). (2.7)

89.2 The mountain to the right with the light gray carbonate outcrop at the top was given the name Caloso in the Spanish land grant surveys of the San Rafael Valley (Robert Lennon, oral commun., 1992). (0.2)

89.4 Junction with road to Nogales. Continue straight on FR 61. (0.4)

89.8 Site of Washington Camp. The Spanish had worked the mineralized deposits of this area for silver prior to the Mexican War of Independence in 1828, but there was virtually no more activity until after 1872 when the first peace was made with the Apaches. The history of ownership and production for the properties around Washington Camp and Duquesne was discussed by Schrader (1915) and Tenney (1929) (app. 8, 9). It is quite an involved history and includes such well known names as Wilfley and the Westinghouse Electric Company.

Around 1890 the Duquesne Mining and Reduction Company of Pittsburgh, Pennsylvania came into the area and began acquiring properties, developing mines, and building various processing facilities. Washington Camp and Duquesne are less than a mile apart; the reduction plant was at Washington Camp and the company headquarters was at Duquesne. Each town had a population of about 1,000. Both towns have been ghosts since the 1950's, although there was a store here as late as the 1940's.

The present residents of the community are chiefly retired people. The green stucco house on the left was the site of the Wonder Bar until about 1980 (Mara Grodzicki, local resident, oral commun. 1992). (0.3)

90.1 Take the Duquesne Road (FR 128) to the right. As you drive up the hill, the A-frame house that can be seen in the valley on the left is near the site of the former Duquesne school. Much of the patented land of the Washington Camp-Duquesne mining area is presently for sale as a single package; it totals 991 acres and is being advertised as a great place for a resort. Perhaps it could be developed as a resort for retired economic geologists and mining engineers. (0.5)

90.6 Bonanza Mine. The ore was taken from the mine to the Washington Camp smelter by an aerial tramway about a mile long. Ore was dumped from the ore buckets into the chutes, then into the smelter. (0.2)

90.8 Duquesne town site. Park along side the road.

STOP 5 DUQUESNE TOWNSITE
Leader: Robert Lenon, Mining Engineer, Ret.

The mine superintendent's house is off the road on the right. Some of the adobe buildings on the left were offices during exploration drilling for the Bonanza Mine in the 1960's. The green frame building on the right was the boarding house.

The following brief description of the geology and mineralization of the Washington Camp-Duquesne area is modified from Simons (1974). An elongate northwest-trending body of biotite-hornblende granodiorite (Tg, fig. 4) was emplaced in early Tertiary time in the southern Patagonia Mountains. The southernmost 7 miles or so of the northeast contact is believed to mark approximately the former trace of the Guajolote fault. A related small stock of porphyritic biotite granodiorite (Tpg, fig. 4) was emplaced in the Washington Camp area. Along the northeast contact of the biotite-hornblende granodiorite, Mesozoic volcanic and sedimentary rocks were hornfelsed and Paleozoic carbonate rocks converted to garnetite, tactite, and marble. Mineralization at Washington Camp and Duquesne is spatially and probably genetically related to the granodiorite bodies.

Return to vehicles and continue on to the southeast. (0.1)

90.9 Foundation for scales on right. The side road to the right goes to the Holland and Empire Mines. (1.1)

92.0 Junction of Duquesne Road (FR 128) and road to Lochiel (FR 61). Turn right toward Lochiel. (3.8)

95.8 The Fray Marcos de Niza monument on the right was constructed by the CCC during the 1930's. The inscription reads: "By this valley of San Rafael Fray Marcos de Niza, vice-commissary of the Franciscan order and delegate of the Viceroy in Mexico, entered Arizona, the first European west of the Rockies, April 12, 1539." (1.3)

97.1 In Lochiel, turn left on FR 61. Lochiel was the name given to the post office here in 1884 by Colin Cameron, one of the owners of the San Rafael Land Grant. The name comes from the Cameron family's ancestral home in Scotland. The Camerons were a prominent Pennsylvania family; Colin Cameron's uncle, Simon Cameron, was Secretary of War under Lincoln.

The earlier name of the settlement here was La Noria (the well) and the Mexican-Americans of the area still use that name (Granger, 1960). (1.4)

98.5 T-junction; turn right. The Cameron House is in view 0.4 mi north of this junction. The architectural style of the house is Louisiana French. Its similarity to Old Main on the University of Arizona campus is obvious. (1.7)

100.2 Cross the Santa Cruz River (note that the river flows south here). (2.6)

102.8 T-junction on the west side of Parker Canyon; turn right. (5.1)

107.9 Pass Bercich Ranch on the east side of Bodie Canyon. (1.8)

109.7 Road junction; turn right. The site of a mining camp called Sunnyside is 6.8

mi to the northeast in Sunnyside Canyon at the base of the Huachuca Mountains. Sunnyside was unique among mining camps in that its residents were members of a Utopian religious colony called Donnellites after their leader, Samuel Donnelly. The colony was established at the Copper Glance Mine in 1887. The men worked in the mine and the women ran the community kitchen. Each family had their own cabin, but all the money was pooled for communal use. There was a prayer meeting each evening. The community prospered until the late 1890's when Donnelly died; shortly after that the mines played out and the colony was forced to disband (Sherman and Sherman, 1969). (0.7)

110.4 Cross Santa Cruz-Cochise County line. (4.7)

115.1 Junction with Lone Mountain Ranch Road to the right; continue straight. (0.2)

115.3 T-junction; go right on FR 61 to Coronado National Memorial. (0.8)

116.1 Exposures of the Morita Formation (Lower Cretaceous Bisbee Group) on the west side of Sycamore Canyon. (2.0)

118.1 Exposures of the Glance Conglomerate (Lower Cretaceous, Bisbee Group) at Bear Creek. (6.3)

124.4 Montezuma Pass in Coronado National Memorial. Park vehicles in parking lot at the pass.

STOP 6 MONTEZUMA PASS OVERVIEW AND GLANCE CONGLOMERATE

Leader: Kenneth Hon, U.S. Geological Survey, Denver

At this stop Ken Hon will give a regional overview of the southern Huachuca Mountains and present evidence, based on new geologic mapping, for the Jurassic Montezuma caldera proposed by Lipman and Hagstrum (1992). Also, the Glance Conglomerate at this locality contains abundant clasts of various Mesozoic volcanic rocks that are no longer present in the region. Ken will discuss the implication that there has been major uplift and erosion here, beginning in the Early Cretaceous.

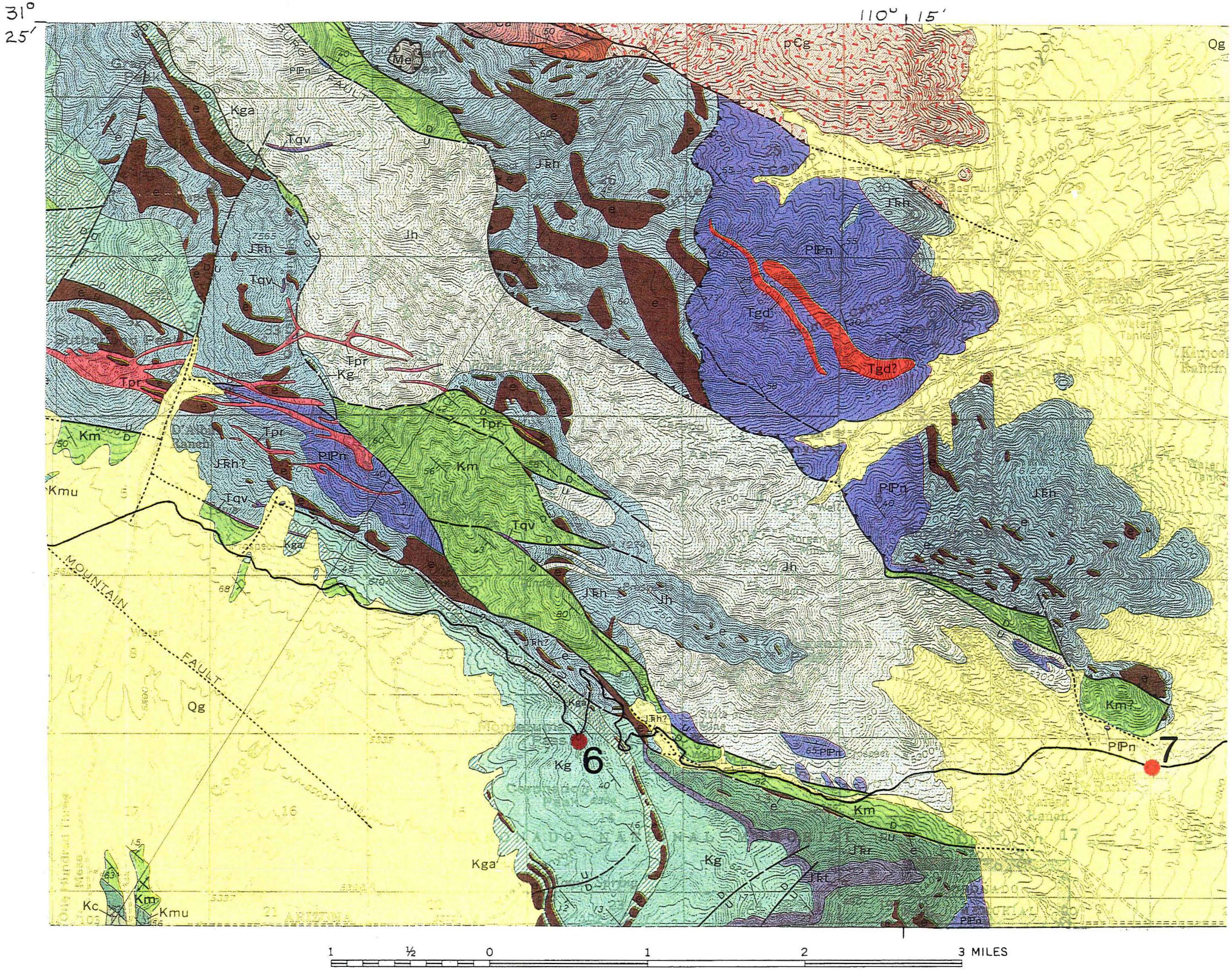
Figure 5 is a geologic map of the Montezuma Pass area of the southern Huachuca Mountains showing the field trip route and stops (Hayes and Raup, 1968). The paper on Jurassic calderas in southeastern Arizona by Lipman and Hagstrum (1992) is in appendix 6. The following is an excerpt from that paper that pertains to the Montezuma caldera:

> "... dacitic welded tuff of intracaldera character ... is as much as 1,400 m thick (with no base exposed) in Montezuma Canyon and adjacent parts of the southern Huachuca Mountains, where it constitutes matrix surrounding huge slide blocks of Paleozoic carbonate. Mappable carbonate masses are as long as 2 km (some of these are composite aggregates of multiple blocks), and many more sedimentary clasts are too small to map."
>
> "The intracaldera dacite tuff is exposed over an elliptical area of 8 x 16 km, elongate northwest and dipping outward from an axial pluton

Figure 5.--Geologic map of the southern Huachuca Mountains in the vicinity of Montezuma Pass (from Hayes and Raup, 1968) showing field trip stops 6 and 7. Scale is 1:48,000. Contour interval is 50 ft in the western part of the map and 25 ft in the eastern part.

List of map units

Qg	Pediment, terrace, and fan gravels, Quaternary
Tpr	Porphyritic rhyolite, Tertiary
Tqv	Quartz veins, Tertiary
Tgd	Microgranodiorite, Tertiary
Bisbee Group, Lower Cretaceous	
Km	Morita Formation
Kg	Glance Conglomerate
Kgg	andesitic lava
e	exotic blocks of Paleozoic sedimentary rocks
Jh	Huachuca Quartz Monzonite, Jurassic
J₮h	Silicic volcanics of Huachuca Mountains, Jurassic and Triassic
e	exotic blocks of Paleozoic sedimentary rocks
Canelo Hills volcanics, Jurassic and Triassic	
J₮t	Rhyolite welded tuff
J₮r	Rhyolite lava
e	exotic blocks of Paleozoic sedimentary rocks
PPn	Naco Group, Permian and Pennsylvanian
Me	Escabrosa Limestone, Mississippian
p€g	Granite, Precambrian


31°
25′
110° 15′
pCg
Qg
Me
FAULT
Kga
Tqv
JTRh
Jh
PIPn
Tgd
Tgd?
Tpr
Kg
Km
Kmu
Km?
MOUNTAIN
FAULT
Qg
6
7
Kga
TRr
TRt
Kc
1 ½ 0 1 2 3 MILES

(Huachuca Quartz Monzonite, dated by K-Ar at 168 Ma; Drewes, 1980). The geometry suggests a deeply eroded caldera resurgent dome, complexly modified by later regional folding and thrusting. A mapped thrust fault between the intrusion and tuff to the northeast (Hayes and Raup, 1968) cannot be a major regional structure, because the same intracaldera tuff is present on both sides of the fault, and the tuff in the mapped hanging-wall block is hornfelsed by the pluton in the footwall. Irregular skarn mineralization is localized along contacts between the Huachuca pluton and carbonate megablocks within the intracaldera tuff."

Return to the vehicles and continue on down the east side of Montezuma Pass. (2.2)

126.6 Pavement begins. The State of Texas Mine is about 0.25 mi north of the road here. (1.3)

127.9 Coronado National Memorial visitors center. (1.7)

129.6 Park vehicles along side of the road.

STOP 7 BOB THOMPSON PEAK CALDERA COLLAPSE BRECCIA
Leader: Kenneth Hon, U.S. Geological Survey, Denver

From this point large exotic breccia blocks can be seen on the side of Bob Thompson Peak that are inferred to be caldera collapse breccia surrounded by intracaldera tuff. The entire sequence was thrust to the southwest up over the late Jurassic Huachuca Quartz Monzonite, inferred to be the caldera resurgent dome (Lipman and Hagstrum, 1992).

Return to the vehicles and continue to the east. (1.0)

130.6 Road makes a right-angle turn to the left. (2.0)

132.6 Junction of Coronado Memorial Road with Rt. 92. Turn right on Rt. 92 toward Bisbee. (15.8)

148.4 Town of Don Luis; continue on toward Bisbee. (2.5)

150.9 Junction of Rt. 92 with Rt. 80 at traffic circle between Bisbee and Warren.

END OF DAY 1

DAY 2

Mileage Comments

0.0 Meet Sunday morning at the overlook area at the Lavender Pit.

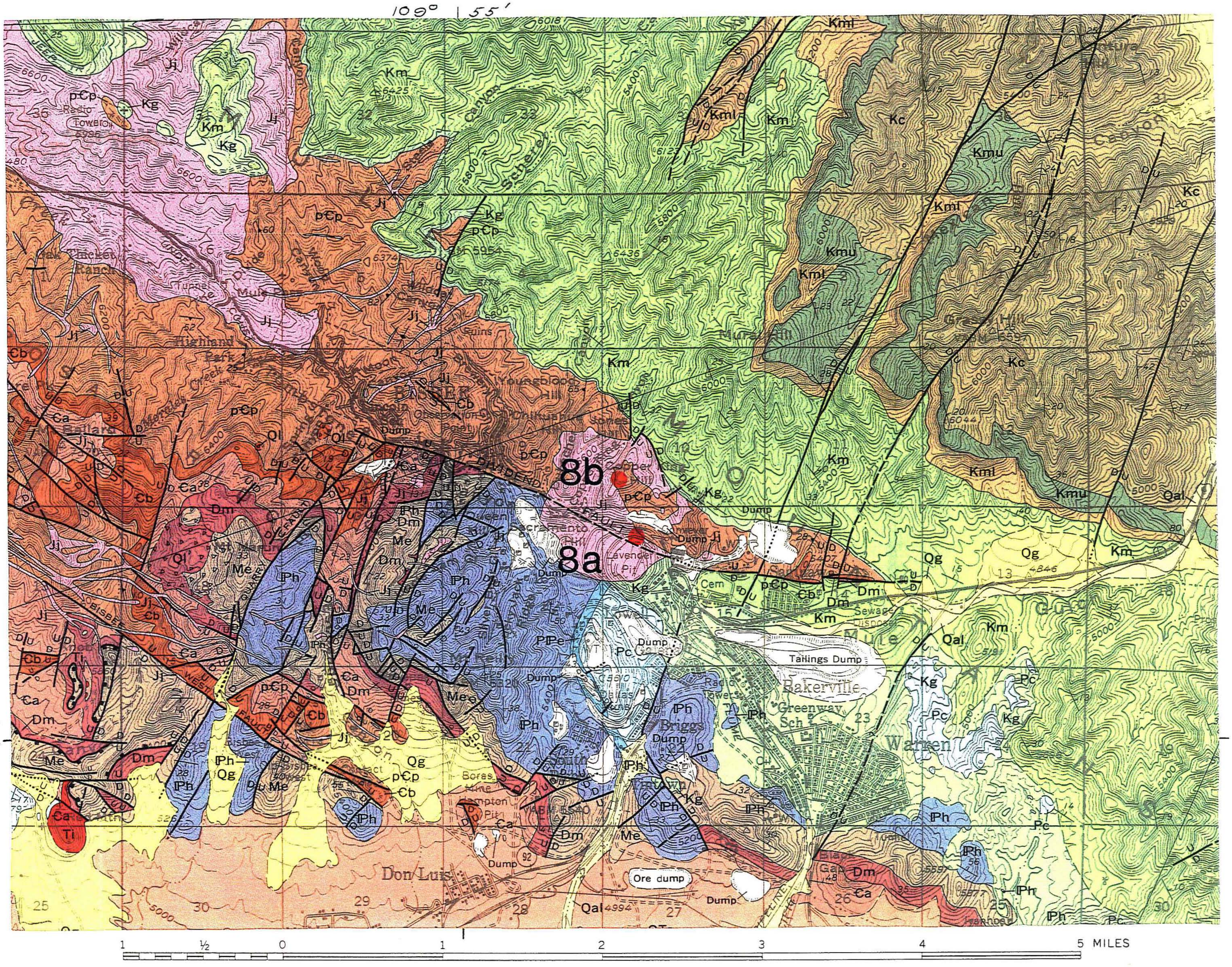
STOPS 8A AND 8B LAVENDER PIT AND COCHISE
Leader: Steve Eady, Phelps Dodge Mining Co.

After a discussion of the Lavender Pit by Steve Eady, we will car pool (leaving low-clearance vehicles at the overlook) and drive to the top of the

Figure 6.--Geologic map of the southern Mule Mountains in the vicintiy of Bisbee (from Hayes and Landis, 1964) showing field trip stops 8a and 8b. Scale is 1:48,000. Countour interval is 40 ft.

List of map units

Qal	Alluvium, Quaternary
Qg	Pediment, terrace, and fan gravels, Quaternary
QTs	Valley fill, Quaternary and Tertiary
Ti	Intrusive quartz latite porphyry, Tertiary
Bisbee Group, Lower Cretaceous	
Kc	Cintura Formation
Kmu	Mural Limestone, upper member
Kml	Mural Limestone, lower member
Km	Morita Formation
Kg	Glance Conglomerate
Jj	Juniper Flat Granite, Jurassic
Naco Group, Permian and Pennsylvanian	
Pc	Colina Limestone
PꝒe	Earp Formation
Ꝓh	Horquilla Limestone
Me	Escabrosa Limestone, MIssissippian
Dm	Martin Limestone, Devonian
Ꞓa	Abrigo Limestone, Cambrian
Ꞓb	Bolsa Quartzite, Cambrian
pꞒp	Pinal Schist, Precambrian



109° 55'
31° 25'
8a
8b
Don Luis
Bakerville
Warren
Greenway Sch
Tailings Dump
Ore dump
Dump
Lavender Pit
Sacramento Hill
Briggs
Mule
Highland Park
Km
Kc
Kmu
Kml
Kg
Qg
Qal
pCp
Jj
Cb
Ca
Dm
Me
IPh
Pc
Ti
1
½
0
1
2
3
4
5 MILES

hill on the other side of Rt. 80 directly north of the Lavender Pit. There Steve Eady will describe the Phelps Dodge Company's Cochise Project.

The Lavender Pit of the Phelps Dodge Mining Company, named for Harrison M. Lavender, was formally dedicated August 7, 1954. Tuck (1957) gave an overview of the initial phases and plans for the development of the Lavender Pit. Tuck's paper reflects the optimism that prevailed in the mid-to late fifties toward the mining industry and industrial growth in general. Appendixes 2 and 3 are two papers by Graeme on Bisbee. His 1981 paper covered all aspects of the history, mining, and geology of Bisbee whereas his 1987 paper gave the history of the first 50 years of mining in Bisbee.

The geology of the Bisbee area and the southern Mule Mountains (Hayes and Landis, 1964) is shown on figure 6. The southern Mule Mountains consist of Precambrian Pinal Schist, overlain by 5,500 to 6,500 feet of Paleozoic chiefly carbonate sedimentary rocks. The schist and Paleozoic rocks were intruded during the Jurassic by the Juniper Flat Granite, a porphyritic leucocratic alkali granite. Mineralization was associated with the Jurassic intrusions. A period of erosion was followed by deposition of about 5,000 ft of largely clastic sediments of the Early Cretaceous Bisbee Group. At a later time, the rocks were tilted about 30 to the northeast. Subsequent erosion resulted in the present map pattern of Bisbee Group rocks on the northeast side of the range and the older rocks on the southwest side. The two periods of erosion produced supergene enrichment of the mineralized zones.

Ore was first discovered in Mule Gulch in 1877 in what was to become Bisbee. The Bisbee (or Warren) district is chiefly a copper district. Mineralization is present in limestone replacement deposits and porphyry copper deposits. Through 1981 the district produced nearly 8 billion pounds of copper, 324 million pounds of lead, 355 million pounds of zinc, 28 million pounds of manganese, 2,792,000 ounces of gold, and 102,215,000 ounces of silver (Graeme, 1987).

Much of the mining history of Bisbee is the history of the Phelps Dodge Mining Company. This history is well covered in the two papers by Graeme (1981, 1987) in the appendix.

0.0 Return to the Lavender Pit overlook and proceed east on Rt. 80. (0.7)

0.7 Enter traffic circle; stay on Rt. 80. (1.8)

2.5 Warren Road goes to the right; continue on Rt. 80.
The town of Warren was named for George Warren who was grubstaked by John Dunn in 1877 to work on his claim in Mule Gulch and to locate new claims. (1.3)

3.8 Sediments of the Lower Cretaceous Bisbee Group crop out along the road and on the hillsides for the next mile, dipping generally to the northeast at moderate angles. The oldest unit exposed is the 2,600-ft-thick Morita Formation, which consists chiefly of mudstone and feldspathic sandstone. The Morita is overlain by the Mural Limestone. The lower part of the Mural is made up of calcareous sandstone and impure limestone about

400 ft thick; the upper part is about 250 ft of thick-bedded limestone. The Cintura Formation overlying the Mural Limestone, is composed of mudstone and feldspathic sandstone much like the Morita Formation. The Cintura is as much as 1,830 ft thick. (1.4)

5.2 Turn left onto the road to Double Adobe, McNeal, and Elfrida. (4.8)

10.0 Road to the left; continue straight. (3.0)

13.0 At Double Adobe, turn left (north) on Central Highway to Elfrida. The community of Double Adobe listed by Granger (1960) seems to be 6.5 mi west of and about 350 ft higher in elevation than the present Double Adobe. Granger reported that the name came from a two room adobe building with 18-inch-thick walls having several gun openings. (9.0)

22.0 Junction with Davis Road; continue north on Central Highway to Elfrida. (6.0)

28.0 Junction of Central Highway with Rt. 666 in Elfrida; go north on 666. A local land owner, G. I. Van Meter, donated the right of way across his land to the railroad and asked that the station here be named for his mother. Thus, the name Elfrida is Danish in origin, not Spanish (Granger, 1960). (1.3)

29.3 Turn left (west) on the Gleeson Road. (7.0)

36.3 Pavement ends. (0.6)

36.9 Courtland Road goes to the right; continue straight. (1.2)

38.1 Former town site of Gleeson. Park alongside of the road.

STOP 9 GLEESON TOWN SITE

Gleeson was named for John Gleeson, an Irishman who, along with his wife, came to Arizona in the 1890's by way of Iowa and Colorado. They lived in Pearce where he worked as a miner and she ran a boarding house. In 1896 Gleeson found a significant copper deposit in the area of silver-lead deposits around Turquoise camp south of Pearce. He organized the Copper Belle Mining Company in 1898. Around 1900 Turquoise was moved to a lower elevation to get a better supply of water, and the new camp was named Gleeson. About 500 or more people lived in Gleeson when much of the town was destroyed by fire in 1912. Twenty-eight buildings burned to the ground, but the town was rebuilt. Production from the mines continued until about 1930. After that, the population declined and the Gleeson post office was closed in 1939 (Tenney, 1929; Granger, 1960, Sherman and Sherman, 1969).

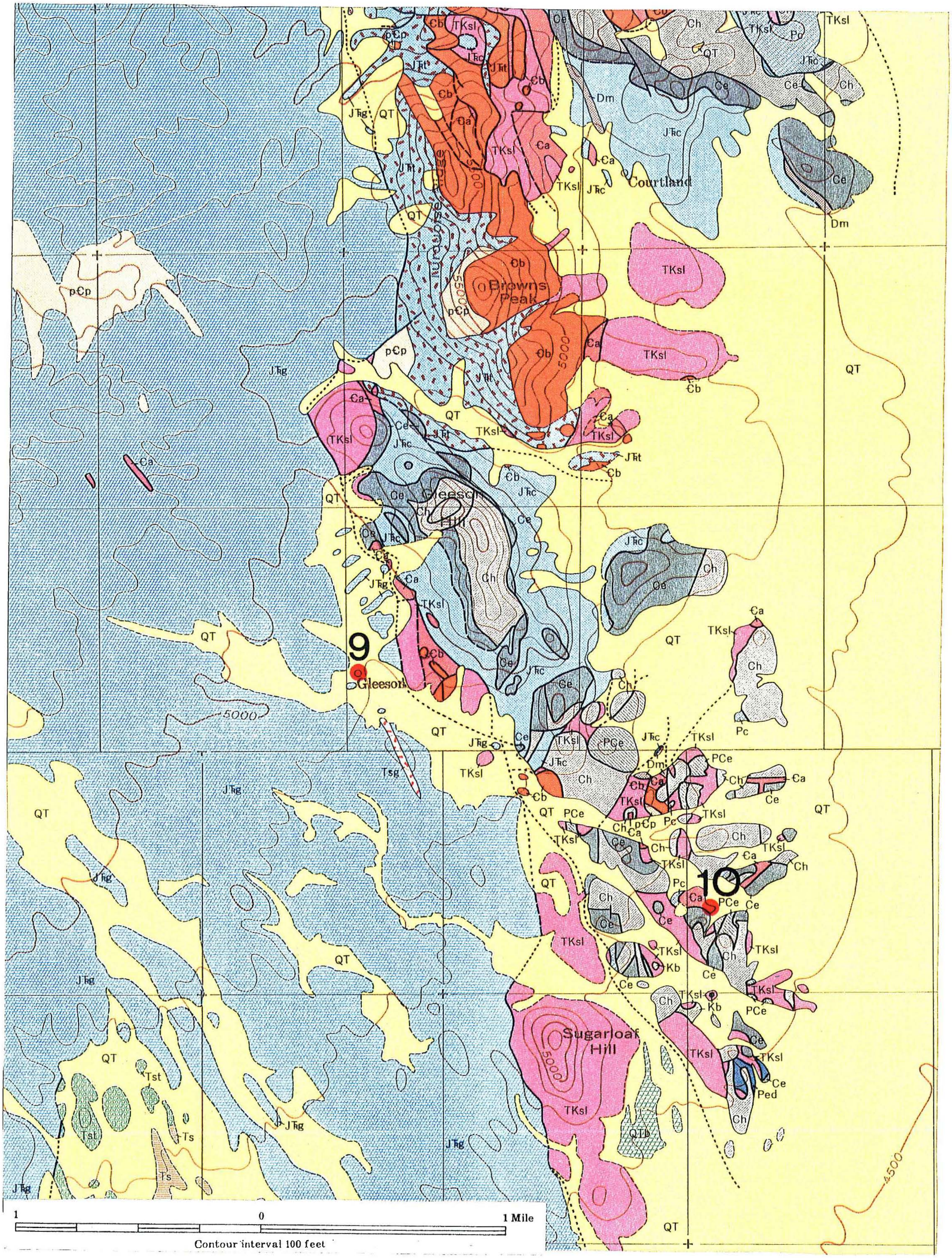
The history of mining in the Courtland-Gleeson district was given by Tenney (1929) (app. 9). Lead-silver deposits were mined in the district first, followed by copper in the late 1890's. The deposits are limestone replacement types contained in megablocks of Paleozoic carbonate rocks that border the eastern side of the 181-178 Ma (Drewes, 1980) Gleeson Quartz Monzonite (fig. 7) (Gilluly, 1956).

Return to the cars and go back east to the Courtland Road junction. (1.2)

Figure 7.--Geologic map of the southern Dragoon Mountains in the vicinity of Courtland and Gleeson (from Gilluly, 1956) showing field trip stops 9 and 10. Scale is 1:31,250.

List of map units

QT	Alluvium, Quaternary and Tertiary
Tsg	Stronghold Granite and related dikes, Tertiary
Sugarloaf Quartz Latite, Tertiary and Cretaceous	
TKsa	andesitic member
TKsl	quartz latite member
Kb	Bisbee Group, Lower Cretaceous
JTRg	Gleeson Quartz Monzonite, Jurassic or Triassic
JTRc	Copper Belle Monzonite Porphyry, Jurassic or Triassic
JTRt	Turquoise Granite, Jurassic or Triassic
Naco Group, Permian and Pennsylvanian (Carboniferous)	
Ped	Epitaph Dolomite
Pc	Colina Limestone
PIPe	Earp Formation
Ch	Horquilla Limestone
Ce	Escabrosa Limestone, Pennsylvanian (Carboniferous)
Dm	Martin Limestone, Devonian
Єa	Abrigo Limestone, Cambrian
Єb	Bolsa Quartzite, Cambrian
pЄp	Pinal Schist, Precambrian


Courtland
Browns Peak
Gleeson Hill
9
Gleeson
10
Sugarloaf Hill
5000
4500
1 0 1 Mile
Contour interval 100 feet

39.3 Continue on to the east about 0.6 mi past the Courtland Road. (0.6)
39.9 Park along side of the road northeast of Sugarloaf Hill.

STOP 10 EVIDENCE FOR DRAGOON CALDERA
Leader: Kenneth Hon, U.S. Geological Survey

The geology of the southern Dragoon Mountains is shown in figure 7 (Gilluly, 1956). The Gleeson Quartz Monzonite of Jurassic age (178-181 Ma; Drewes, 1980) is overlain on the east side of the range by megablocks of Paleozoic sedimentary rocks and minor Precambrian Pinal Schist. The contacts between the blocks and with the quartz monzonite were interpreted by Gilluly (1956) and Drewes (1980) as thrust faults and used as evidence for regional Laramide thrusting. Gilluly (1956, p. 134, 156) puzzled over some of the complex structural relationships between blocks and noted that the limestone blocks were mixed in with tuff; he interpreted the blocks as a thrust breccia zone.

In gully exposures south of the road, we will see large blocks of Paleozoic carbonate rocks engulfed by the Jurassic(?) tuff of Courtland. Lipman and Hagstrum (1992) described these exposures as follows: "Tuff is molded around irregular margins of shattered sedimentary blocks, and compacted-pumice foliation in the tuff locally dips steeply, reflecting the draping and squeezing between blocks. Sheared contacts and shearing internally within the tuff are rare; little evidence exists for significant tectonic disruption."

Figure 8, taken from Lipman and Hagstrum's paper (1992) shows geologic maps of the two different interpretations.

Return to cars and drive back west to the Courtland Road junction. (0.6)

40.5 Turn left (north) toward Courtland. (2.7)
43.2 "Y" junction; bear left toward Courtland. (1.0)
44.2 Former town site of Courtland, named for Courtland Young, one of the owners of the Great Western Mining Company. The company was organized by Courtland and his brother, W.J. Young, in 1900 after they bought a number of copper claims in the vicinity. Three other large mining companies (Copper Queen, Calumet and Arizona, and Leadville) began acquiring copper properties nearby and by February, 1909 Courtland was a boom town. At its peak, the town had a population of 2,000; there was a water system, telegraph service, a motion-picture theater, milk delivery, two newspapers, and branch lines of the El Paso & Southwestern and Southern Pacific Railroads. Courtland was a ghost town by 1942 when its post office was closed (Tenney, 1929; Granger, 1960; Sherman and Sherman, 1969).

One of the few buildings remaining is the jail. It's the adobe and stucco building with a facade on the right side of the road. The remains of a sidewalk are a little farther along on the left side of the road. The first jail was just an abandoned tunnel with a wooden door. In an

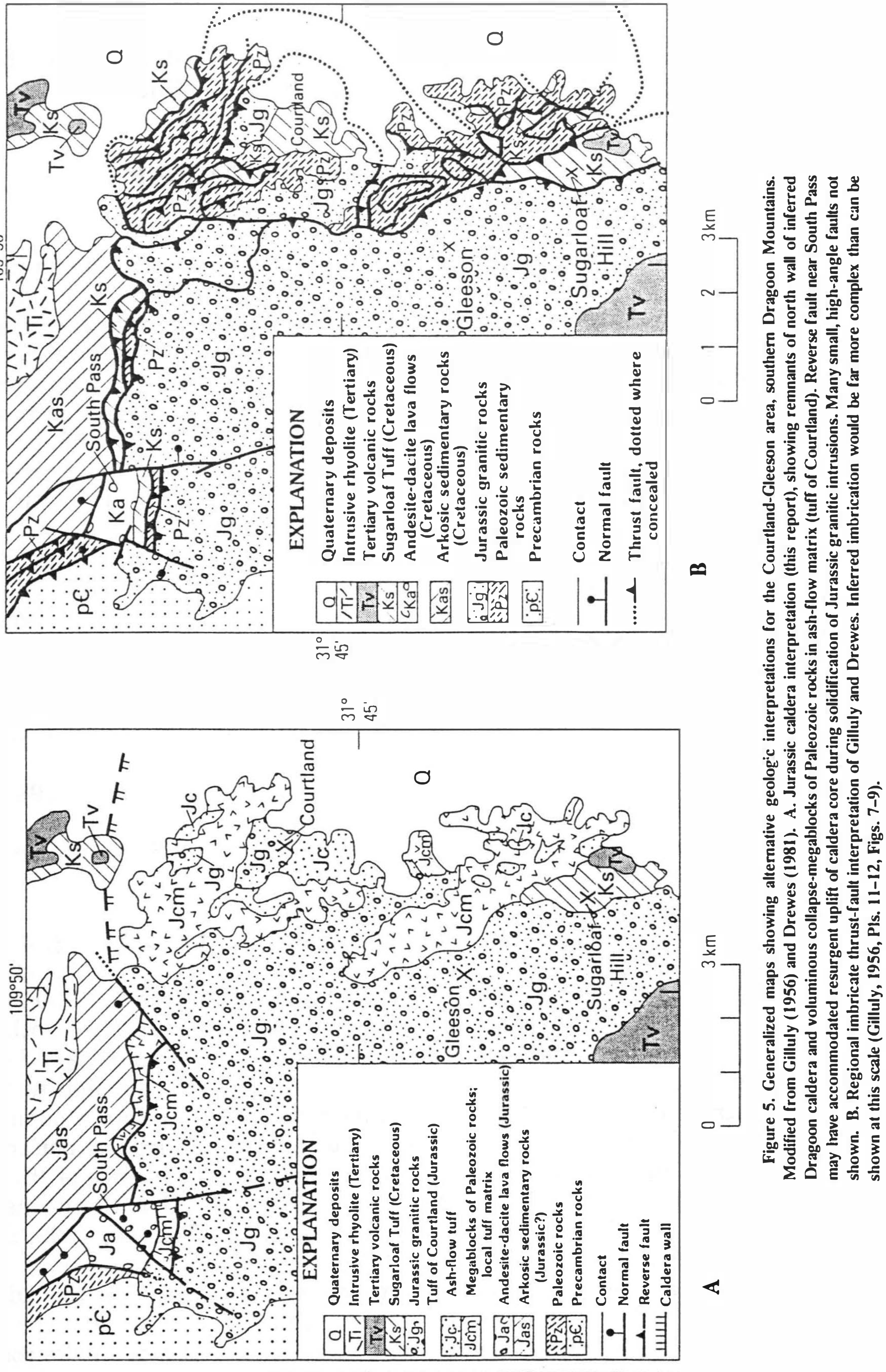


Figure 8.--Geologic maps showing alternative interpretations of the geology in the Courtland-Gleeson area (from Lipman and Hagstrum, 1992, fig. 5).

incident that helped convince Cochise County officials that a new jail was needed, a prisoner nearly asphixiated himself while trying to escape by burning the door down with his bedding (Sherman and Sherman, 1969). (5.0)

49.2 The bedrock highs exposed in the Sulphur Springs Valley to the east and north are part of the structural boundary between the central undrained subbasin (Willcox Playa) of the Sulphur Springs basin and the southern subbasin, which drains to the south. (4.3)

53.5 Commonwealth Mine on the right. The history of the Commonwealth Mine was given by Tenney (1929) and is included in the appendix. (0.2)

53.7 Town of Pearce and the old post office site. The town was named for John Pearce who discovered a rich deposit of silver and gold on a hill near here in 1895. Pearce and his wife had started out in Tombstone where he was a miner and she ran a boardinghouse. They saved enough money to buy a ranch in the Sulphur Springs Valley. According to Pearce, one day when he was driving cattle over the hill, he picked up a rock to throw at a recalcitrant cow. The rock seemed unusually heavy, so instead of throwing it at the cow, he put it in his pocket and had it assayed. The assay ran 2,100 ounces of silver a ton. Pearce went back to the hill with his brother where they located six claims. The Pearce brothers worked the richest part of the deposit for about half a year and then sold their claims for $250,000 cash to the Commonwealth Mining and Milling Company organized by John Brockman, D.M. Barringer, and R.A.F. Penrose, Jr. (Tenney, 1929; Granger, 1960).

By 1919 Pearce had nearly 1,500 residents and was the third most important town in Cochise County after Douglas and Willcox. The Commonwealth mine was closed in the thirties, however, and the population began the inevitable decline (Sherman and Sherman, 1969).

The sign on the old post office in Pearce reads as follows:

> "The Old Post Office was decommissioned in the late 1960's. During the hey day of the Commonwealth mine, it served 2,500 people. Although the interior remains intact, this property is now a private residence.
>
> Pearce saw its demise when the mine flooded, killing most of the miners. Their families left soon after, leaving behind all but their basic necessities. Until the 1970's, the townsite stood just as it had been abandoned decades before.
>
> Please do not disturb the residents of the Old Post Office." (1.1)

54.8 Junction with Rt. 666; take Rt. 666 to the left (north). (1.1)

55.9 Community of Sunsites; the Pearce post office has been moved here. Continue north on Rt. 666. (7.3)

63.2 Turn left (west) onto Dragoon Road. (6.5)

69.7 Dragoon Mountains on the south. (2.7)

72.4 Community of Dragoon; follow the road to the right across the railroad tracks. (0.1)

72.5 Turn right and drive north to the I-10 interchange at The Thing. (2.0)

74.5 Continue on across I-10. (0.4)
74.9 Bear right and drive north; the road curves to the left around the tailings. (1.8)
76.7 Park at the Arimetco facility.

STOP 11 JOHNSON CAMP AND ARIMETCO'S SOLVENT EXTRACTION ELECTROWINNING PLANT
Leader: John Peterson, Mine Geologist, Arimetco

Mining of the copper and zinc deposits on the eastern side of the Little Dragoons was carried out in a primitive way by Mexican miners before the Southern Pacific Railroad was finished in 1881. By the end of 1882, however, many claims had been patented in the area, including the Peabody, Republic, and Mammoth claims, which were to be among the major producers.

The first community was Russellville, the site of a small smelter built by the Russell Gold and Silver Mining Company of Philadelphia. The smelter was moved to the Peabody Mine in 1883 after a water line had been laid from Russellville to the mine. The new town site was named Johnson for the mining company's general manager.

The Peabody mine was closed in the 1880's and not reopened until 1899 when the Dragoon Mining Company purchased it. They employed as many as 200 Mexican miners and shipped between $250,000 and $1,000,000 of oxidized copper-silver ore until the company failed in 1903.

Activity in the district reached its peak during the years of World War I, particularly at the Republic Mine. Johnson had a population of about 1,000 and supported half a dozen businesses and a number of pool halls and boarding houses. When copper prices fell in 1920, all the mines were closed and there was almost no mining in the district until 1945. The town of Johnson became a ghost camp (Cooper and Silver, 1964).

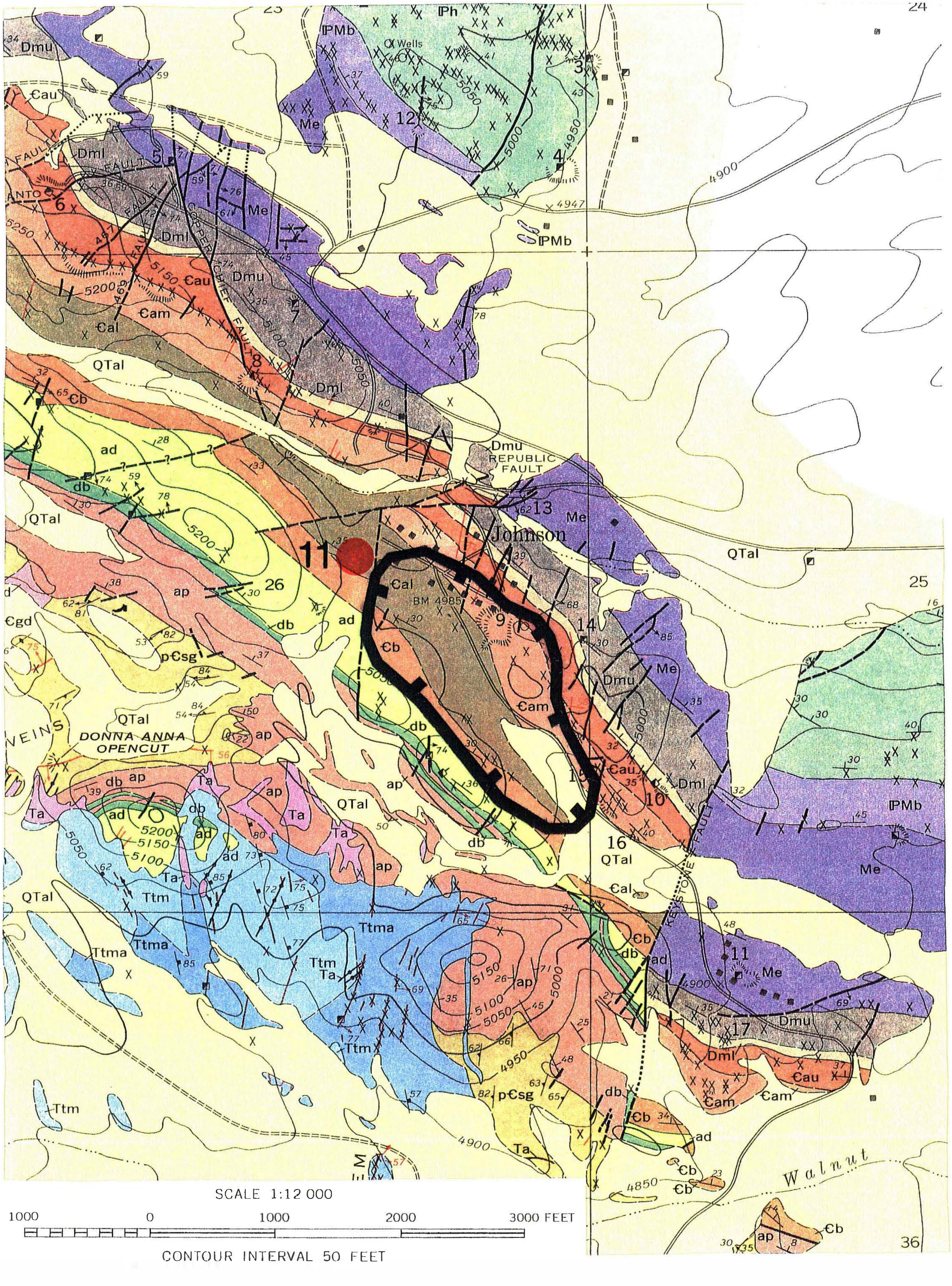
Johnson is in the Cochise mining district in the Little Dragoon Mountains. Figure 9 is a geologic map of the area (Cooper and Silver, 1964) showing the field trip stop. The history of the mining and description of the mines and prospects of the Johnson copper-zinc area by Cooper and Silver (1964) is in appendix 1. Cooper and Silver described the general features of the deposits around Johnson as follows:

> "The Dragoon quadrangle, which is the most productive part of the Cochise mining district, has yielded fairly large amounts of copper and zinc, moderate amounts of tungsten, and a little lead, silver, gold, and marble. The principal ore deposits are in and near the Texas Canyon Quartz Monzonite stock (50, 52 Ma; Drewes, 1980).
>
> Copper and zinc replacement deposits near Johnson had yielded, by the end of 1959, about 1,130,000 tons of ore with a value of about $25,600,000. These deposits are of the pyrometasomatic type. The ore minerals are sphalerite, chalcopyrite, and locally bornite. These

Figure 9.--Geologic map of the Johnson Camp area (from Cooper and Silver, 1964) showing field trip stop 11. Heavy black line is the approximate outline of the open pit.

List of map units

QTal	Alluvium, Quaternary and Tertiary
Ta	Aplite, Tertiary
Ttm	Texas Canyon Quartz Monzonite, Tertiary
Ttma	altered phase
Ph	Horquilla Limestone, Pennsylvanian
PMb	Black Prince Limestone, Pennsylvanian or Mississippian
Me	Escabrosa Limestone, Mississippian
Matrin Formation, Devonian	
Dmu	upper member
Dml	lower Member
Abrigo Formation, Cambrian	
€au	upper member
€am	middle member
€al	lower member
€b	Bolsa Quartzite
db	Diabase, Precambrian
Apache Group, Precambrian	
ad	Dripping Spring Quartzite including Barnes Conglomerate
ap	Pioneer Shale including Scanlon Conglomerate
p€gd	Johnny Lyon Granodiorite, Precambrian
p€sg	Pinal Schist, Precambrian


REPUBLIC FAULT
KEYSTONE FAULT
COPPER CHIEF FAULT
DONNA ANNA OPENCUT
Johnson
BM 4985
Walnut
QTal
Me
Dmu
Dml
Cau
Cam
Cal
Cb
ad
db
ap
pCsg
Ta
Ttm
Ttma
PMb
Ph
Wells
SCALE 1:12 000
1000 0 1000 2000 3000 FEET
CONTOUR INTERVAL 50 FEET

minerals, associated with some pyrite, a little scheelite, and traces of molybdenite have replaced beds of metamorphosed limestone of Paleozoic age near fissures and other structures that provided channels for mineralizing solutions. The principal ore bodies have the form of tabular masses and chimneys in the plane of the beds. More than 95 percent of the ore produced has come from such bodies in garnetite derived from the middle member of the Abrigo Formation."

Cyprus Minerals Company acquired the Johnson Camp property in 1975 and developed an open pit operation in the vicinity of the Republic Mine in about 1974. From 1975 to 1985 they produced 102 million pounds of copper. Arimetco bought the property from Cyprus in 1989.

Return to I-10. (2.2)

78.9 Go west on I-10 and return to Tucson. (63.5)

142.4 Total mileage.

END OF FIELD TRIP

ACKNOWLEDGMENTS

I have received invaluable assistance from many people in all stages of the planning and organization of this field trip. I thank Anna Domitrovic for her help in planning the route of the trip. I thank Richard Graeme for giving a talk and slide presentation on the history, geology, and mineralogy of Bisbee. F. N. Houser provided help with many aspects of the field trip. The trip would not have been possible without the seven leaders who volunteered their time and knowledge: Mary Farrell, Leslie Cox, Robert Lenon, Spencer Titley, Kenneth Hon, Steve Eady, and John Peterson. The road log was improved by reviews by Thelma Harms and F.N. Houser

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GEOLOGY OF THE GOLD PLACERS IN THE GREATERVILLE DISTRICT, ARIZONA

by

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INTRODUCTION

The Greaterville district, situated on the eastern flank of the Santa Rita Mountains (see fig. 1, road-log, this volume), was active from the early 1870's through the 1940's. Lode production of gold was by far surpassed by the placer activity which began in 1874 and peaked before 1890. Interest in the placers was revived in 1904, as described in the "Kentucky Camp" article (appendix 10, this volume). A synopsis of the literature on the Greaterville district placers was given by Johnson (1972, p. 35-37). She found accounts of the production ranged from $500,000 to $7 million for the value of gold recovered before 1900; the most recent activity was in 1948, when 535 ounces (oz) of gold (averaging 0.006 oz per cubic yard) were mined in Louisiana Gulch (fig. 1).

Purpose

In order to view the gold placer deposits in the Greaterville district in a modern context, they are presented here, for the first time since 1910, over present day topography (fig. 1) and geology (fig. 2). Accordingly, the possible gold sources are re-examined and the geologic processes that contributed to the accumulation of the gold placers are described.

Description of the lode deposits

Early accounts of the Greaterville district attribute the introduction and probable lode source of gold to the intrusion of light colored, chalky appearing, pyritiferous quartz latite porphyry. Indeed, prior to the 1874 discovery of the placers, early miners of the St. Louis Mine (the Morning Star Mine site (figs. 1 and 2)) and nearby workings recovered native gold and silver- and gold-bearing cerussite, as well as argentiferous galena and sphalerite, pyrite, chalcopyrite, and barite, from quartz-calcite veins in the intrusive mass and adjacent sedimentary rocks at Granite Mountain (Hill, 1910; Schrader, 1915; and Tenney, 1929).

According to Tenney (1929, p. 276-278), after the discovery of placers, the search for lodes was renewed. Work began at several localities (see Schrader, 1915, p. 153-158) including the Snyder (also known as the Anderson or Conglomerate) and the Mountain King (or Enzenberg) Mines (figs. 1 and 2). The ore mined at the Snyder Mine included gold, galena, cerussite, chalcopyrite, and "horn silver" (cerargyrite). Schrader (1915, p.154) described the ore as scattered through the brecciated and silicified contact zone between Paleozoic limestone and Precambrian granodiorite. Drewes (1971a), however, showed the Snyder mine on a fault contact between Precambrian

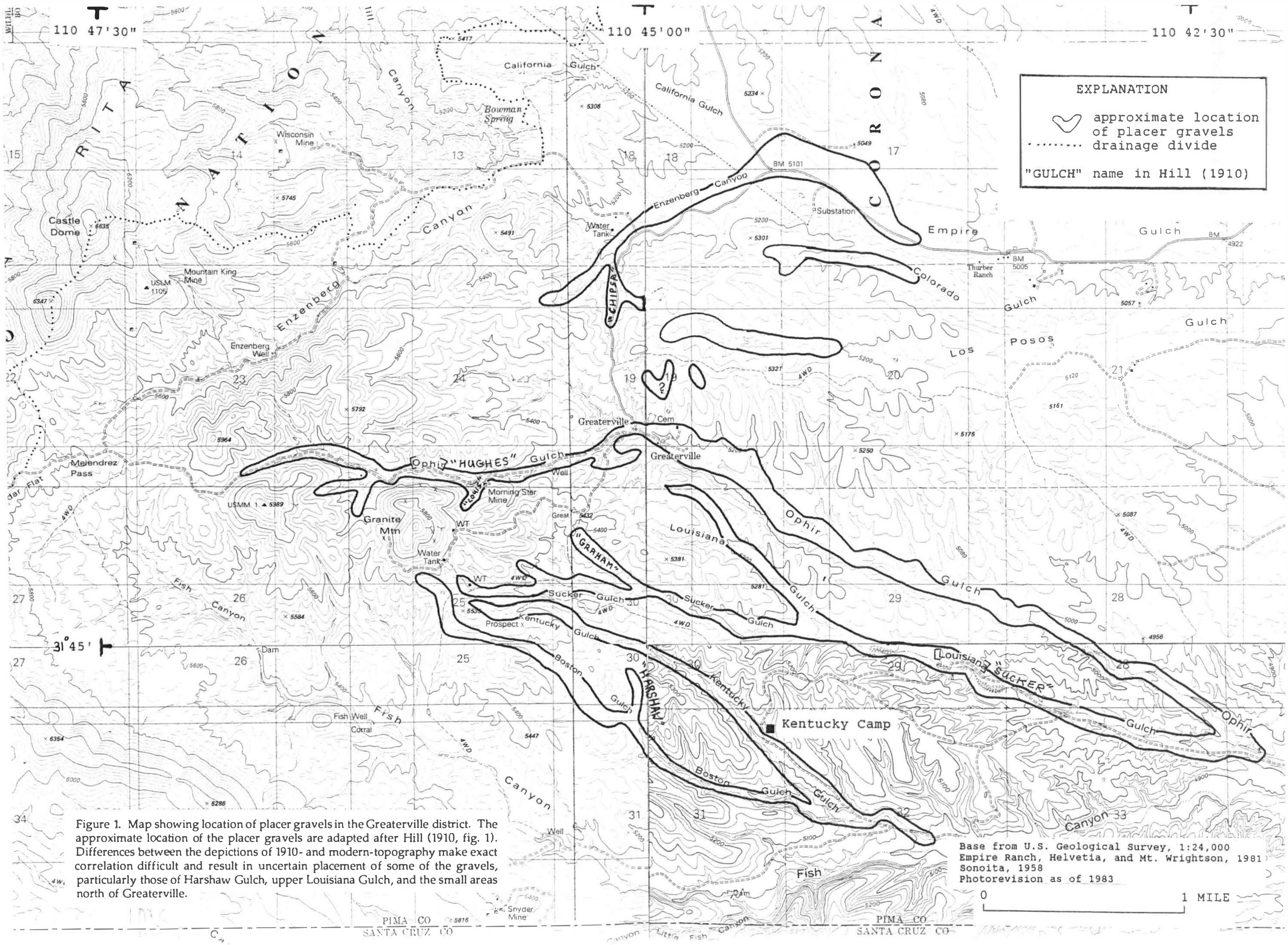


Figure 1. Map showing location of placer gravels in the Greaterville district. The approximate location of the placer gravels are adapted after Hill (1910, fig. 1). Differences between the depictions of 1910- and modern-topography make exact correlation difficult and result in uncertain placement of some of the gravels, particularly those of Harshaw Gulch, upper Louisiana Gulch, and the small areas north of Greaterville.

Figure 2. Map showing geology and location of placer gravels in the Greaterville district.

EXPLANATION

Qg — Gravel (Pleistocene)--terrace remnants

Placer gravel (Pleistocene)--after Hill (1910)

QTg — Gravel of upper (QTgu) and lower (Tgl) basin fill, undivided (Pleistocene to Miocene)

Tr — Rhyolite dikes (Oligocene)

Tp — Quartz latite porphyry stocks and dikes (Paleocene)

Kbt — Bisbee Group (Lower Cretaceous)--Turney Ranch Formation

Kbs — Bisbee Group (Lower Cretaceous)--Shellenberber Canyon Formation-present in Drewes' (1971a) structure section

Kba — Bisbee Group (Lower Cretaceous)--Apache Canyon Formation

Kbl — Bisbee Group (Lower Cretaceous)--Willow Canyon Formation and Glance Conglomerate, undivided

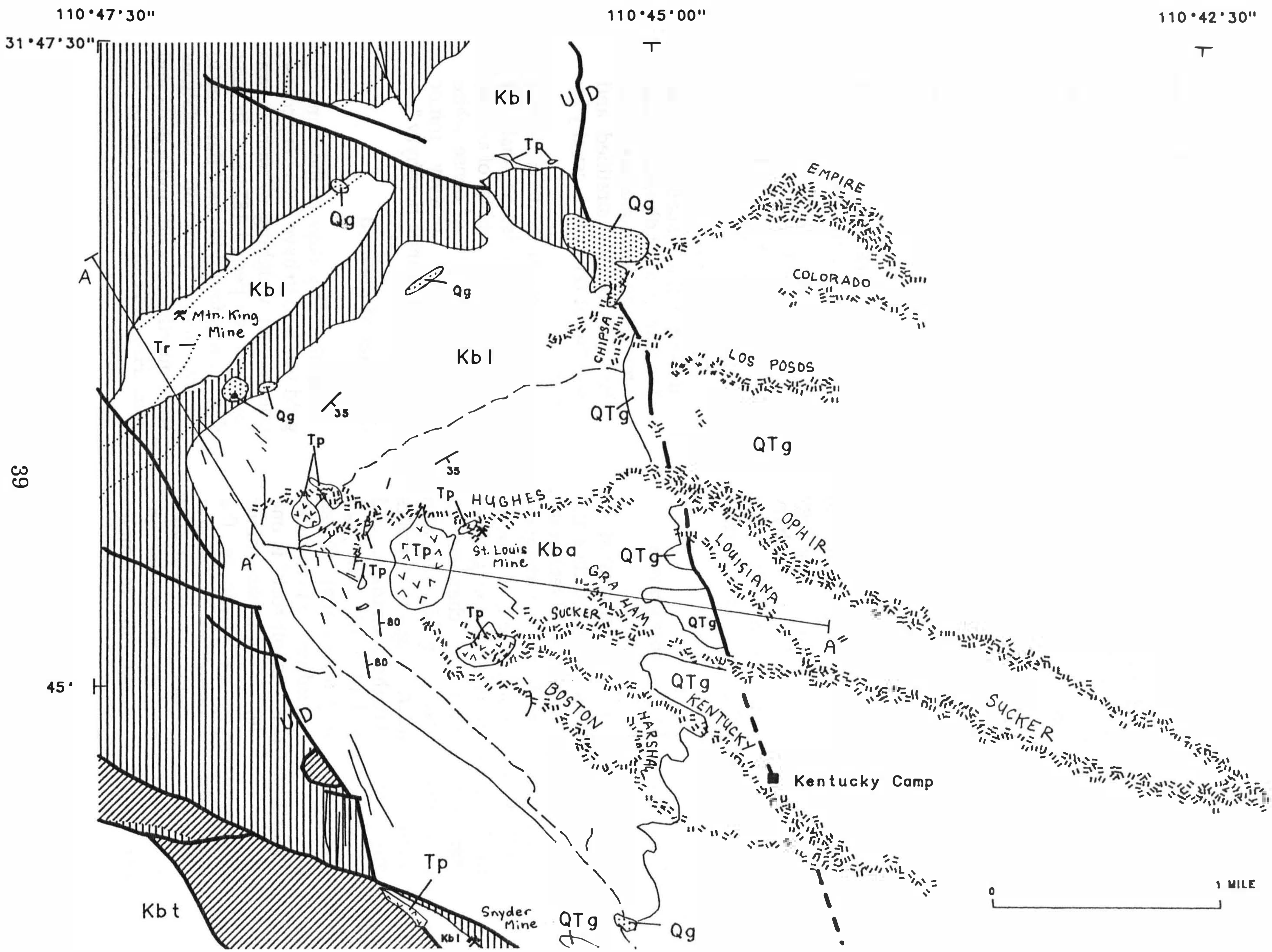
Sedimentary & volcanic rocks, undivided (Mesozoic & Paleozoic)

Continental Granodiorite and (Middle Proterozoic) gneiss

----- Contact-Dashed between Kba (Apache Canyon Formation) and Kbl (Willow Canyon Formation and Glance Conglomerate)

U / D — Fault-Dashed where approximately located. D on downthrown side; U on upthrown side

80 — Strike and dip of bedding



Geology modified from Drewes (1970, 1971a,b, and 1980) and State bedrock map by Reynolds (1988).

granodiorite and Glance Conglomerate, described as consisting locally of a limestone cobble conglomerate. At the Mountain King Mine, small tonnages of high grade lead-silver ore as well as gold, copper, and zinc were recovered from faults and permeable fracture zones in the Willow Canyon Formation (Lower Cretaceous) (as reported in the U.S. Geological Survey Mineral Resource Data System). The nearby rhyolite dikes appear to post-date the mineralization.

A Paleocene age (55.7 1.9 Ma) for the quartz latite porphyry (fig. 2) was established by the potassium-argon method (Drewes, 1970, p. A8). Emplacement thus occurred at the end of the Laramide orogeny (see geology section below). The porphyry intrusions lie within or near the head of several of the productive placer gulches (fig. 2).

Description of the placer gravels

The placer beds were almost at the surface in the heads of the gulches and buried to depths of 10 to 20 feet in the lower eastern ends of the diggings (Hill, 1910). Although the gold placers in the upper reaches of the gulches were mostly found in channels on Cretaceous bedrock, gold was also found in older, higher terraces preserved in Hughes, Graham, and Sucker Gulches (Hill, 1910). The gold placers in the gulches that dissect basin-fill were found on "cement rock" (Hill, 1910). The "cement rock" is one of the multiple, diastem-like minor disconformities characteristic of the upper basin-fill described by Menges (1981, p. 59-60). Gold was concentrated on the riffled surface of the diastem-like horizon that texturally resembles the surface of the weathered Cretaceous beds.

The placer gravels were given a Pleistocene age upon the discovery of vertebrate fossils in one of the placer pits (Blake, 1898).

No better description of the placer gravels can be found than on page 19 in Hill (1910):

> "The pay dirt is found on bed rock distributed rather evenly through a 2-foot bed of angular gravels in a fine red-brown, somewhat clayey matrix. Some of the gravels are yellow to gray-brown, but these as a rule were not so rich as the heavily iron-stained beds. The conditions were essentially the same in all the gulches, and the thickness of the pay varied little from place to place.
>
> The constituents of this bed are rather fine, usually less than 1 inch in greatest dimension,....In a few places the materials of this bed are roughly stratified and somewhat cemented, usually by lime.
>
> ....The coarse material is red and yellow sandstone, shales of various colors, pebbles of arkose, a few fragments of dense white rhyolite, and a very minor amount of granite porphyry."

Character of the gold

In the early days of the camp the gold was said to have been very coarse; one nugget weighing 37 ounces was found in the period 1874-84. In later days, it was found in small flakes up to 0.1 inch long. Common associations were quartz and gold, and galena and gold (Hill, after Mr. Coyne, 1910).

GEOLOGY

The Laramide orogeny in southeastern Arizona is dated as Late Cretaceous (about 90 Ma) to Paleocene (about 52 Ma) (Drewes, 1969). Two phases of the Laramide orogeny are identified in the Santa Rita Mountains. The earlier phase is associated with regional northeast-directed compression (Drewes, 1970, p. A11). In the Greaterville district the compression is most evident in the strongly folded Bisbee Group of Early Cretaceous age. The later phase is associated with northwest-oriented compression (Drewes, 1970, p. A11). In the Greaterville district the Paleocene quartz latite porphyry associated with the gold mineralization was intruded in the later Laramide phase.

The Continental Granodiorite of Middle Proterozoic age and the Bisbee Group of Early Cretaceous age are hosts to the Paleocene intrusives. The rocks of the Bisbee Group rest unconformably on the granodiorite (fig. 2). The intruded Bisbee rocks consist of arkosic conglomerate, arkose, siltstone, and limy siltstone of the Willow Canyon Formation and siltstone, silty shale and laminated limestone of the Apache Canyon Formation (the uppermost unit of the Bisbee Group exposed in this area) (Drewes, 1970, p. A6). Although the basal Bisbee Group unit, the Glance Conglomerate is exposed in the area, it is not intruded at the surface. Whether additional units, such as Paleozoic limestone, intervene between the granodiorite and Bisbee Group at depth, has been speculated upon (Drewes, 1970) but is not known.

Drewes (1970) suggested that the fold and fault structures imposed by the early Laramide events served as conduits for the Paleocene stocks and the mineralizing fluid. Mapping by Drewes (1970, 1971a, 1971b) shows that the Paleocene stocks and dikes were intruded along the southeast-trending fold axes of the asymmetrically folded Cretaceous rocks (fig. 2).

Upper Cretaceous sedimentary and volcanic rocks are absent in the Greaterville district but are preserved in the northern and southern Santa Rita Mountains. If the andesite that lies on top of tilted Glance Conglomerate (just 1,000 feet north of the area shown in fig. 1) is coeval with the Paleocene intrusions, it is likely that Upper Cretaceous rocks were mostly removed before the arrival of the Paleocene intrusions. The thickness to which volcanics accumulated during the last stages of the Laramide is also not known. This is of interest because one wonders how close to exposure the pronounced regional erosion that occurred in the Eocene (Menges, 1981, p. 17) is likely to have brought the gold-source rocks (the subvolcanic Paleocene stocks and related veins in adjacent Lower Cretaceous and Precambrian rocks).

In any case, the suspected gold-source rocks could not have been exposed to weathering and disaggregation before the mid-Tertiary tectonic event (between 40 and 24 Ma) which is represented in the area by the rhyolite dikes (26.1 0.8 Ma by the potassium-argon method (Drewes and Finnell, 1968, p.521)). The absence of placer deposits downstream of the widespread Tertiary rhyolite dikes and their unaltered appearance also support the idea that the mineralization is genetically associated with the older (Paleocene) stocks. The mid-Tertiary event brought an additional layer of cover to the region and probably to the Greaterville area. The thickness of the Tertiary volcanics is not known, nor whether they were deposited on top of Laramide volcanics, Upper Cretaceous rocks, or Lower Cretaceous rocks.

Menges (1981) established the post-Eocene stratigraphy for the area that encompasses the Greaterville district. This stratigraphy consists of (units in parenthesis correspond to fig. 2):

1) early to mid-Tertiary (25-20 Ma) fanglomerates that predate all Miocene (Basin and Range) graben formation--(not exposed in the Greaterville area but may be preserved at depth east of the Basin and Range (B&R) fault).
2) mid- and late-Miocene syntectonic Basin and Range fill units–(Tgl–the main unit deposited during the B&R event; in places uppermost fill accumulated after tectonism ended and overrides B&R basin-boundary faults).
3) undeformed post-tectonic upper Basin and Range fill (5.8-3.3 Ma with a minimum age of 2.5-2.0 Ma for the Martinez surface)--(QTgu--overrides B&R basin-boundary faults).
4) undeformed Quaternary climatic terraces that developed during basin dissection--(Qg).

In the Sonoita Creek basin south of Greaterville, Menges (1981) described deformed Tertiary (Oligocene to mid-Miocene) sediments whose clasts record a topographic highland that preceded and is quite different from the mid-Miocene highland that dominated the subsequent Basin and Range faulting and basin-filling episode. One thus surmises that if the locally derived Oligocene to mid-Miocene Tertiary sediments were available for examination, the clast compositions would reveal the presence and proportions of Cretaceous and Tertiary rocks in the early Tertiary highlands of the Greaterville area. This would help establish the earliest possible exposure of the gold bearing lodes.

PHYSIOGRAPHY

Melendrez Pass (5,860 ft in elevation) and drainage divide (fig. 1) mark approximately the western extent of what Menges (1981, p. 70 and 75) called the Martinez surface, or "high basin stand" of the general Sonoita-Patagonia area (fig. 3). A projection of the Martinez surface, the highest and oldest geomorphic surface in the basin (Menges, 1981), up to Melendrez Pass is interrupted by the topographically higher Granite Mountain (fig. 4). The underlying bedrock terrain is an exhumed, dissected, bedrock (or pediment) surface. This pediment surface has the same altitude and stratigraphic-structural position within the basin as upper Basin and Range fill (Menges, 1981). The maximum development and extent of the pediment ends with the Martinez "high basin stand" after which basin dissection began (Menges, 1981).

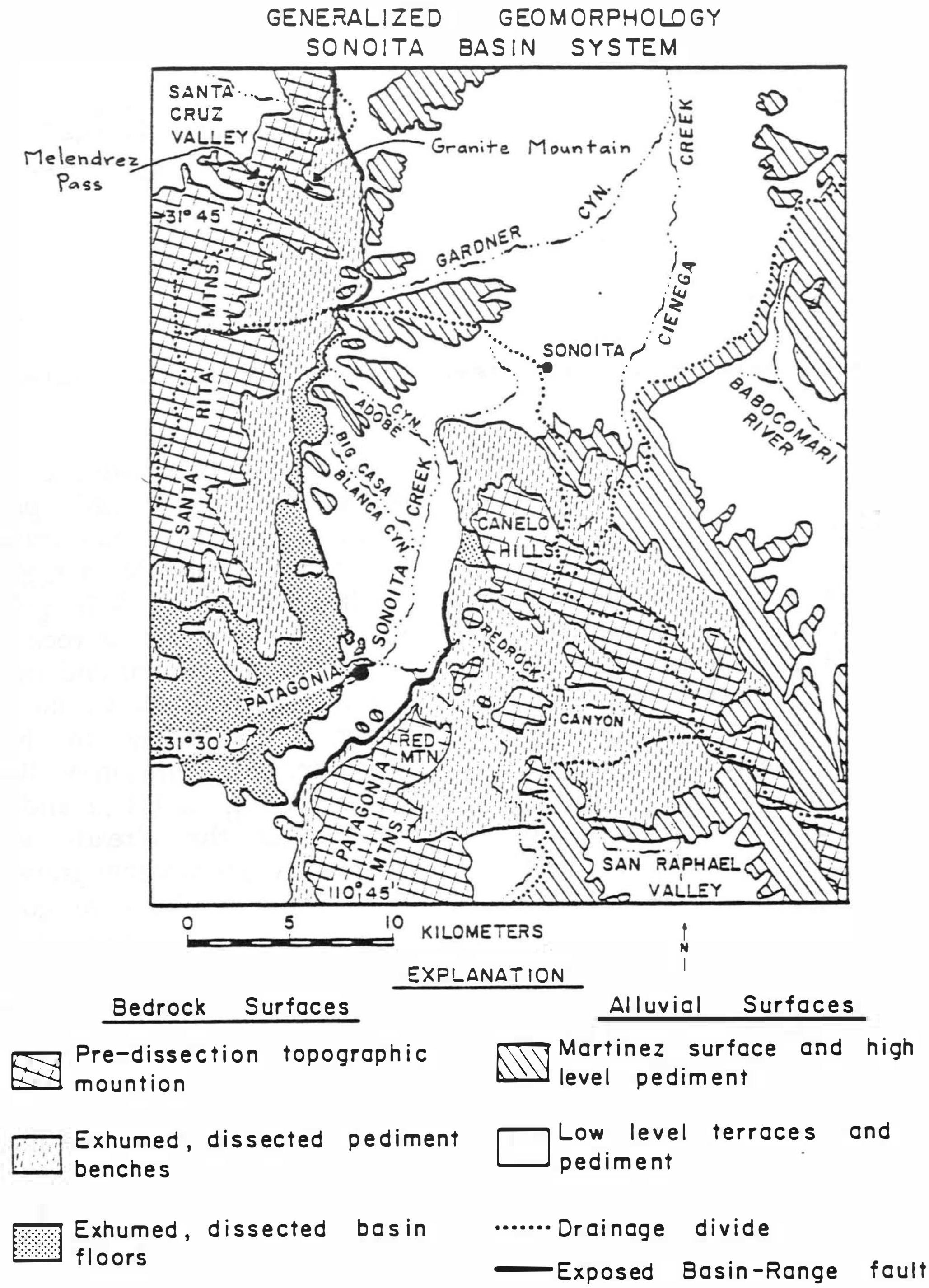


Figure 3. Generalized map of the geomorphology of the Sonoita-Patagonia area (from Menges and Pearthree, 1989). The predissection landscape represented by preserved remnants of the Martinez pediment and surface was partially reconstructed by Menges (1981).

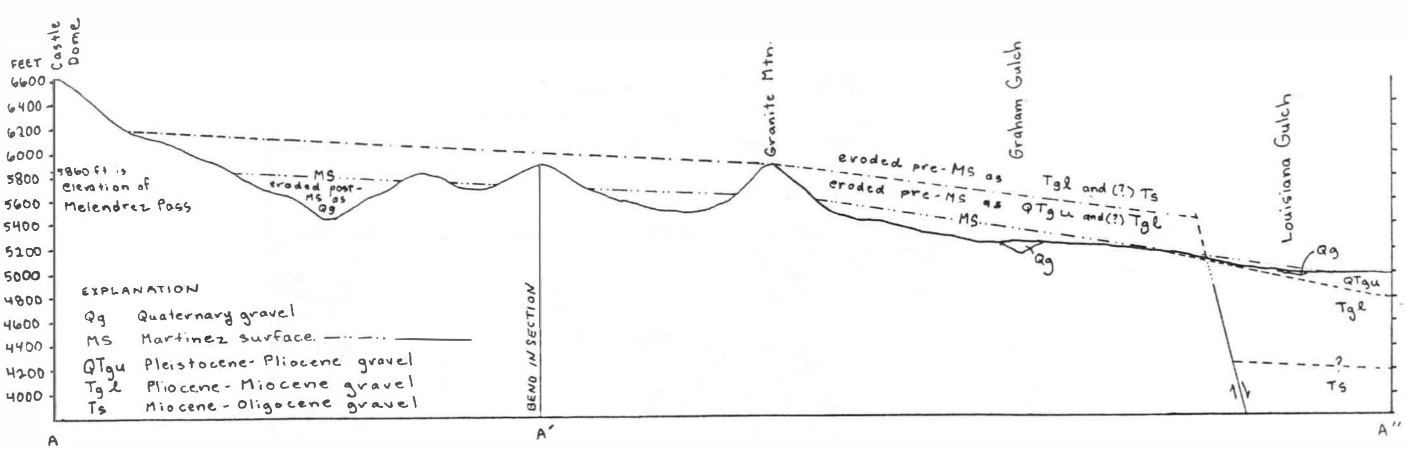


Figure 4. Schematic cross section showing the projected Martinez surface. Located on Figure 2 same scale; vertical exaggeration 2X's.

DISCUSSION

Placer gravels

Boston, Kentucky, Sucker, and Hughes Gulches, as well as two short branches to Hughes, head in the area that lies topographically above the Martinez surface and are the only gulches which presently head in altered Laramide intrusives (figs. 1 and 2). This indicates that placer accumulation began prior to the end of basin aggradation (prior to the Martinez surface).

Using Menges' (1981) ages for undeformed, post-tectonic, upper Basin and Range fill and his estimate for the slow aggradation of the upper Basin and Range fill (100-60 ft/m.y.), one calculates a 200-330 ft thickness for the upper Basin and Range fill (fig 4, QTgu). One might assume that most of the rock that was once between the projected Martinez surface and the top of Granite Mountain was eroded prior to the Martinez and constitutes a large part of the upper Basin and Range fill (fig. 4, Qtgu)). Rock that was once above the present Granite Mountain exposure probably constitutes a large part of the lower basin-fill (fig. 4, Tgl), and rock that was once between the projected Martinez surface and the present day (exhumed pediment) surface probably constitutes the Quaternary terraces (fig.4, Qg).

If most of the lode gold were hosted by the interval of rock between present day pediment and the top of Granite Mountain, it would now be dispersed, according to hydraulic conditions of the time, in the Basin and Range fill (fig. 4, QTgu and Tgl) in addition to the already exploited Quaternary (Pleistocene) gravels.

If some of the lode gold were hosted above the top of Granite Mountain, there is a chance that some gold gravels may occur in the Oligocene to mid-Miocene sediments (fig. 4, Ts).

Lode source for placer gravels

Most of the evidence supports the long held idea that the Paleocene intrusions introduced the lode sources of gold as quartz-calcite veins. Yet, it is possible that epithermal replacement of favorable Cretaceous beds deserves more attention as an additional gold source for the placers. Tunnels into the north side of Granite Mountain revealed several feet of altered mineralized sedimentary rocks in sharp contact with the intrusive (Hill, 1910, p. 16). However, no one has reported chemical analyses of Cretaceous rock except where it is adjacent to the intrusive bodies.

All of the gold gulches are east of the drainage divide and, except for Colorado and Los Posos Gulches, head in folded Cretaceous rocks (figs. 1 and 2). The heads of Colorado and Los Posos Gulches probably were located in Cretaceous pediment after cessation of Basin and Range faulting and prior to the dissection of the Martinez surface and its pediment equivalent. Graham Gulch, which was one of the most productive areas in the district, lies entirely within Cretaceous rock.

The lack of gold gravel in the upper Ophir Gulch probably turned the attention of the prospectors away from the Cretaceous beds and on to the more obviously mineralized Paleocene intrusions and veins. However the lack of gold gravel in upper Ophir Gulch could be a function of climate and inopportune preservation rather than the notable absence of Paleocene intrusions.

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Appendix 1

exerpts from

Geology and Ore Deposits of the Dragoon Quadrangle, Cochise County, Arizona

by John R. Cooper and Leon T. Silver

U.S. Geological Survey Professional Paper 416

1964

HISTORY OF MINING

COPPER AND ZINC

According to Dinsmore (1909, p. 833–834), the copper deposits near Johnson were worked in a primitive way by Mexican miners before the Southern Pacific Railroad was completed in 1881. The railroad was a great impetus to mining, and before the end of 1882 many claims in the area had been patented, including the Peabody, Republic, and Mammoth claims.

The owners of the Peabody claim, the Russell Gold and Silver Mining Co. of Philadelphia, erected a small smelter at what came to be known as Russellville, which is about 2 miles southwest of the mineralized area and is the nearest point where a permanent water supply was obtainable. In 1883 a pipeline was laid from Russellville to the Peabody mine and the smelter was moved there. Hamilton (1883, p. 87) wrote that the mine was "thoroughly opened by shafts, drifts, levels, etc.," that the smelter had been in operation for more than a year, and that regular shipments of bullion were being made. Dinsmore (1909, p. 833–834) reported that more than $1 million was produced during the eighties, before the mine was declared worked out at a depth of a little more than 150 feet and was closed. This estimate of production is probably exaggerated as the slag dumps from this early operation indicate that only about ten thousand tons of ore were smelted. The grade of ore mined from the Peabody prior to 1902 is not known, but that subsequently mined has averaged 7.4 percent copper and 4.2 ounces of silver per ton. This is considerably below the grade required by Dinsmore's estimate.

After the Peabody mine was closed some time in the eighties, there was apparently no activity in the district until the late nineties when Messrs. A. H. Wien and T. K. Mitchell did extensive prospecting and made some small shipments of ore.[9] About 1900 the high price of copper resulted in a short-lived mining boom during which the Little Dragoon Mountains were prospected by many individuals and small companies. The tungsten deposits were discovered in 1898, and by 1902 most of the copper and tungsten showings of the area had been discovered and explored by pits and shafts.

In 1899 the Dragoon Mining Co., a subsidiary of the Federal Copper Co. of New York, purchased the Peabody mine and reopened it, employing as many as 200 Mexican miners. Oxidized copper-silver ore of a reported value between $250,000 and $1,000,000 was

[9] This and many other details of the history since 1898 have been obtained from the files of the Willcox "Star" (now "Range News").

shipped between 1899 and 1903 when the company failed. According to Dinsmore (1909, p. 833–834) the mine was still less than 300 feet deep. The subsequent production from the mine is dwarfed by that from other mines, although the Bonanza Belt Copper Co., organized in 1907, and its successor, the Peabody Consolidated Copper Co., shipped 14,200 tons of ore containing 2,138,000 pounds of copper and 57,000 ounces of silver in 1907–18. The mine. idle since 1918, was owned in 1957 by the Coronado Copper and Zinc Co.

The Black Prince Copper Co., formed by Denver capitalists in 1901 with Hugh Mackay as president, was an important factor in the development of the district, even though the company produced very little ore. By 1903 it controlled a compact group of 28 claims southwest of the Peabody mine and was doing fairly extensive development work at the Republic and Mammoth mines, as well as in several other parts of its holdings. The objective seems to have been to find a large body of ore, and only development ore was shipped. The company disposed of the Republic and Mammoth mines after a year or two and concentrated its activities on the ground between the Peabody and Mammoth mines, where, in 1905–11, the Black Prince vertical shaft was sunk to a depth of nearly a thousand feet. No ore was found in the shaft or in a crosscut from it. In 1912–18, 1,370 tons of high-grade oxidized ore was shipped from shallow workings near the shaft. The Black Prince group of eight patented claims was purchased in 1949 by the Coronado Copper and Zinc Co.

The Republic and Mammoth mines have had common ownership at least since 1900, by which time they were developed by surface cuts and shallow inclined shafts down the dip of outcropping ore bodies. In 1903 the Black Prince Copper Co. extended the Mammoth shaft to 270 feet and the Republic shaft to more than 160 feet and cut a number of levels at both mines. This work developed a small tonnage of both oxide and sulfide ore; the transition from oxide to sulfide ore is said to have occurred at a depth of 50 to 150 feet. The mines were ripe for small-scale operations; and by 1905 the Arizona Consolidated Mining Co., formed by Philadelphia capitalists, was operating both mines. In the same year, the Arizona and Michigan Development Co., formed by the owners of a smelter in Benson,[10] purchased the Copper Chief mine from A. H. Wien, who had held it since the late nineties.

Both the Arizona Consolidated and the Arizona and Michigan faced a serious problem in the fact that their ore was lower grade than that at the Peabody mine and would scarcely justify transportation expenses, including that of wagon haulage to the railroad. The two companies sought different solutions, the Arizona and Michigan interests promoted a branch railroad to the mines, and the Arizona Consolidated interests built a smelter at the Republic mine.

In 1906 the Johnson Dragoon and Northern Railroad Co., formed by the same interests as the Arizona and Michigan Development Co., started constructing a standard-gage railroad between Johnson and the Southern Pacific tracks at Dragoon. The railroad was completed in November 1909, but it was little used prior to World War I. During the war years it was a major factor in the successful operation of a number of mines. The heyday was reached in 1916, when more than 80,000 tons of ore was shipped from the Republic and 4 or 5 smaller mines, and Johnson had a population of perhaps 1,000. The town included half a dozen business houses and several pool halls and boarding houses. When the Republic mine closed in 1920, the railroad fell into disuse and the tracks were removed in 1925.

The Arizona Consolidated Mining Co. shipped about 12,000 tons of ore from the Republic and Mammoth mines in 1905–07. In 1909 the company was reorganized as the Arizona United Mining Co. and constructed a 125-ton smelter at the Republic mine to treat the low-grade sulfide ore. The smelter went into operation in 1909 but was soon abandoned because certain necessary fluxing ores were not available. The company continued to make intermittent small shipments of ore during 1909–13, but the most important event in this period was the discovery of the Main Manto ore body at the Republic mine, a much larger ore body than any previously found in the district.

The Main Manto ore body nowhere reached the surface. Its discovery was due to perseverance, faith, and luck, coupled with the good judgment of the mine superintendent, J. M. Libbey. The exposed bedded ore bodies at the mine had ended above the 300 level, but the inclined shaft had been extended to the 700 level in spite of the fact that drifts and crosscuts at the 300 and 500 levels had found only a few stringers of ore. About 90 feet below the 500 level the shaft went through the Republic fault, below which it was in beds 300 feet or more below the ore horizon stratigraphically. There is no evidence that anyone at the time, or for many years afterward, realized the direction and amount of the fault movement although Mr. Libbey may have suspected it.

The company was discouraged and weakened financially by the unsuccessful smelter and deep exploration projects but decided to make a final attempt to find ore on the 700 level before closing the mine (John Walker,

[10] The Benson copper smelter, constructed 1902–05 by the Southwestern Smelting and Refining Co., apparently was never operated. Some work was done on it as late as 1919.

oral communication, 1949). The officials at the head office in Philadelphia had long held the geologic opinion that the best chances of finding ore were in the footwall in or near a supposed porphyry in that direction. An old map in the possession of the Coronado Copper and Zinc Co. shows the hornfels derived from the lower shale member of the Abrigo formation as "porphyry"; another possible objective was the Precambrian diabase sill, called the "birds-eye porphyry" by some prospectors in the Johnson area. To explore the "porphyry" area crosscuts on the 300 and 500 levels had been driven into the footwall (pls. 8, 10) and Mr. Libbey was instructed to drive a long crosscut into the footwall on the 700 level. Mr. Libbey drove the crosscut (now caved) and also, on his own initiative, drove another crosscut northeastward into the hanging wall. The head office of the company was never enthusiastic about the latter project, and at the time it struck the Manto ore body in 1912 the miners were working without wages other than room and board (John Walker, oral communication, 1949).

With the outbreak of World War I and the subsequent rise in the price of copper, the Main Manto ore body became attractive for mining, but the Arizona United Mining Co. was too weak financially to capitalize on it. Early in 1914, all the Arizona United property at Johnson was leased to the Cobriza Mines Development Co., a leasing concern controlled by the Goodrich-Lockhart Co. of New York. The Cobriza Co. also leased the Johnson Dragoon and Northern Railroad and began shipping 1,000 to 5,500 tons of ore per month, mostly from the Republic mine but in part from the Mammoth mine. The operation was so profitable that the Arizona United Mining Co. bought out the Cobriza interest in 1918 and began operating it for itself.

Other mines were also active during the war years. The Cooper Chief mine, operated by the Arizona and Michigan Development Co., had its main productive life during this period and yielded nearly a tenth as much ore as the Arizona United property; the Peabody mine continued to contribute appreciably to the total production. A small amount of copper was obtained from the Keystone, Black Prince, and Johnson Copper Development groups of claims, and from the Centurion mine. It is probable that small unrecorded shipments were made from other properties.

The fall in the price of copper in 1920 forced all the mines to suspend operations and for 20 years thereafter there was almost no mining in the district. The Republic mine soon filled with water to a few feet below the 700 level, where the water stood until it was pumped out in 1942. The town of Johnson disappeared except for a few buildings.

There were significant property transactions during the 1920–40 period. The Keystone Mining Co., which had made small ore shipments during the war years, built a 200-ton flotation concentrator on its property in 1920–25. The concentrator was operated for a short test run in 1925, but has been idle since that time. The Arizona United Mining Co. and the Dragoon Mountain Mining Co., which then owned the Copper Chief mine, were merged in 1923 as the Arizona United Development Co. This company later gained control of the Peabody mine. As a result of these transactions, the Arizona United property included all the large mines, and also a large continuous block of ground in the most productive part of the district, the Republic-Copper Chief-Mammoth belt.

The period that Johnson was a ghost camp was marked by great advances in the selective flotation of ores—a technique of potential importance to the district as it provided a means for profitable recovery of the zinc contained in the ore. For the early operators, zinc was a liability for which a penalty had to be paid to the smelters. In 1939 the American Metal Co. made a lease and option agreement with the Arizona United Development Co. Geologic maps of the surface and some of the mine workings were made, and seven diamond-drill holes were drilled. The American Metal Co. gave up its interest about the end of 1940. In 1941 W. A. Hooton of Tucson took a lease and option on the property and began shipping ore on a small scale from the Republic mine. In 1942 some of his ore was shipped to the Shattuck-Denn custom concentrator at Bisbee, and there, for the first time, ores from the district were treated by selective flotation.

In 1942 the Coronado Copper and Zinc Co., controlled by the H. S. Mudd interests of Los Angeles, took over Mr. Hooton's lease and option, with the arrangement that Mr. Hooton could continue mining until August 1, 1945, provided he would operate at the Mammoth rather than at the Republic mine. This he and his successor, Mr. Nicholas Duyn, did. The Coronado Copper and Zinc Co. dewatered the lower levels of the Republic mine and, after considerable exploratory work, purchased the property outright.

After purchasing the property, the Coronado Copper and Zinc Co. built a selective flotation concentrator with capacity of 200 tons per day at the Republic mine and also a small company town in the vicinity. An adequate water supply was obtained by drilling a well in Sulphur Spring valley, 8½ miles east of the mine. Power for pumping, mining, and milling was obtained by building a 9½-mile powerline to connect with the REA system in the Sulphur Spring valley. The mill went into operation in May 1945. From that time until 1957, operations were continuous except for one year, July 1949 to July 1950, when all operations in the district were suspended because of low metal prices. Two concentrates—a copper concentrate and a zinc concentrate—were produced and trucked to Dragoon for shipment to smelters. Between 2 and 3 pounds of zinc was produced for each pound of copper. Some ores that had a relatively high content of copper but low content of zinc were shipped direct to copper smelters. In 1957 operations were again suspended because of low metal prices.

The Coronado Copper and Zinc Co. has operated three mines in the district. Operations started at the Republic mine and continued there until 1952 when the mine was shut down because of exhaustion of known ore bodies. The Mammoth mine was operated until 1949. A large ore body, now known as the A ore body of the Moore mine, was discovered in 1947 about a thousand feet east of the Mammoth mine by exploratory diamond drilling from the surface. The new Moore shaft was started about a year later, and production from the A ore body started in 1951. After the closing of the Republic mine, the Moore mine was the only producing mine in the district through 1957.

Except for the St. George claim, owned by F. M. Lebold and S. N. Lebold, of Chicago, the productive copper-zinc area at Johnson was held in 1955 by two property holders, the Keystone Copper Mining Co., of Dragoon, and the Coronado Copper and Zinc Co. The Coronado property extended northwestward continuously from near the Hagerman and O. K. shafts to include the Mayflower, Republic, Copper Chief, Mammoth, Black Prince, Johnson Copper Development, Mackay, and Peabody workings. (See pl. 6.) The Mayflower, Black Prince, Johnson Copper Development, and Mackay properties were not part of the old Arizona United group but were purchased by the Coronado Copper and Zinc Co. after 1945. The Keystone property adjoined the Coronado property on the southeast and included the Hagerman, O. K., and many smaller workings. The property also included the Peacock group of claims, the ownership of which was long in litigation but was settled in favor of the company (N. M. Rehg, president, Keystone Mining Co., oral communication, 1954).

rediscovered by B. X. Williams in 1908. The Texas Arizona Mining Co. was formed, and the Texas Arizona mine was opened at the site of the discovery. The company, with J. R. Hubbard of Tucson as manager, did considerable development work and made small ore shipments from time to time from 1910 to 1917, when work ceased. Various other operators made a few small shipments of ore from the property in 1920–28. In recent years the mine has been held by the Chambers family, who, in 1949, drove an exploratory drift on the lowest level without finding ore. Recorded production for the period 1909–28 was 712 tons of ore averaging about 40 percent lead and 50 ounces of silver per ton. Some oxidized zinc ore was shipped in 1911–13.

The ore at the Texas Arizona mine is mostly in small replacement lenses in limestone. Other deposits of the same kind have been found south of the mine; and some small quartz veins carrying lead and silver occur 3 to 4 miles north of the mine near the present route of Highway 86. These deposits have yielded small shipments of hand-sorted ore, which, like that from the Texas Arizona mine, carried about 1¼ ounces of silver for each 20 pounds (1 percent) of lead.

TABLE 1.—*Copper, zinc, lead, silver, and gold production, Johnson Camp area, Cochise district, Arizona*

Year	Number of producing mines	Ore (tons)	Copper (pounds)	Zinc (pounds)	Lead (pounds)	Silver (ounces)	Gold (ounces)	Total value
Prior to 1907	----------	[1]20,000	[1]2,500,000	----------	----------	[1]60,000	----------	[1]$450,000
1907	4	7,275	523,934	----------	4,147	8,830	----------	110,835
1908	2	447	68,024	----------	----------	1,120	----------	9,573
1909	3	2,788	209,314	----------	----------	2,192	17.92	28,672
1910	4	3,836	271,003	----------	119,778	13,406	28.86	47,522
1911	3	194	15,235	22,423	89,507	4,562	6.00	9,752
1912	7	3,975	604,178	23,800	121,380	22,809	17.10	120,821
1913	9	4,363	790,633	8,155	27,712	19,264	3.59	135,933
1914	6	20,044	2,136,877	----------	77,956	29,761	5.27	303,812
1915	6	42,420	3,661,603	----------	12,995	37,327	2.88	660,377
1916	7	81,221	6,130,841	----------	27,073	59,816	1.00	1,549,435
1917	8	53,359	4,084,329	----------	13,171	44,493	14.00	1,153,106
1918	6	43,893	3,877,495	----------		31,698	1.00	989,460
1919	4	12,090	1,130,622	----------	----------	8,568	1.00	219,913
1920	3	11,139	1,055,293	----------	48,818	11,383	3.00	210,549
1921	1	17	451	----------	12,684	839	1.00	1,489
1922	1	25	941	----------	----------	7	----------	134
1923	2	28	4,599	----------	3,911	252	----------	1,156
1924	2	599	69,476	----------	----------	495	----------	9,433
1925	4	2,239	215,941	----------	----------	1,845	----------	31,994
1926	3	221	27,591	----------	----------	368	1.00	4,113
1927	3	71	7,079	----------	3,592	164	----------	1,247
1928	5	946	64,643	----------	703	772	.54	9,812
1929	3	453	56,349	----------	----------	592	1.03	10,254
1930	4	1,335	143,201	----------	----------	1,649	.90	19,238
1931	2	128	31,315	----------	----------	789	1.40	3,108
1932–35[2]								
1936	1	10	2,373	----------	----------	12	----------	227
1937	1	39	3,694	----------	----------	22	----------	464
1938[2]								
1939	1	18	3,077	----------	----------	3	----------	322
1940	1	22	3,602	----------	----------	----------	----------	407
1941	1	891	116,000	----------	----------	938	1.00	14,390
1942	3	7,395	413,000	567,000	17,300	3,631	17.00	107,040
1943	1	193	8,700	----------	----------	59	----------	1.173
1944	2	4,351	229,200	95,500	----------	1,447	----------	$42,858
1945	2	33,183	985,000	2,600,000	3,500	6,217	8.00	436,977
1946	2	58,110	1,974,500	5,753,500	200	12,062	----------	1,031,564
1947	1	66,583	2,072,000	6,285,200	8,000	15,580	----------	1,210,881
1948	1	67,150	1,936,700	5,749,300	----------	15,777	----------	1,199,200
1949	2	37,566	1,377,200	3,519,900	----------	11,079	----------	717,803
1950	2	21,823	996,200	2,050,400	800	9,469	12.00	507,465
1951	1	64,654	2,700,000	6,486,000	----------	23,475	23.00	1,855,903
1952	1	77,748	3,676,000	8,532,000	----------	26,930	22.00	2,330,812
1953	1	76,836	3,698,000	7,786,000	----------	28,889	12.00	1,983,282
1954	1	76,880	3,894,600	7,132,000	----------	30,857	----------	1,947,090
1955	1	75,128	3,896,500	6,590,500	----------	34,046	----------	2,294,839
1956	1	76,668	3,337,400	5,590,200	----------	31,147	----------	2,212,442
1957	2	44,716	2,208,900	5,019,500	----------	22,926	----------	1,267,890
1958	2	1,410	31,300	----------	400	193	----------	8,454
1959	1	28,979	746,900	1,026,400	----------	7,777	----------	354,373
Total	----------	1,133,459	61,991,813	74,837,778	593,627	645,537	202.49	25,617,594

[1] Estimated.
[2] No production for Johnson Camp area.

The amount of tungsten produced is not known and cannot be estimated accurately, because most of it was mined from surface pockets and placers of unknown grade by many constantly changing small operators. Figures reported by various operators, statements in contemporary newspapers and mining journals, and observations made in the course of geologic mapping suggest the total production may have been about 75,000 units of WO_3. A unit of WO_3 is 20 pounds of tungsten trioxide. Tungsten concentrates are generally sold on the basis of units of contained tungsten trioxide.

Marble production for 1953–59 is given in table 2. The amount of marble produced prior to 1953 is not known.

TABLE 2.—*Marble production from Ligier quarries near Dragoon, Ariz., 1953–59*

Year	Dimension stone		Terrazzo		Other uses			Total crushed	
	(Short tons)	(Value)	(Short tons)	(Value)	(Short tons)	(Value)		(Short tons)	(Value)
1953	30	$1,800	300	$6,000	600	$12,000	Roof chips	900	$18,000
1954	--------	--------	115	2,530	500	11,002	do	615	13,532
1955	--------	--------	41	820	--------	--------	--------	41	820
1956	--------	--------	236	4,556	640	10,205	Roofing granules	--------	--------
					234	1,844	Plaster	1,110	16,605
1957	--------	--------	700	15,400	1,000	14,100	Roofing granules	1,700	29,500
1958	--------	--------	900	16,300	600	10,800	do	1,500	27,100
1959	--------	--------	1,376	29,067	1,000	15,000	do	2,376	44,067
Total	30	1,800	3,668	74,673	4,574	74,951	--------	8,242	149,624

MINES AND PROSPECTS

JOHNSON CAMP COPPER-ZINC AREA

CORONADO COPPER AND ZINC CO. PROPERTIES

The Coronado Copper and Zinc Co., of Los Angeles, Calif., owns a large group of mining claims and fractions extending continuously from near the Hagerman and O.K. shafts northwestward to include the Republic, Copper Chief, Mammoth, Moore, Black Prince, Johnson Copper Development, Mackay, and Peabody workings (pl. 6). The property represents a consolidation of claims once of diverse ownership. The property is bounded on the southeast by the Keystone Mining Co. property.

MOORE MINE

The Moore mine, located a little less than a mile northwest of the Coronado Copper and Zinc Co. concentrator at Johnson, is the most recent development in the district. The first ore body, now known as the A ore body, was discovered in 1947 by diamond drilling from the surface. A new vertical shaft called the Moore shaft [12] was started about a year later and large-scale production got under way in 1951. Since the Republic mine was shut down in 1952, the Moore mine has been the only active mine in the district. Its total production by the end of 1954 had amounted to roughly 250,000 tons of ore averaging about 2½ percent copper and 6½ percent zinc. The mine was shut down in 1957 because of the fall in metal prices.

The Moore shaft is a vertical three-compartment shaft 800 feet deep. From it three levels have been driven, called the 400, 500, and 600 levels respectively (pl. 7). An inclined winze from the Mammoth mine connects with the 400 level.

The mine workings reveal complex block faulting that can be interpreted in several ways. The interpretation given on the section (pl. 7) and block diagram (fig. 31), is based on data available early in 1954 and involves the following sequence of faulting.

[12] Named for R. W. Moore, then general manager of the Johnson Camp unit of the Coronado Copper and Zinc Co. and later president of the company.

1. Fault A, a small normal fault of the Easter type, known only in a small part of the 500 level and not well understood.
2. Northeasters with small displacement of the normal type (including 467, No. 1 and No. 2 faults; and perhaps the 469 and No. 3 faults though the principal movement on them was later).
3. Easters with normal displacement (East 90 and Old Manto faults and perhaps the Mammoth fault though its principal movement was later).
4. Copper Chief fault, a Northwester with substantial right-lateral displacement. The No. 9 fault was formed as a segment of the Copper Chief fault at this stage.
5. Large normal movement on Mammoth fault offsets Copper Chief fault about 50 feet to the left.
6. Large normal movement on 469 fault offsets East 90, Mammoth and Copper Chief faults.
7. Renewed movement on Copper Chief fault, this time with relatively small downthrow on the west. As the old northern segment was now out of line, the movement at the north end took place on the No. 3 fault.

The metalization certainly followed stage 3 and was probably later, as the 469 fault contains veinlets of quartz and hypogene sulfides on the 500 level.

The principal ore bodies in the mine are chimneys or thick elongate lenses in the plane of the favorable beds (unit 5 of the Abrigo and the upper part of unit 4). Those mined or thoroughly explored to 1954 are 375 to 600 feet long, 50 to 175 feet wide parallel to the beds, and 30 to 70 feet thick perpendicular to the beds. The long axes are controlled by fault fissures or obscure northward-trending folds(?). Two of the ore boundaries tend to be plane surfaces parallel to the beds. The lateral boundaries, where not fissure-controlled, are irregular in detail because some beds were more easily replaced than others but the projections formed in this way are generally only a few feet long and the sides of the ore bodies are characteristically vertical or at some other large angle to the plane of the beds. To 1954 no important tabular extensions like those at the Republic mine had been found.

The A ore body is a lozenge-shaped mass 375 feet long, 175 feet wide, and as much as 60 or 70 feet thick plunging N. 10° W. in the favorable beds below the east end of the 400 level. It ends to the northwest against the 469 fault, though ore, now thoroughly oxidized, extends into the fault zone in one part of the 500 level (pl. 7). The structural feature that has localized the ore is very obscure. Baker (1953, p. 1275) believed it is a shallow fold.

The B ore body resembles the contracted extension of the A ore body offset 200 feet to the north by the 469

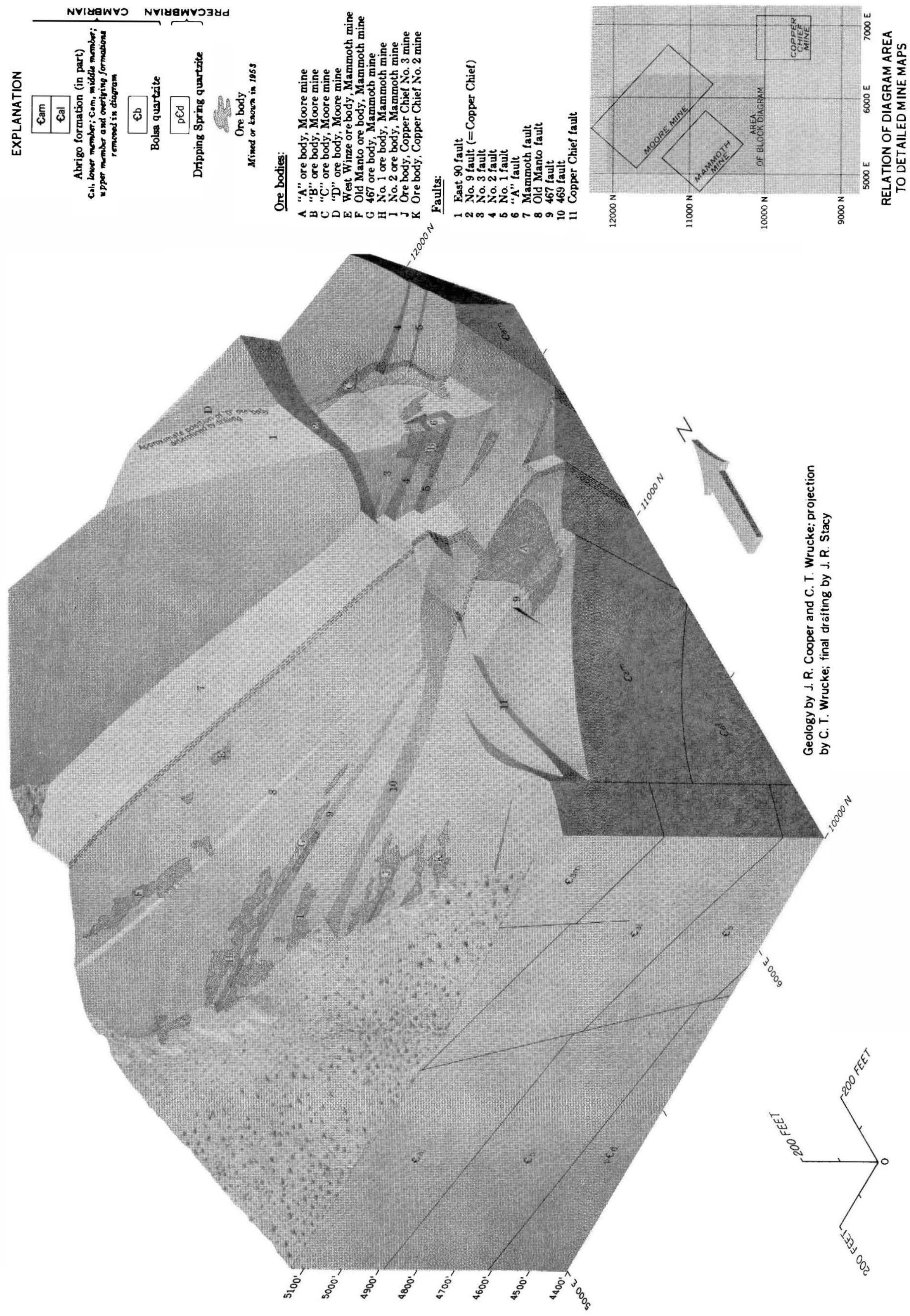

FIGURE 31.—Block diagram of the Moore mine-Mammoth mine area showing relation of ore bodies to stratigraphic units and structure.

fault (pl. 7 and fig. 31). At the south end next to the fault the ore body is mostly above the 500 level. It plunges very gently to the northwest across the fault blocks defined by the No. 1 and No. 2 premineralization faults and ends against the E. 90 and No. 3 faults a little below the 500 level.

The C ore body is a nearly horizontal chimney in the favorable beds (Abrigo unit 5 and upper part of unit 4) between the 469 and No. 9 faults. The long axis of the chimney is controlled by the East 90 fault as shown in plate 7 and figure 31. Its diameter averages about 60 feet and only its downward bulges and undulations appear on the 500 level (pl. 7).

The D ore body is west of the No. 9 fault and about 100 feet above the 500 level. As known early in 1954, it appeared to be exactly like C in characteristics and geological controls (fig. 31). Late in 1954 after the illustrations for this report were prepared, ore was discovered in the same favorable beds immediately south of the East 90 fault in the block west of the No. 9 fault. The early drilling suggested it might be a chimney resembling the C and D ore bodies but structurally above rather than below the East 90 fault.

In addition to the principal ore bodies, some ore has been mined from a small mass at the top of unit 5 of the Abrigo intersected 100 feet southeast of the shaft on the 400 level (pl. 7), from a small body in white tactite cut by the shaft above the 400 level, and from a body in Martin unit 6 cut by drill hole No. 97 from the surface a short distance north of the main part of the workings (pl. 7). The ore in white tactite had a copper-zinc ratio near 1:1 and contained several percent of each metal. The body in the Martin formation is high-grade oxidized copper ore. As the discovery and development took place after our field work was completed, little information can be given concerning the mineralogical and structural details or the size of the mass. The ore is soft and porous. It contains much malachite and little gangue other than the original carbonate. Early shipments contained about 20 percent copper and very little zinc.

The ore bodies so far discovered in the mine and the unmined extension of the West Winze ore body of the Mammoth mine (p. 168) bottom considerably above the 600 level. There has been considerable unsuccessful exploration for relatively shallow ore south and southeast of the workings, and a limited amount of exploration for deeper ore to the north and northeast.

One of the most favorable targets for exploration is the faulted extension of the East 90 fault east of the 469 fault. To the end of 1954, its location had not been established. At that time, Arthur Baker 3d tentatively concluded that it was represented by the Easter shear zone that we designate Mammoth fault(?) in the stub crosscut east of the B ore body on the 500 level (pl. 7) and shown on the block diagram (fig. 31) downdip from the A ore body. Baker's interpretation is appealing if the B ore body is in fact the faulted extension of the A ore body as hinted previously to simplify description. (See fig. 31.) It faces geometric difficulties, however. The best match of the A and B ore bodies is obtained if the postore displacement on the 469 fault was 200 feet in a right-lateral sense without any vertical component of movement. All structures in existence at the time of faulting must have been offset the same amount and in the same direction. The offset of the contact of the garnetite and white tactite is in reasonably good agreement (185 ft on the 400 level; 220 ft on the 500 level); but the offset of the supposed East 90 fault on the 500 level is much too short (70 ft).

Even greater geometric difficulties are found with the other faults that we regard as older than the 469 fault. No right-lateral offset of the Copper Chief No. 9 fault system is apparent at the surface (pl. 6) or underground (fig. 31). If the Mammoth fault was offset 200 feet to the right it should pass through the A ore body. But mine workings and drill holes from the surface have shown conclusively that there is no Easter fault of consequence through the A ore body or updip from it.

It is possible, of course, that we have interpreted the fault sequence incorrectly. The Mammoth fault could be younger than the 469 fault but did not offset it appreciably because movement was parallel to the trace of the 469 surface. In this case the Mammoth could pass below the A ore body but not without crossing the 500 level. No fault that can reasonably be considered the Mammoth fault is to be seen on the 500 level west of the 469 fault.

On the basis of information available to us, we believe the 469 fault was not a strike-slip fault, but rather a normal fault which offset beds and Easter faults in opposite directions because of their opposite dips. According to this interpretation, the Mammoth fault is entirely above the 500 level workings west of the 469 fault; east of the 469 fault, the shear zone designated Mammoth fault(?) could represent part or all of the Mammoth fault. The faulted extension of the East 90 fault would be expected several hundred feet farther north in ground that had not been explored in 1954.

REPUBLIC MINE

The Republic mine is just east of the settlement of Johnson and is the site of the concentrating plant of the Coronado Copper and Zinc Co. The mine was opened in 1882 or earlier and worked at intervals until 1952 when it was shut down because of exhaustion of the known ore bodies. Total production was probably

550,000 tons of ore with a value somewhat in excess of $10 million.

Access to the mine is by an inclined shaft down the dip of the beds to the 700 level, about 400 feet vertically beneath the surface. Deeper workings are connected to the 700 level by winzes. The deepest level in 1954, the 1600 level, is 900 feet vertically beneath the surface. There is about 21,000 feet of drifts and crosscuts, in all, as well as raises, winzes, and stopes. The principal workings are shown on plate 8.

The geology of selected levels of the mine is shown on plate 9; and sections are given on plate 10. The beds strike near N. 50° W. and dip about 40° NE., and they are cut by many faults and fissures of the Northeaster and Easter sets. The Republic fault, a major flat-dipping Easter with normal movement, is exposed at the south end of the 1200 and 700 levels (pl. 9), in the shaft near the 600 level (pl. 10), and in the roof of the eastern part of the 700 Station stope (pl. 8). The workings driven from the shaft above the 700 level are entirely on the south or hanging-wall side of the Republic fault. The rest of the workings are on the north or footwall side of the fault except for several hundred feet of workings at the south end of the 1200 level and a short crosscut from the 700 Station stope.

Prior to our mapping, the Republic fault was not recognized, and the large ore bodies in the footwall block were thought to occur in the Martin formation, because of their position with respect to surface outcrops (pl. 10). As a result of the regional studies of the stratigraphy and metamorphism, it is now very clear that all the ore in the mine was in the middle member of the Abrigo formation, and most of it was in unit 5 at the top of that member. As a result of misconceptions regarding the stratigraphic position of the ore bodies and the structure, the favorable beds on the hanging-wall side of the Republic fault have never been thoroughly explored. Unit 5 on this side of the fault has the form of a wedge defined by its surface outcrop and the fault. The wedge has its apex 1,150 feet northwest of the shaft collar and widens to about 850 feet between the south end of the 1200 level and the surface.

Mining in the hanging-wall block of the Republic fault was all prior to 1912. Stopes, now caved, were opened east and west of the shaft above the 200 level, and another shallow ore body evidently was mined 850 feet northwest of the shaft, from a quarrylike opening about 100 feet across. The ore at the three localities was in garnetite derived from unit 5. The body just west of the shaft was a tabular mass in the plane of the beds along Northeaster zone H (pl. 9). This mass was 2 to perhaps 5 or 10 feet thick, about 150 feet long parallel to the trace of fault zone H, and 50 feet wide parallel to the strike of the beds. Details of the ore body east of the shaft are not now determinable but the body must have been considerably larger than shown on plate 8 for caving has caused appreciable subsidence of the land surface for several hundred feet from the shaft. There is no evidence of this ore body on the 300 level (pl. 9).

Since discovery of the Main Manto ore body, attention has been focused on the footwall block of the Republic fault. As the 500 and higher levels from the shaft are stratigraphically below the most favorable ore horizon west of fault G (pls. 9 and 10), the shaft and the segment of the 300 level that is southeast of the shaft provide the only exposures of the most favorable beds in the hanging-wall block between the stopes near the surface and the 1050 level. A horizontal hole drilled southwestward from the 1050 level penetrated the Republic fault and showed that unit 5 was barren and only slightly garnetized. Weak garnetization in unit 5 was also shown by limited exploration at the 1200 level and in 3 diamond-drill holes from the surface 200 to 800 feet farther east. The weak garnetization revealed by this deep exploration is in striking contrast with the intense garnetization in the shaft and on the 500 and higher levels. The contact of garnetite and marble is a favorable locus for metalization, and thus is a valid target for future exploration. Other specific targets in the block are provided by the intersection of Northeasters with the favorable beds. A small body of metalized ground was found at such an intersection at the south end of the 1200 level (pl. 9). The position of the intersection of large Northeasters with the favorable beds is shown on a structure contour map accompanying an earlier publication (Cooper, 1950, fig. 15). Experience has shown that the footwall side of metalizing fissures is most likely to be mineralized.

The large ore bodies on the north or footwall side of the Republic fault were not exposed at the surface. The Main Manto ore body, which was mined during World War I and which probably averaged a little more than 4 percent copper, had the form of a chimney plunging between 1° and 25° S. 60° to 85° E. (pl. 10). Excluding lateral extensions described later, the chimney was 1,500 feet long, 30 to about 100 feet wide in the plane of the beds, and 15 to 40 feet thick. Between the upper or northwest end, which is about 100 feet beneath the surface, and the 900 level, the manto was in the topmost beds of unit 5 of the Abrigo formation. Below the 900 level it cut gradually downward across the beds to the No. 1 fault. East of the No. 1 fault, which is a premineralization fault, the ore body turned toward the south and more abruptly downward across the beds as a sort of tail of little economic importance. Where it ended a short distance below the 1300 level it was in beds more than 100 feet strati-

1-10

graphically below the top of the middle member. The 1300 level, named many years ago from its distance down the gently inclined East winze, is at a slightly higher elevation than the 1200 level named later from its distance down the Northeast winze. The ground on the eastward projection of the ore body has been explored thoroughly by diamond-drill holes from the 1300 level without finding any important extensions.

The long axis of the manto was approximately parallel to the Republic fault and 190 to 200 feet down the dip of the beds from it. Below the 700 level the manto followed the axis of a gentle anticlinal flexure in the beds. Above the 600 level there is no indication of the flexure and the localizing structure was probably obscure Easters satellitic to and somewhat steeper than the Republic fault. Such structures are illustrated by the 700 fault (pls. 9 and 10) and other Easters to be seen in the stopes at the upper end of the manto.

Above the 700 level, the Main Manto had several extensions in the plane of the beds. One of these, mined during World War I, ran updip between the No. 9 fault and the North Winze fault. The only downdip extensions known in this area are a thin hanging-wall streak which was mined here and there to the 700 level. Very little evidence of exploration for a possible footwall streak can be seen in this area.

East of the North Winze fault there was a downdip extension of considerably greater importance called the West ore body (pl. 8), which was also mined during World War I. This extension merged with the manto along a base 375 feet long and ended in depth as fingers following several Northeasters. In a stratigraphic sense, the extension split into a lower footwall streak and an upper hanging-wall streak, as well shown on the 700 level (pl. 9). Below the 600 level, the two streaks were mined separately. The longest finger of ore, a part of the footwall streak running down along the North Winze fault, was mined to about 25 feet below the 900 level. On the deeper projection of this finger, ore was mined in recent years above the 1200 level and between the 1200 and 1500 levels (760 ore body of pl. 8). This ore was in the same beds as on the upper levels, but the beds are here broken by large Easter faults of the reverse type. Baker (1953, p. 1276) believed this ore was localized along the axis of a shallow fold in the beds, but this fold is obscure and it seems just as likely that the structural control is a combination of the North Winze fault and the Easters.

For several hundred feet east of the West ore body, the Main Manto lacked extensions of any kind and was nearly circular in cross section. One thin downdip extension (hanging-wall streak), just west of the Northeast Winze, was mined to the 900 level.

Farther east, between the 700 and 900 levels, the manto expanded: and between the 900 and 1100 levels blossomed out into extensions of great importance. A large body of ore occurred in unit 4 just south of the manto, and a large tabular extension of this body called the Northeast Winze ore body occurred to the north in beds at the top of unit 5 (pls. 8 and 10). These extensions, which have yielded about half the total ore produced from the mine, were high in zinc (6 or 7 percent) and low in copper (about 2 percent) when compared with the Main Manto and most of the other ore bodies in the mine. A small chimney of high-copper ore within the Northeast Winze ore body along the No. 3 (Northeast Winze) fault was mined during World War I between the 900 and 1250 levels. The rest was mined by the Coronado Copper and Zinc Co. after 1942.

The Northeast Winze ore body, which has been mined to the 1600 level, was about 800 feet long in a N. 10° W. direction, 200 to 400 feet wide on the various levels, and 15 to 40 feet thick perpendicular to the beds. It appears to have been localized along the axis of a shallow anticlinal flexure in the beds, as Baker (1953, p. 1274) was first to point out. As shown on the geologic map (pl. 9) and on the Northeast Winze section (pl. 10) which crosses the ore body obliquely, it was at the same stratigraphic horizon throughout and was continuous except for separation caused by the 1280 Easter fault. It ended in depth between the 1500 and 1600 levels against the 1600 fault, an Easter with reverse stratigraphic throw of about 120 feet in the vicinity of the ore body (pls. 9 and 10). There was no evident reduction in the size of the ore body as the fault was approached. A possible extension on the north or footwall side of the 1600 fault has been sought by many drill holes put down from the 1400, 1500, and 1600 levels. Ore in minable grade and thickness was found, but no body could be blocked out that is large enough to justify the costly winze necessary to reach it. The structure of the block is complex and not well understood. If further exploration by drilling is undertaken at some future time, crosscuts to the northeast from the present workings should be driven to provide drill sites from which new information could be obtained. Only a small part of the footwall block can be explored satisfactorily by drilling from the present workings, and this part has been thoroughly explored.

Several hundred feet southwest of the Main Manto and in beds about 150 feet below it stratigraphically, there is a much smaller metalized chimney known as the West Manto. It follows a slight anticlinal flexure nearly parallel to the Main Manto. Not all the West

Manto is commercial ore. In 1920, or earlier, the 700 Station ore body was mined between the 500 and 650 levels (pl. 8). The Republic fault seems to cut off the ore body at its east end; but a low-grade stem, taken to mark the general course of the manto, continues downward on the footwall side of the Republic fault. This stem was found on the 700 level and led the miners to the ore body above. It is now evident that the stem continues downward at least to the 1200 level and contains other masses of ore. It has been explored by crosscuts on the 1050 and 1200 levels, by a raise from the 1050 level to the 700 level, and by several diamond-drill holes. The Coronado Copper and Zinc Co. opened the West Manto stope above the 1050 level (pl. 8) but later abandoned it because the ore proved to be thin and the ground bad for mining.

The principal ore bodies at the Republic mine were within the relatively uplifted block between the Republic and 1600 Easter faults. Without further exploration of the adjacent relatively depressed blocks, it is impossible to tell whether this is due to structural favorability of the uplifted block or simply to the fact that this block has been more thoroughly explored.

MAMMOTH MINE

The Mammoth mine is about three-quarters of a mile northwest of Johnson in a conspicuous hill known as Mammoth Hill. Its productive life started in 1882 or earlier and continued at intervals until 1949, when operations were suspended. Since the eighties, the Mammoth and Republic mines have had the same owners, and production from the two mines has been reported as a unit in most of the years for which there are records. Production from the Mammoth is very much less than from the Republic but probably exceeds that from the intervening Copper Chief mine. The Mammoth ore is similar to that from the other two mines but, on the average, is somewhat richer in copper.

The principal workings of the mine, shown on plate 7, consist of partly caved inclines and underhand stopes down the dip of the favorable beds and more extensive openings from the main inclined shaft that passes through the Old Manto stope to the 600 level. The favorable beds have been explored for a length of 650 feet on the 600 level and 2 stopes have been opened above it—a small stope near the west end and a larger stope near the east end. The eastern stope which is on the 467 ore body connects with an underhand stope from the surface. Below the 600 level there are two winzes corresponding in position to the two ore bodies on the level. A small ore body is partly developed and mined from the West winze. The East winze provides access to a stope at the bottom of the 467 ore body and extends to the Moore mine workings.

All ore bodies at the Mammoth mine are in unit 5 at the top of the middle member of the Abrigo formation. The No. 1, No. 2, and several smaller tabular ore bodies, 2 to perhaps 10 feet thick, cropped out at the surface and were mined many years ago by underhand methods (pl. 7 and fig. 31). The Old Manto ore body, mined during World War I, had only a small inconspicuous lead exposed at the surface, but good ore occurred 30 feet below. The body was a chimney about 300 feet long, 25 to 60 feet wide, and 10 to 25 feet high plunging gently eastward in the favorable beds on the footwall side of the Old Manto fault, a small Easter that may be traced on the surface as far east as the Moore shaft (pl. 6). The 467 ore body, mined during 1945–48, was a chimney 400 feet long, 25 to 45 feet wide, and nearly 25 feet high which ran almost down the dip of the favorable beds in the footwall of the 467 fault, a Northeaster. The body was discovered in depth and mined to within a very few feet of an old underhand stope from the surface—a good illustration of the fact that in districts of this kind one may be very close to good ore without realizing its presence. The 467 fault crosses the old stope obliquely and enters the east wall about a hundred feet down the incline. The fault has a subordinate branch at this point, running in a more northerly direction, and the early miners followed this branch downward.

The northern wall of the Old Manto stope shows 3 to 15 feet of low-grade zinc ore for a length of 250 feet. Lenses of similar ore downdip on the 600 level may represent the extension. A little of this ore was mined in both areas in the early 1940's by W. A. Hooton, a lessee, but the operations were not profitable. The stope later opened at the bottom of the West winze yielded good grade copper ore. The shape of the stope and diamond drilling from the surface and from the 400 level of the Moore mine suggest that the mined area represents the upper part of a small manto that plunges about 25° in a nearly easterly direction and extends about 400 feet from the bottom of the West winze. The ore is entirely above the 400 level from the Moore shaft, from which it would be most readily mined.

COPPER CHIEF MINE

The Copper Chief workings are about half a mile northwest of Johnson, between the Republic and Mammoth mines. The first mining was prior to 1900, but most was in 1905–19 by the Arizona Michigan Development Co. The mine has been closed since 1923, the date of merger of the Copper Chief and Republic-Mammoth properties. Production records extending back to 1903 indicate a production of 24,100 tons of ore averaging 4.2 percent copper and 0.5 ounces of silver per ton.

The principal workings, shown in figure 32, consist of the Copper Chief No. 1 inclined shaft which is 400 feet long, has about a thousand feet of drifts and crosscuts on several levels, and also raises and stopes. A vertical shaft, no longer accessible, was sunk several hundred feet northwest of (downdip from) these workings and a crosscut extended into the favorable beds 125 feet vertically below the bottom of the incline. Two other inclined shafts, known as the Copper Chief No. 2 and No. 3 inclines, are located 980 feet and 1,170 feet, respectively, northwest of the No. 1 incline. The stopes adjoining these shafts are shown on the block diagram of the Moore mine-Mammoth mine area (fig. 31).

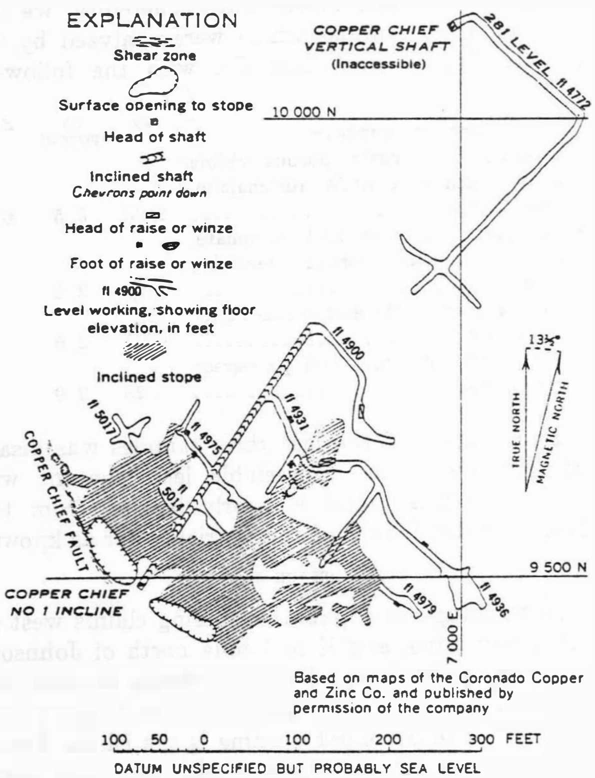

Figure 32.—Composite map of Copper Chief mine.

The Copper Chief ore bodies were tabular bedding replacements in the top 25 to 30 feet of the middle member of the Abrigo formation, which here dips 25° to 40° NE. The main ore body was exposed at the surface just east of the Copper Chief fault and was 230 feet long parallel to the strike of the beds and 5 to perhaps 20 feet thick. It ended in depth along an irregular line 100 to 325 feet down the dip of the beds. The ore was thickest and extended deepest near small Northeaster faults. The projection of the longest finger of ore is represented on the bottom level by a lens 6 inches thick. No ore was found in the vertical shaft workings though there is much slightly metalized garnetite on the dump. Diamond drilling north, east, and southeast of the vertical shaft has thus far failed to find ore.

The Northeasters are regarded as the mineralizing fissures but, for some reason, valuable deposits appear to have been formed only near the Copper Chief fault. Perhaps the Copper Chief fault was a dam for solutions rising along the intersection of Northeasters and favorable beds; or movement on the Copper Chief fault may have caused Northeasters near it to become open and permeable to ore-forming solutions. There is no evidence in the shape of the ore body to suggest that the Copper Chief fault was a channelway for the solutions.

Ore at the No. 2 and No. 3 inclines was in the same beds as at the No. 1 incline. (See fig. 31.) At the No. 2 incline, a lens roughly 6 by 60 by 140 feet in maximum dimensions has been mined. The long and intermediate axes are in the plane of the beds, and the long axis is nearly parallel to the dip. The lower part of the incline, which here cuts down gradually through the beds, and a short drift at its bottom have developed a small block of submarginal zinc ore containing some copper on the projection of the long axis of the ore body. From the No. 3 incline, about 3 feet of beds was mined, and no ore remains in the walls of the workings.

The ore produced from the three inclines is said to have been nearly all oxidized, consisting of malachite, chrysocolla, copper oxides, and native copper in a gangue of garnet and other lime silicates. The mineralized ground at the bottom of the No. 3 incline is unoxidized and consists of garnetite with some residual limestone and streaks of sphalerite and chalcopyrite.

PEABODY MINE

The Peabody mine is about a mile north of Johnson, at the north end of a low hill of Horquilla limestone. It was the first mine in the district to be extensively worked and is now nearly all caved. Therefore, information regarding the mine must come largely from descriptions of others. The following history has been pieced together from the files of the "Willcox Star" and from several other sources.

In 1882 the Russell Gold and Silver Mining Co., controlled by S. S. Campbell and other Philadelphia interests, owned the Peabody mine and started to smelt its ore in a small furnace about 2½ miles south of the mine, at what became known as Russellville, where a supply of water was available. The following year, a pipeline was laid from Russellville to the mine, and the smelter was moved there. That year, Hamilton (1883,

p. 87) wrote, "Regular bullion shipments are made, and the mine is thoroughly opened by shafts, drifts, levels, etc." Some time in the eighties, the mine was considered worked out; the smelter was removed, and the property was sold. The slag dumps resulting from this early operation indicate that perhaps 10,000 tons of ore were smelted. The value of the output has been estimated at more than $1 million (Dinsmore, 1909.).

From some time in the eighties until 1899, the property was owned by W. D. Hubbard of Hartford, Conn., who is said to have bought it for $10,000. Apparently the only mining in this period was by lessees, A. H. Wien and T. K. Mitchell, who made small shipments of high-grade ore in the late nineties.

In 1899 the Hubbard interests sold the property for $25,000 to the Dragoon Mining Co., organized by the Federal Copper Co., of New York with George Jaycocks, president, and H. J. Clifford, mine manager. The Dragoon Mining Co. started to mine vigorously. The ore was hauled to Cochise in wagons and shipped from there to the smelter in El Paso via the Southern Pacific Railroad. For nearly 3 years, a few contemporary press reports state that between 50 and nearly 200 Mexican miners were employed, and that ore shipments ranged from 3 cars per week to 2 cars per day. Production fell off in 1902, and in 1903 the company failed. The value of the production by the Dragoon Mining Company has been variously estimated between $250,000 and $1,000,000.

Between 1907 and 1918 the Peabody mine was worked by the Bonanza Belt Copper Co. and its successor, the Peabody Consolidated Copper Co. The recorded production was 14,200 tons of ore averaging 7.5 percent copper and 4 ounces of silver per ton. The mine has been closed since 1918, though lessees have shipped a few hundred tons of ore, sorted from the dumps.

The Peabody mine is in the Horquilla limestone, which, in the vicinity of the mine, is recrystallized and has thin bands of garnet, idocrase, wollastonite, and other lime-silicate minerals. Chalcopyrite, bornite, and sphalerite—or more commonly their oxidation products—occur in the silicated layers and along crosscutting fissures. A host of prospect pits and opencuts are scattered over the hill slope; the main workings are at the north end of the outcrop area and extend out under the alluvial cover. In the small part of these workings that was accessible in 1945 (fig. 33), tabular ore bodies were mined in the plane of the beds and in the plane of a typical Easter. A few Northwesters are known but typical Northeasters seem to be wholly lacking. According to Scott (1916, p. 141), the ore "occurs in a contact vein between lime and diabase and in several replacement veins all within a 100-foot belt." The "diabase" is almost certainly the lamprophyre of our report, as shown by fragments on the dumps.

According to Scott (1916, p. 141), the ore at the Peabody mine was oxidized to a depth of 200 feet—which is probably about the maximum depth reached. The ore mined in the eighties was very rich in copper and silver, according to local residents and according to Dinsmore (1909) who stated that it was rarely below 15 percent copper and that many carloads ran 40 to 45 percent. The ore produced after 1906 averaged 7.5 percent copper and 4 ounces of silver per ton.

We found no reference to the occurrence of zinc in the mine but did find a few pieces of high-grade sulfide and oxide zinc ore on the dump. As oxidized zinc minerals are difficult to recognize in the field, dry bone ore might have been overlooked. Therefore, we collected four grab samples which were analyzed by the Coronado Copper and Zinc Co. with the following results:

Description of specimen	*Cu*	*Pb* (*percent*)	*Zn*
1. Oxidized zinc ore, rusty, porous, visible hemimorphite, a little aurichalcite, and malachite	2.95	3.5	44.2
2. Many seams of silica and carbonate, weathered surface porous resembling bone	.38	3.2	.5
3. Porous, cut by white and reddish gray carbonate veins	.25	2.6	.3
4. Rusty, seams of white and pale-green carbonate	.23	2.9	.2

The zinc content of the last three samples was disappointingly low. The appreciable lead content was surprising as this metal is nearly lacking from the replacement sulfide ores of the district so far as known.

BLACK PRINCE WORKINGS

Mine workings on 8 patented mining claims west of the Peabody mine, and ½ to 1 mile north of Johnson, are known as the Black Prince workings because the work was done by the Black Prince Copper Co. (1901–11). The principal opening is the Black Prince vertical shaft, said to be nearly a thousand feet deep: a crosscut was driven toward the southwest on the 900 level. The shaft was inaccessible at the time of our fieldwork but was reconditioned by the Coronado Copper and Zinc Co. in 1957 to get drill sites for deep exploration. No ore was found in the shaft or the crosscut. The shaft is entirely in the Horquilla, Black Prince, and Escabrosa limestones; but units 5, 6, and 7 of the Martin formation were reached in the crosscut (Richard Bergman, oral communication, 1957). The favorable beds of the Abrigo formation were tested by drilling from the crosscut, but, to our knowledge, no ore was found.

In addition to the shaft there are numerous pits,

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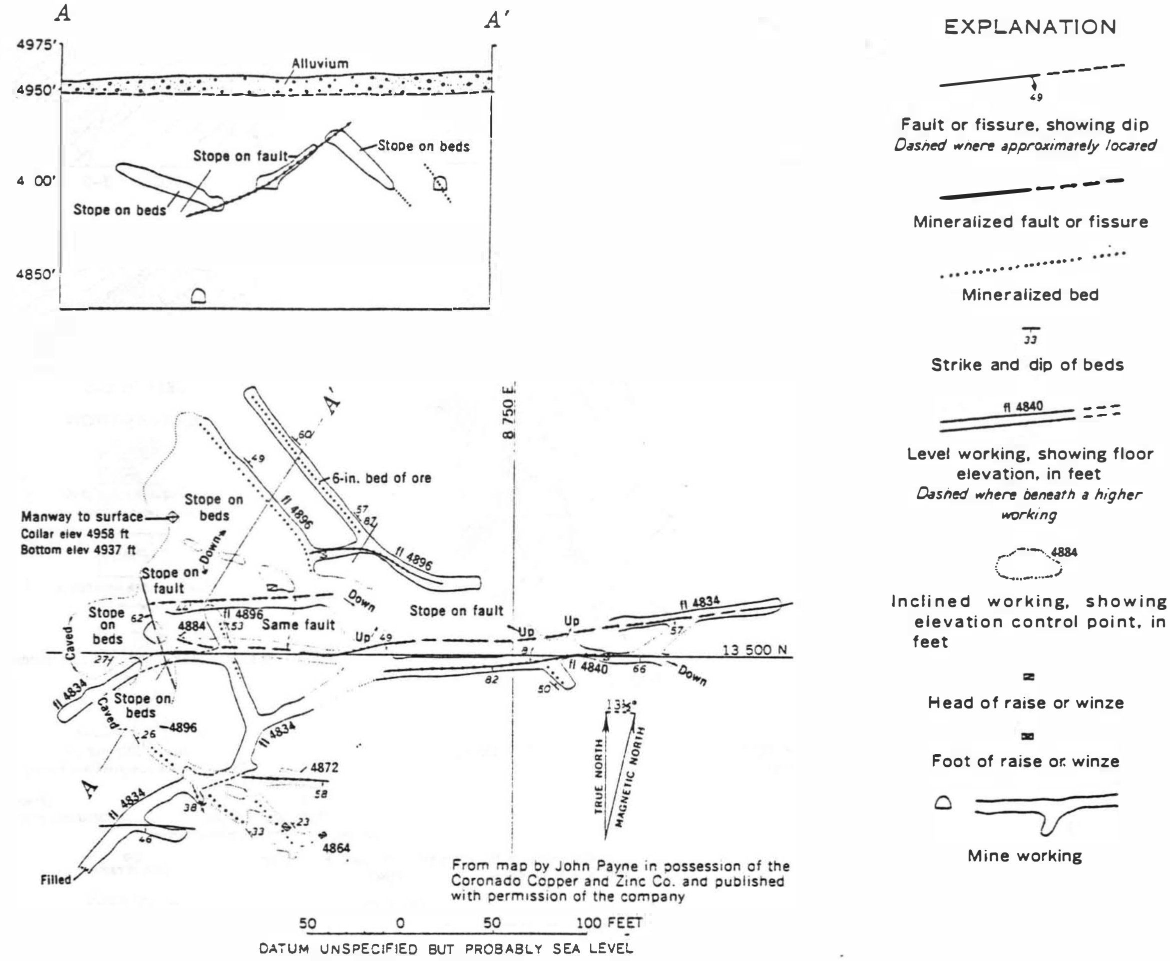

FIGURE 33.—Composite geologic map and cross section of the accessible part of the Peabody mine.

several small underhand stopes from the surface, and the Copper Bell adit which is 1,100 feet south-southeast of the shaft. The only production recorded is 1,400 tons of ore, which averaged 8.6 percent copper and 5 ounces of silver per ton, and which was shipped from the Copper Bell adit and nearby surface workings in 1902–18.

All the limestone of Carboniferous age exposed at the surface contains traces of copper minerals and a few stringers rich in quartz and bornite. Commercial ore appears to be confined to thin layers in the Horquilla limestone and to concentrations along fault fissures. These occurrences are illustrated at the Copper Bell adit, shown in figure 34. Oxidized ore was here mined along a typical Northeaster and, to a more limited extent, from a thin band of garnetite in the Horquilla limestone. The sulfides bornite, chalcopyrite, and sphalerite occur in the garnetite on the adit level. Sulfide ore appears to have been of no interest to the miners for the garnetite band was not explored on the adit level, even though it carries appreciable quantities of sulfides, particularly bornite, at the two places exposed. The small fold, to be seen on the surface and used as a basis for the interpretation of underground map and cross sections, is an uncommon type of structural feature in the Johnson district.

MACKAY GROUP

Several claims between the Peabody mine and the Climax (Johnson Copper Development) shaft are known as the Mackay group. During 1900 and 1901, the "Willcox Star" reported shipments of rich copper ore from this property, first by Melzer Osborn and Sam Bigler, and later by Col. H. C. Hooker and associates, who purchased the property in 1900. The production came from the Magazine and Peoples Party claims that adjoin the Peabody claim on the southwest and southeast respectively. In 1906 and 1907 the Magazine Copper Co. shipped 454 tons of ore, which averaged 7.3 percent copper and 3.1 oz per ton silver and was reportedly from the Peoples Party claim. No record of later production has been found.

The bedrock is the Horquilla limestone, which ap-

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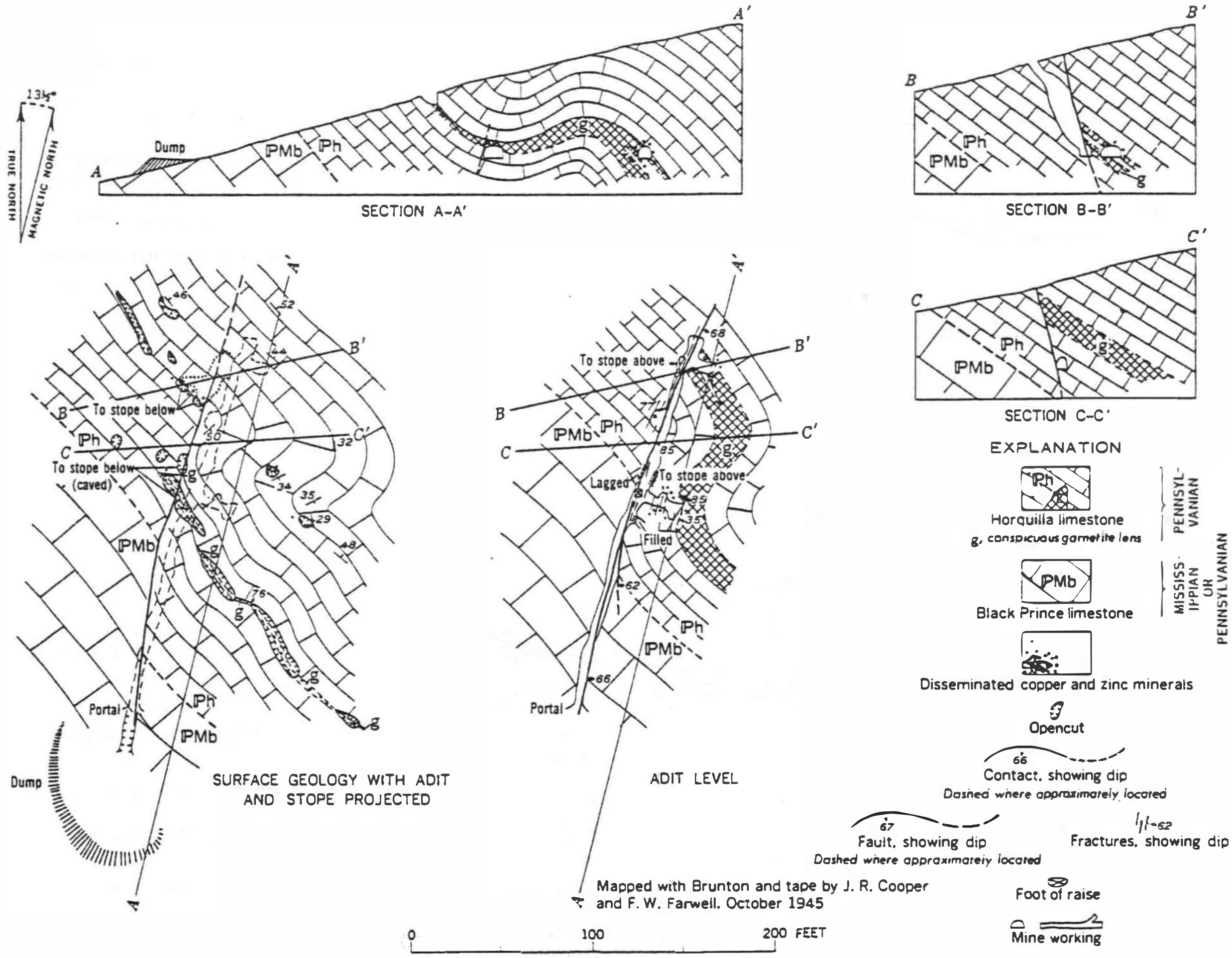


FIGURE 34.—Geologic maps and sections of the Black Prince (Copper Bell) adit.

pears to be mineralized in the same way as in the nearby Peabody, Black Prince, and Johnson Copper Development workings. Ore minerals—principally bornite, chalcopyrite, and their oxidized equivalents—are concentrated locally in silicated beds, which are generally less than 5 feet thick and which are separated by much thicker beds of barren limestone. The most extensive workings are on the Peoples Party claim and consist of a vertical shaft now inaccessible and many pits and small underhand stopes. These workings are on the faulted extension of the beds that are mineralized on the Peabody claim. The ore on the Magazine claim came from a shallow incline and surface workings.

JOHNSON COPPER DEVELOPMENT (CLIMAX) SHAFT

The Johnson Copper Development shaft is on the Climax claim, which is just southwest of the old Mackay group and southeast of the Black Prince group (pl. 6). The shaft, said to be more than 700 feet deep, was sunk between 1908 and 1916(?) by the Johnson Copper Development Co. A little additional work by this company was done at intervals through 1930. The shaft has not been maintained in recent years and is no longer accessible. Little if any ore came from it, for the total recorded production of the Johnson Copper Development Co. was half a dozen small shipments between 1912 and 1930, totaling only 207 tons of ore. Some of this ore came from open pits on the property. The grade (average 9.9 percent copper, 5.2 ounces per ton silver) was good and similar to that of the ore from the nearby Peabody, Black Prince, and Mackay workings.

Local miners report that the upper part of the Climax shaft is vertical and the lower part inclined. According to Scott (1916, p. 141), it is vertical to a depth of 250 feet where there is a 500-foot drift and a 500-foot winze. The collar is in the Horquilla limestone, and the dump suggests that the workings are entirely within the formations of Carboniferous age. Copper carbonates were found near the surface, and bornite has been reported at depth (Dinsmore, 1909, p. 834; Scott, 1916, p. 142).

OTHER PRODUCTIVE WORKINGS

The Coronado Copper and Zinc Co. property includes the outcrop of the favorable beds in the Abrigo formation between the Republic mine and the Keystone fault. Part of the early production from the district came from opencuts and shallow inclines in this area. Ore was mined from several zones in the middle member of the Abrigo formation. The largest and presumably most productive workings (no longer accessible) are on the Chicora and Southern claims, which were patented in 1882 and have belonged to the owners of the Republic mine since that date. The Mayflower claim, which adjoins the Chicora on the north and the Republic on the east, was worked early in this century by a local company called the Mayflower Mining Co. with George Parsons, manager. Two carloads of ore averaging 5½ percent copper were shipped late in 1907 from a short incline below the outcrop. Soon thereafter a vertical shaft, called the Mayflower shaft, was sunk to intersect the mineralized beds several hundred feet below the surface. There is no record of ore shipments from the shaft. The size and composition of the dump indicate that underground workings are not extensive though the middle member of the Abrigo formation evidently was reached.

In 1905, 50 tons of ore averaging 12½ percent copper was shipped from an opencut on the Copper King claim 300 yards north of the Republic shaft. The ore occurred in the Escabrosa limestone along a small and relatively steep Easter, a short distance south of the Republic fault. The ore pocket appears to have been completely mined out. Its importance is in suggesting that ore bodies of importance may occur if similar structural conditions are duplicated in depth where the favorable beds of the Abrigo formation make up the hanging wall of the Republic fault.

KEYSTONE COPPER MINING CO. PROPERTY

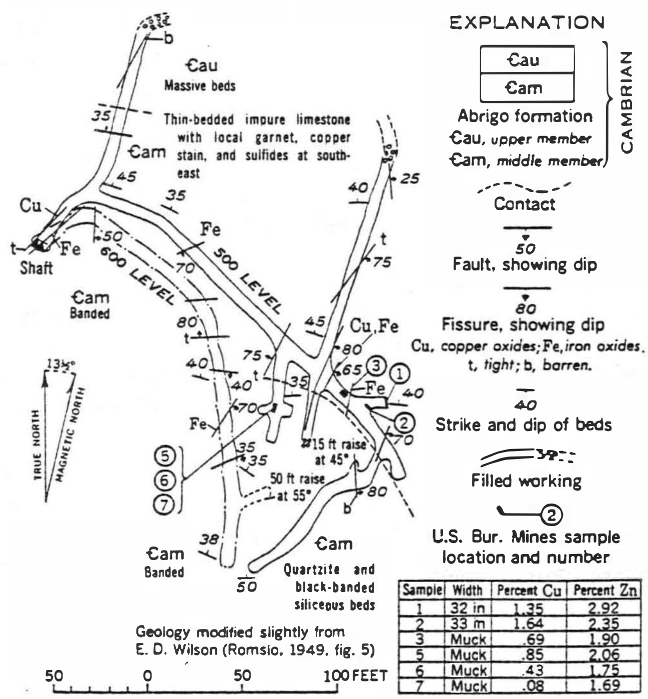
The Keystone Copper Mining Co. of Dragoon (N. M. Rehg, president and general manager; executive office El Dorado, Kans.) owns 50 unpatented claims and fractions, southeast of the Coronado Copper and Zinc Co. property. The Keystone property includes a small block of ground just west of the Keystone fault and most of the outcrop of the Paleozoic formations east of that fault. Development consists of many pits and shafts, the deepest of which are the Keystone (Hagerman) and O.K. shafts. A 200-ton flotation concentrator was completed near the Keystone shaft in 1925 and was operated for a brief period. Most active mining was during World War I, and the last shipments were in 1937. Records for the period 1916–37 show a total production of 1,853 tons of ore averaging 4½ percent copper. This ore came from the O.K. and Keystone shafts and from other workings.

In 1947 and 1948 the U.S. Bureau of Mines drilled 20 exploratory diamond-drill holes near the Keystone shaft and 2 holes near the O.K. shaft. Nine of the holes near the Keystone shaft were on the St. George claim, which was owned by F. M. Lebold and S. N. Lebold of Chicago rather than by the Keystone Copper Mining Co. The detailed results of the work have been published by the Bureau of Mines (Romslo, 1949). In the following pages, the results are discussed in more general terms in connection with the mine involved.

KEYSTONE (HAGERMAN) MINE

The Keystone or Hagerman mine is a mile southeast of Johnson near the Dragoon road. Access is by a vertical shaft reported to be 680 feet deep. Levels known as the 60, 200, 300, 500, and 600 are 60, 200, 325, 487, and 565 feet, respectively, below the collar. In 1945 water was standing in the shaft about 3 feet below the 600 level. We did not examine the underground workings because ladders had been removed from the shaft and the hoist was not operating at the time of our work in the vicinity. The mine map (fig. 35) is taken from the report by Romslo (1949, fig. 5) and shows geology of the deeper levels as mapped in 1945 by E. D. Wilson of the Arizona Bureau of Mines. Surface geology and sections are shown on plate 11.

Ore produced from the Hagerman workings is said to have come largely from the upper levels, presum-



Sample	Width	Percent Cu	Percent Zn
1	32 in	1.35	2.92
2	33 in	1.64	2.35
3	Muck	.69	1.90
5	Muck	.85	2.06
6	Muck	.43	1.75
7	Muck	.08	1.69

FIGURE 35.—Geology of the 500 and 600 levels from Keystone (Hagerman) shaft.

ably from the Escabrosa and Martin formations. No maps or other data are available for these levels, which were not readily accessible in 1945. The 500 and 600 levels are in the Abrigo formation. At the east end of the 500 level, the middle member is partly garnetized and, at one place, about 3 feet of beds are weakly mineralized with copper and zinc sulfides (fig. 35).

Bureau of Mines drill hole 1 confirmed the extension of this mineralized zone about 20 feet southeast of the showing on the 500 level as shown on section *B–B′* (pl. 11). Drill holes farther southeast failed to reveal its presence but indicate two other loci of low-grade sulfide mineralization, as shown on section *A–A′* (pl. 11). Along the line of section *A–A′*, for a distance in excess of 160 feet, parts of unit 5 of the Martin, 2 to 13 feet thick, contain 0.6 to 1.2 percent copper but little other metal. The Abrigo formation is mineralized somewhat sporadically in the vicinity of a fault inferred from the absence of beds in the drill holes. This fault, which was not observed at the surface, has a calculated strike of N. 63° E., a dip of 36° SE., and normal displacement. It is classified as an Easter and regarded as premineralization. The Abrigo formation near it contains local concentrations of chalcopyrite and sphalerite and also concentrations of molybdenite. The best molybdenite showings are in the upper member and include 0.9 of a foot of 4.1 percent molybdenum in hole 23 and 7.3 feet of 1.02 percent molybdenum in hole 22. Complete assay data for all the holes are given by Romslo (1949, p. 18–21). The metal occurrences are of interest chiefly in clarifying the geologic factors that localized the metals and in providing leads in the search for commercial ore bodies.

O.K. MINE

The O.K. mine is near the northwestern boundary of the Keystone property and 1,800 feet southeast of the Republic shaft. Development consists of an inclined shaft, which is reported to be 450 feet long, and some short level workings and small stopes (fig. 36). In 1945 water was standing in the shaft at an elevation of 4,723 feet, 385 feet on the incline and 223 feet vertically below the collar. Several carloads of ore were shipped from the mine prior to 1920 ("Willcox Star," Apr. 30, 1920).

The shaft is at the very top of the Abrigo formation and is parallel to the dip of the beds, which strike about N. 30° W. and dip 30° to 35° NE. The basal beds of the Martin formation are exposed at places in the workings. Small faults and fissures strike N. 30° to 70° W. Near the surface the quartzite unit at the top of the Abrigo formation contains seams and pockets of iron oxide and oxidized copper minerals, mostly chrysocolla. A small ore body in this unit was mined just north of the shaft, as indicated on the mine map (fig. 36). The ore body was about 6 feet thick, judging from ore remaining in the stope walls and pillars.

At a depth of 330 feet along the incline, the shaft intersected a steep northwestward-striking vein, 1 to 4 inches thick, of chalcopyrite, sphalerite, and pyrite associated with quartz and oxidized ore minerals. This vein has been explored by a drift 150 feet long and a winze 10 feet deep. A little stoping has been done along the vein.

To test the possibility that the known deposits might represent leaks from a larger body in more favorable beds below, the U.S. Bureau of Mines drilled two diamond-drill holes at the points indicated on the map. A few bands that contain scarce chalcopyrite were found in the upper member of the Abrigo formation in both holes but the middle member was unmineralized. Assay data and abbreviated geologic logs of the holes are given by Romslo (1949).

ST. GEORGE CLAIM

The St. George patented mining claim, just south of the Keystone (Hagerman) shaft, was worked prior to 1890 and was intermittently worked to the early years of this century. It was owned in 1955 by F. M. Lebold and S. N. Lebold, of Chicago. The principal development is in the Martin formation and consists of an open pit from which several inclines—now inaccessible—descend parallel to the dip of the beds. According to the "Willcox Star" of July 3, 1903, 25 carloads of ore averaging 7.5 percent copper had been shipped prior to that date. There is no indication of subsequent production.

The surface geology and sections of the claim are shown on plate 11. The ore mined occurred at the top of unit 1 of the Martin formation and, judging from remnants in the cut and on the dump, appears to have been thoroughly oxidized. Perhaps 2 to 5 feet of beds was mined, but little of the remaining material appears to be of ore grade. Drill holes reveal only scarce traces of metalization at this horizon (pl. 11).

Diamond-drill holes a short distance northeast of the open pit revealed a zone of disseminated ore minerals in the middle member of the Abrigo formation (section *C–C′*, pl. 11). The mineralized beds are lower stratigraphically than the large ore bodies of the district but are about at the horizon of the West Manto ore body of the Republic mine and shallow ore bodies on the Chicora and Southern claims. The ore minerals are chalcopyrite, sphalerite, bornite, and scarce scheelite and molybdenite. The gangue is largely garnet and other lime silicates. Only thin streaks are of ore grade.

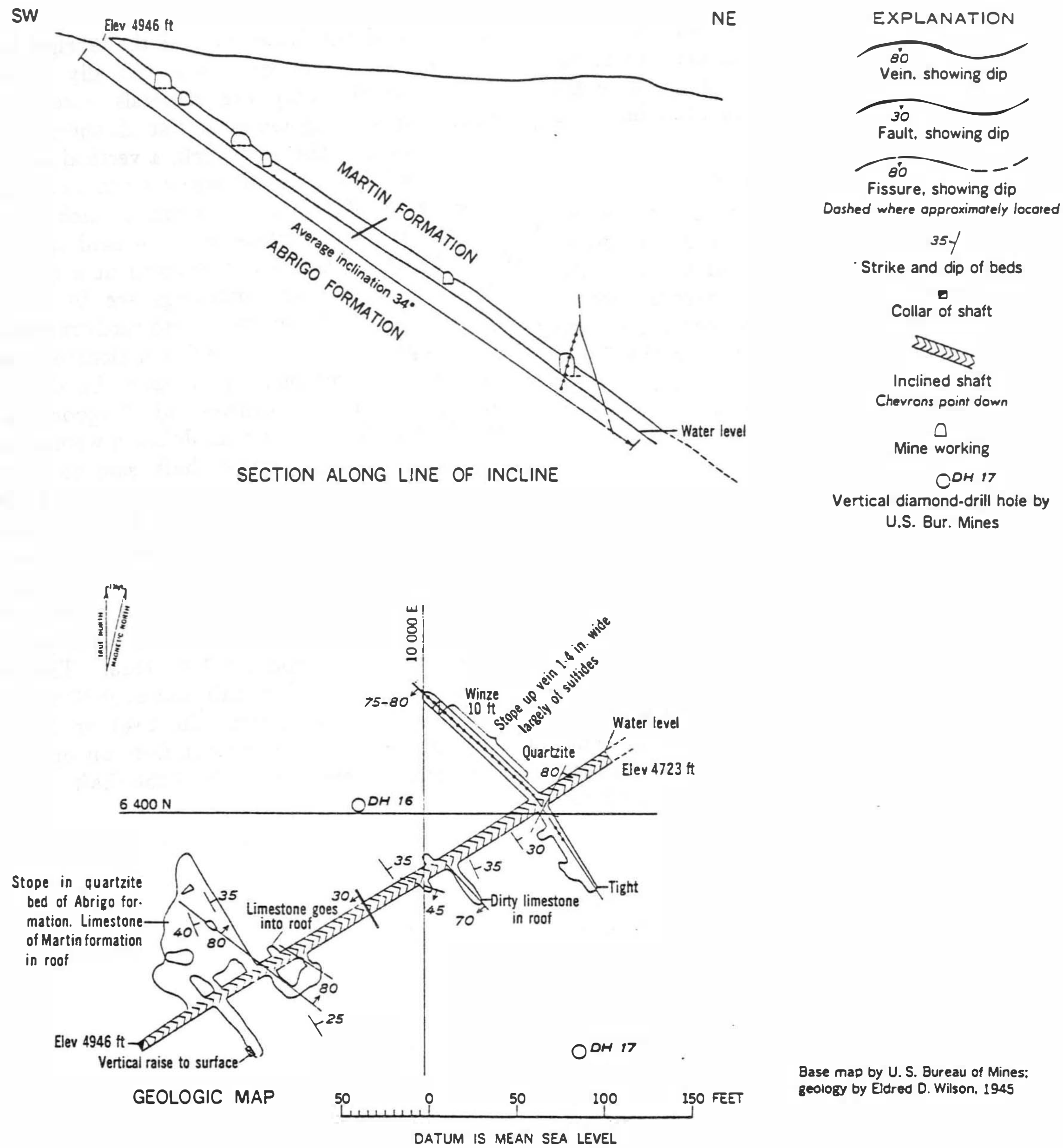


FIGURE 36.—Geologic map and section of the O.K. mine.

The richest concentration is in drill hole 5, in which one 5-foot interval averaged 2.2 percent copper, 2.2 percent zinc; and another 15.8-foot interval averaged 1.9 percent copper, 3.6 percent zinc. In adjacent drill holes 10, 11, and 12, the thicker interval is represented by 12.7 to 18.5 feet ranging in grade from 0.9 to 1.3 percent copper and 0.6 to 1.8 percent zinc. Detailed assay data and abbreviated logs of the holes are given by Romslo (1949).

Parts of the middle and upper members of the Abrigo formation are missing in all the drill holes on the St. George claim. To explain the absence of beds, we have inferred a preore fault that is approximately parallel to the bedding, as shown on the sections (pl. 11). This fault has not been recognized at the surface but could explain the peculiar and unexplained narrowing toward the west, of upper units of the Abrigo and the Martin as shown on the geologic map (pl. 11). Drill holes 7, 8, and 9 in the western part of the claim indicate complex faulting that cuts out hundreds of feet of beds, as shown in section *C–C′* (pl. 11). This could be due to faults similar to the one inferred farther east or to the Keystone fault, which trends northeast and has a throw of about a thousand feet. The former interpretation is shown tentatively on the section because the trace of the Keystone fault on the topography indicates a steep dip.

PROSPECTS NEAR JOHNSON

There has been considerable prospecting in the vicinity of Johnson beyond the limits of the properties so far described, both beneath the alluvial cover to the east and in the bedrock exposures to the west and south. Although traces of ore minerals have been discovered in every formation down to and including the Pinal schist, no ore has been produced so far as known and no promising signs for disseminated deposits of importance have been uncovered. Some notes concerning a few of the more extensive workings follow.

PITTSBURG (COCHISE DEVELOPMENT CO.) SHAFT

The Pittsburg shaft, 1,850 feet east-southeast of the Peabody shaft, was sunk in 1907 by the Cochise Development Co. The shaft is vertical and said to be 600 feet deep. A crosscut on the 500 level is reported. The collar is in alluvium but limestone and hornfels of the Horquilla limestone were reached. No ore was produced but the dump shows traces of copper minerals. Work ceased about 1910 but the Pittsburg claim and the Treasure claim which adjoins it on the northwest were patented in 1917 and were owned in 1955 by Mrs. Thomas Adams of Dragoon.

LIME MOUNTAIN WORKINGS

The Lime Mountain workings consist of several adits totaling about 1,200 feet in length on the east flank of Johnson Peak 1½ miles northwest of Johnson. The earliest work in the area appears to have been by the Lime Mountain Copper Co., formed in 1907, but much of the work was done by Mr. Pete Dworshek of Johnson who later held the claims. The adits explore parts of the Martin formation and the upper member of the Abrigo formation in the vicinity of northward-trending faults. The formations are not metamorphosed. Traces of oxidized copper minerals are to be seen here and there in the sheared and locally silicified rock that marks the faults. No ore has been produced.

EMPIRE WORKINGS

The Empire Gold and Copper Mining Co., formed by Los Angeles and Arizona interests with J. L. Brooks as president and general manager, did much exploratory work west of Johnson in 1905–09. No ore was produced. The first work was in the form of 3 adits which are on the south slope of Johnson Peak, 1½ miles west of Johnson. There are in all about a thousand feet of drifts and crosscuts and a connecting raise roughly 150 feet long. The upper part of the Bolsa quartzite and the lower part of the Abrigo formation are explored. The rocks are virtually unmetamorphosed and the only ore minerals noted are weak copper stains along joints and small shear surfaces.

In addition to the adit work, a vertical shaft known as the Empire No. 1 shaft was sunk in the Pinal schist 1 mile west of Johnson. The shaft, which is now completely filled with surface wash, is said to have been 400 feet deep. A 150-foot crosscut at a depth of 225 feet is reported. The workings are in the slightly broken ground between two northward-trending faults. Some copper stains are to be found along cracks.

In 1909 the company purchased the O. T. Smith property, 1½ miles southwest of Dragoon, and soon thereafter the operations near Johnson were abandoned. The Empire No. 2 vertical shaft, said to be 300 feet deep, was sunk on the property west of Dragoon. (See pl. 1.) The shaft is in the Horquilla limestone, which is partly silicated and cut by small quartz veins that contain bornite, chalcopyrite, and locally galena and scheelite. Shipments of 60 tons of ore averaging 11 percent copper and 4 ounces of silver per ton are reported for the period 1909 to 1913. The property later reverted to O. T. Smith and in 1947 was held by Lynn Burrell of Dragoon. In 1946 or 1947 Bruce Gilbert made a small shipment from an opencut on a narrow quartz vein just south of the shaft.

Appendix 2

exerpts from

Famous Mineral Localities:
Bisbee, Arizona

by Richard W. Graeme

The Mineralogical Record
V. 12, no. 5
September-October 1981

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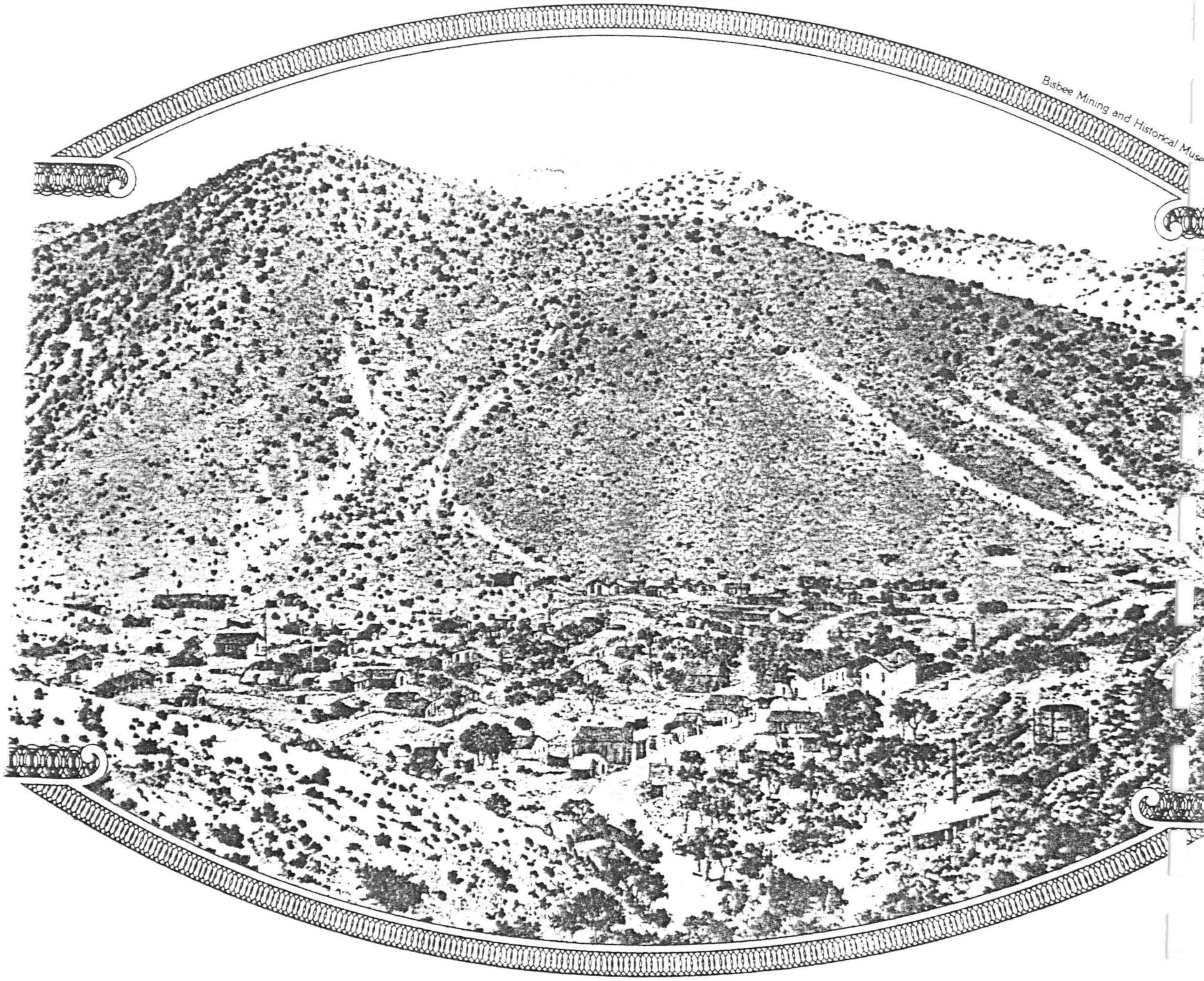


Early Bisbee

2-2

famous mineral localities:

Bisbee, Arizona

by **Richard W. Graeme**
P.O. Box 440
Hanover, New Mexico 88041

Bisbee, Arizona, ranks among the most famous and prolific of all American mineral localities. Vast numbers of exceptional specimens populate museums and private collections around the world. Though most famous for azurite, malachite and other copper minerals, Bisbee has produced more than 200 different mineral species since the first claim was filed over 100 years ago.

Introduction

Bisbee is located in the Warren mining district of Cochise County, Arizona. Situated in the Mule Mountains at an average elevation of 4950 feet, this picturesque community has grown up along the steep canyon walls. Once a city of 25,000 (Cox, 1938), it is today the home of some 8,000 people.

Typical of the basin and range province, the Mule Mountains rise about 3250 feet above the surrounding broad valley plains, achieving a maximum elevation of 7300 feet. This provides a very temperate environment with the summer temperatures seldom above 95°F while the winter minimums are infrequently below 25°F. Rainfall has an annual mean of 18 inches, most of which falls during July and August in brief but often violent thunderstorms.

The hills, once stripped of their growth, are now sparsely covered with oak and low brush grading into juniper and piñon pine with a few isolated stands of ponderosa pine at the higher elevations. Deer, javelina and game birds are common in the areas surrounding the town.

Active mining began late in 1877 and continued with only minor interruptions until mid-1975. During the last century, hundreds of millions of tons of ore and waste were removed from two open pits and nearly 2000 miles of underground workings. All of this was within a zone approximately 2 by 3 miles, with an overall depth of 4000 feet . . . roughly 4.6 cubic miles.

Copper was by far the most important metal; however, zinc, lead, silver, gold and manganese have all been economically significant. Indeed, Bisbee has produced more zinc, lead, silver and gold than any other district in Arizona.

Gold and silver production was not significant in the district until the early years of this century with the advent of electrolytic refining. Manganese was, for the most part, mined only during the two wars.

Metal production through 1975 is listed below for copper, zinc, lead, silver, gold (Stanley Keith, personal communication) and manganese (Mills, 1956).

Copper	**Zinc**	**Lead**
7.7 billion pounds	355 million pounds	324 million pounds
Silver	**Gold**	**Manganese**
100 million ounces	2.7 million ounces	10,989,900 pounds

The amount of copper produced, nearly 8 billion pounds, is difficult to imagine. It would form a cube of solid copper 241 feet on an edge, nearly the length of a football field. Copper is still being produced by leaching of the pit, dumps and underground mines. This should continue for many years.

Ownership of all the important mines remains in the hands of Phelps Dodge Corporation. The workings and hills containing them are quite hazardous and therefore closed to all entry.

History

The settling of the many mining districts of the American West is filled with stories of men and women of exceptional courage and foresight; Bisbee is no exception. Perhaps even greater quantities of these rare virtues were required of those who chose the desert Southwest. An unforgiving land, it claimed more lives than all of the Indians and outlaws combined. The Mule Mountains and their main canyon, Mule Gulch, at least, were a bit more hospitable. Here was water and abundant game among the great oaks, willows and tangled wild grape vines lining the stream.

A search for water (and hostile Apaches) brought John Dunn and his party to this canyon. A member of a government scouting party from Camp Bowie, Dunn camped with his group at the first spring they found. The next day, the water being disagreeable, Dunn went further up the canyon until he found a fine spring near what is now known as Castle Rock.

Returning to his group along the rough, south side of Mule Gulch, he found a piece of cerussite float. He traced it to an outcrop at the base of a huge pinnacle of hematite, later known as the Iron Monster (Duncan, 1911). Along with Lieutenant J. A. Rucker and T. D. Bryne, Dunn located the first claim in the district on August 2, 1877, calling it the Rucker claim.

Bisbee Mining and Historical Museum

Figure 1. **John Dunn, discoverer of the first ore near Bisbee in 1877.**

On the way back to Camp Bowie, Dunn met George Warren, a prospector. Dunn told him of his find and grubstaked him. Warren was supposed to locate as many claims as possible, naming Dunn in each. This agreement was never honored by Warren.

As a young boy, George Warren was wounded and captured by the Apaches when they killed his father. For 18 months, he remained their prisoner. Prospectors, upon seeing a white boy with the Indians, traded 15 pounds of sugar for him. Warren then stayed with the prospectors for some time, learning the "art" himself (Hart, 1926).

Many of the claims located in the district during the next six months had Warren as either the locator or a witness. In spite of his early work, George Warren, for whom the district is named, is better remembered for his folly. Legend has it that he lost his share in the Copper Queen mine in a foot race with a horse and rider over a short course . . . a loss that ultimately was worth more than $20,000,000 (Duncan, 1911). The remainder of his property was taken into "protective custody" by some unscrupulous associates.

Penniless, Warren went to Mexico and sold himself into peonage. Judge G. H. Berry, hearing of this, paid his debt and returned him to Bisbee in 1885. With a small pension from the mining company, George Warren spent the remainder of his life sweeping saloon floors and cleaning cuspidors in exchange for drinks of rotgut whiskey. He died in about 1895, disdained and soon forgotten (Hart, 1926).

The early years in Mule Gulch, as Bisbee was then known, were uncertain ones. The cerussite outcrop found by Dunn was very small and soon gone. A second and much larger prospect had been found in Hendricks Gulch, large enough to warrant building a small smelter, but this venture too ended in failure. Bisbee was struggling to survive.

The copper stain long known to exist on the Copper Queen claim had, to this point, been of little interest. Silver, often found mixed with lead, was the most sought after metal, not copper. Then, with just a little development, the rich ores that became so famous were uncovered.

In the spring of 1880, Edward Riley optioned the Copper Queen claim for $20,000. Having no money himself, he sold half interest in the mine for the same amount to Messieurs Martin and Ballard through the mining firm of Bisbee, Williams, and Company in San Francisco. With this action came the formation of the Copper Queen Mining Company.

Until then, the ore had been carried by 24-mule team wagons to the West Coast, then shipped to Wales for smelting. To eliminate this terrible expense a smelter was soon erected under the direction of Lewis Williams while his brother Ben took charge of the mining. Operations began in earnest and at a profit.

In June of 1881, D. W. James and W. E. Dodge, the principals of Phelps, Dodge, and Company, asked Dr. James Douglas to examine the Atlanta, a claim adjoining the Copper Queen mine. This claim had been offered to the company for $40,000. Douglas was chosen because he had previously been in Mule Gulch to visit the Copper Queen (Douglas, 1909).

Making the requested examination, Douglas emphatically recommended the purchase, but cautioned "that the risks were too great to be taken by a purchaser who was not able and prepared to lose all that he had invested," (Douglas, 1909). The risks were accepted. Thus entered an old established mercantile firm into mining, an entry that was to build one of the greatest copper companies in the world.

Douglas himself was placed in charge of exploration on the Atlanta claim. An anomaly in this rough, primitive camp, he was well educated, cultured, and sensitive to the needs of others. Though often monetarily poor, he was a man of exceptional integrity. When asked about his fee for examining the Atlanta and given the choice of cash or a share of the mine, he reflected, "the cash was greatly needed, but I told them that as I had advised them to take more than an average risk, I would share it with them. And on that sudden impulse and hasty decision depended my whole subsequent career—successful beyond anything I had ever dreamed of," (Langton, 1940).

For over 2 years Douglas searched and explored, sinking prospect holes on small bunches of ore wherever they could be found: two years of vexation and disappointment. Having spent $80,000 in these effects, James and Dodge were thoroughly disheartened—not a single car of ore had been produced.

It was now the spring of 1884, the neighboring Copper Queen orebody had suddenly pinched out and only 90 days of ore remained. All efforts at the Copper Queen to find an extension of the ore failed. Douglas still could not believe that only one orebody was here—surely others were nearby. So it was that James and Dodge, with much misgiving, committed a final $15,000 for a 400-foot shaft on James Douglas's faith. Douglas reflected, "John Prout and I selected the site where the shaft was to be sunk. But long before it reached the 400-foot level, the gloom which hung over both companies had been dissipated, for at 210 feet from the surface the shaft penetrated a very rich orebody, which was almost simultaneously entered by the level being driven east from the foot of the Copper Queen incline. The Atlanta shaft was sunk for 200 feet through ore," (Douglas, 1909).

After some months of negotiations, the terms of amalgamation were arrived at and, in 1885, the Copper Queen Consolidated Mining Company was formed (hereinafter referred to simply as the Copper Queen Company). This precluded, for the time being at least, the bitter litigation over ownership of the apex of the ore that was so common in many of the western mining camps.

During these years the camp, now called Bisbee after Judge DeWitt Bisbee of San Francisco (an investor in the mines and father-in-law to Ben Williams), had its problems. The threat of Indian attack was still very real. Often were the times when the mine whistle would sound the warning: Apaches had been sighted! Men would grab their rifles while the women and children sought safety in the Copper Queen mine (commonly just called "the Queen") where supplies of food and water were kept for such emergencies.

While the town itself was never attacked, many of the nearby ranches were. In June of 1885, Billy Daniels, a deputy sheriff of Bisbee, and several other men were ambushed at the mouth of Mule Gulch. Daniels was killed but the others escaped (Duncan, 1911).

The often savage acts by the Indians were no match for the heinous crimes the early citizens of Bisbee suffered at the hands of their own. From its first murder in August 1880 until the formation of a citizens vigilance committee for public safety, the "Forty-five-sixty" in March of 1891, nearly two dozen people were shot down. The "Bisbee Massacre" of December 8, 1883, was the most tragic of these crimes:

Arizona Historical Society

Figure 2. **George Warren, itinerant prospector who filed many of the early claims in the mining district that was later named for him.**

In hopes of getting the mine payroll, five masked men robbed the Goldwater and Castaneda store, where it was to be deposited upon arrival. While three men went into the store, the others remained outside guarding the street. Johnny Tappiner, a splendid young man, stepped unawares from the Bon Ton Saloon and was shot. Coming out of Joe May's saloon at the same time, a man named Howard was shot. Tom Smith, a deputy, immediately commanded that the shooting stop. He was shot twice and killed. Mrs. Annie Roberts, an expectant mother, was killed when the outlaws fired through the open doors of her restaurant. Running out of the Azurite Saloon, J. A. Nally was shot and so seriously wounded that he died within a few days (Duncan, 1911).

For all their violent actions, very little reward was to be had; the payroll had not yet arrived. Taking all they could find, $600 and a gold watch, they fled to the east. The stage with some $7000 in payroll money arrived less than an hour later.

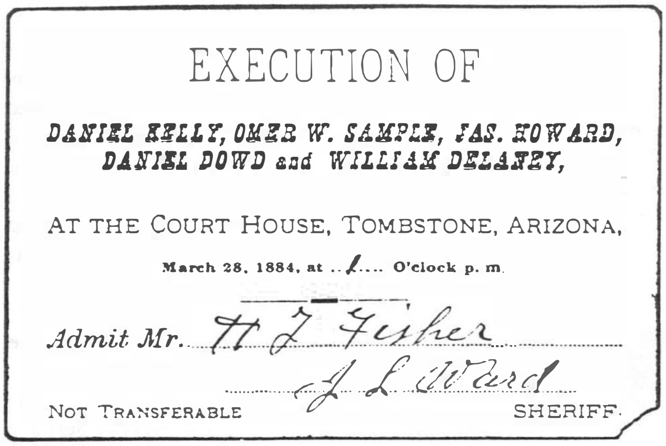
A posse was formed and the trail of the outlaws found. Just outside of Mule Gulch, one John Heath, an early volunteer to the group, tried to persuade Deputy Sheriff Billy Daniels that the bandits had turned north. Daniels, unconvinced, led the posse across the Sulphur Springs Valley to the Chiricahua Mountains, while Heath and another man went north.

The outlaws had returned to a prospector's cabin where just a few weeks earlier they had planned the crime. Dividing the loot, they then separated. Daniels, after a discussion with a prospector, was told the names of these desperados and learned that the man who masterminded the whole affair had not returned with them, his name—John Heath. Daniels sent word to arrest Heath and continued on in pursuit of the others.

The outrage that followed the crime united many people in the effort to capture the remaining five. Within a few weeks, their work was finished and all were confined in the Tombstone jail. One was captured in New Mexico; two near Clifton, Arizona; one in Chihuahua, Mexico; and the last in Sonora, Mexico.

All five of the outlaws were tried together, found guilty of first degree murder, and sentenced to be hung. Heath was tried separately, found guilty of second-degree murder, and sentenced to life imprisonment. This so angered the people of Bisbee that a group went to Tombstone, removed Heath from the custody of the Sheriff, and lynched him from a telegraph pole. To the end, Heath swore his innocence. The general acceptance of this action is shown by the coroner's jury verdict that: "We the undersigned, a jury of inquest, find that John Heath came to his death from emphysema of the lungs—a disease common in high altitudes—which might have been caused by strangulation, self-inflicted or otherwise," (Hankin, undated).

Arizona Historical Society



EXECUTION OF

DANIEL KELLY, OMER W. SAMPLE, JAS. HOWARD,
DANIEL DOWD and WILLIAM DELANEY,

AT THE COURT HOUSE, TOMBSTONE, ARIZONA,

March 28, 1884, at ..1.... O'clock p. m.

Admit Mr. W. L. Fisher

J. L. Ward

NOT TRANSFERABLE SHERIFF.

Figure 3. Invitation to a hanging. The men listed on the invitation had been convicted of murder in the "Bisbee Massacre" and sentenced to hang. Their ringleader, however, received a life sentence instead.

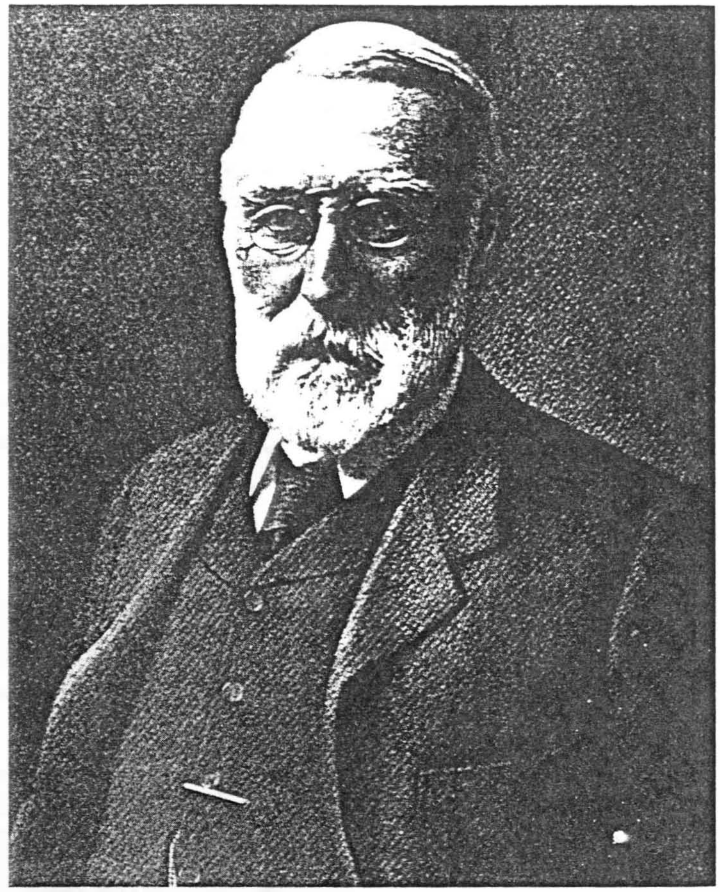
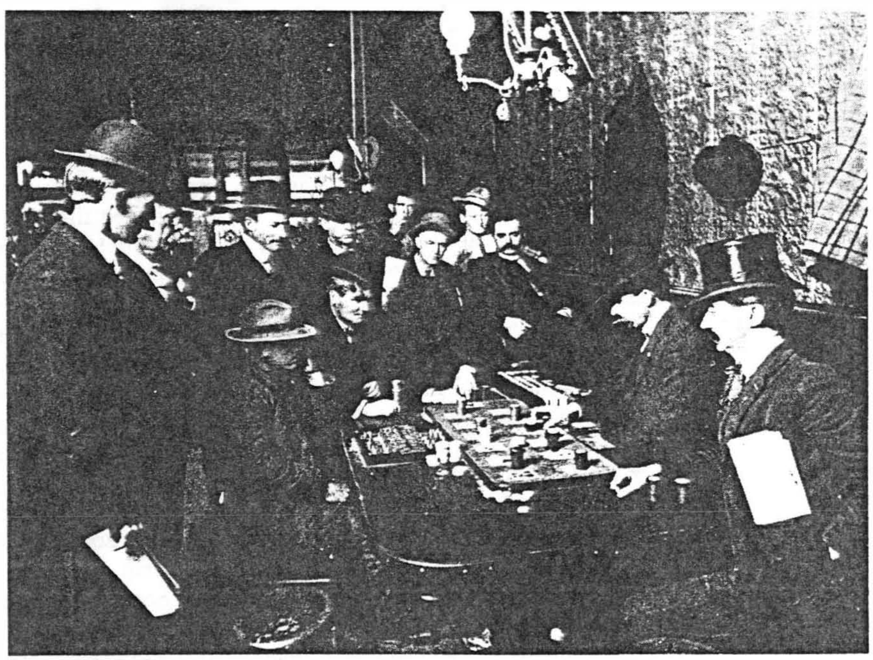


Figure 5. Dr. James Douglas, called to Bisbee by Phelps, Dodge and Company in 1881 to consult on the possible purchase of the Atlanta claim. Douglas had previously worked at the famous Wheatley mine, Phoenixville, Pennsylvania. In lieu of a fee, Douglas accepted part interest in the Atlanta claim, and subsequently became a major influence in the progress of mining at Bisbee (from Langton, 1940).

Arizona Historical Society

Figure 4. Incensed by the lack of a death sentence for John Heath, ringleader of a group the rest of whom were hung for murder, Bisbee townspeople formed a lynch mob and hung him from a telegraph pole. An inquest following his death found that his demise "might have been caused by strangulation, self-inflicted or otherwise."



Bisbee Mining and Historical Museum

Figure 6. Gambling was a favorite pastime in the saloon of Downs, Walsh and Whaley in Bisbee. The man at left is Tony Downs (great-great uncle of the author).

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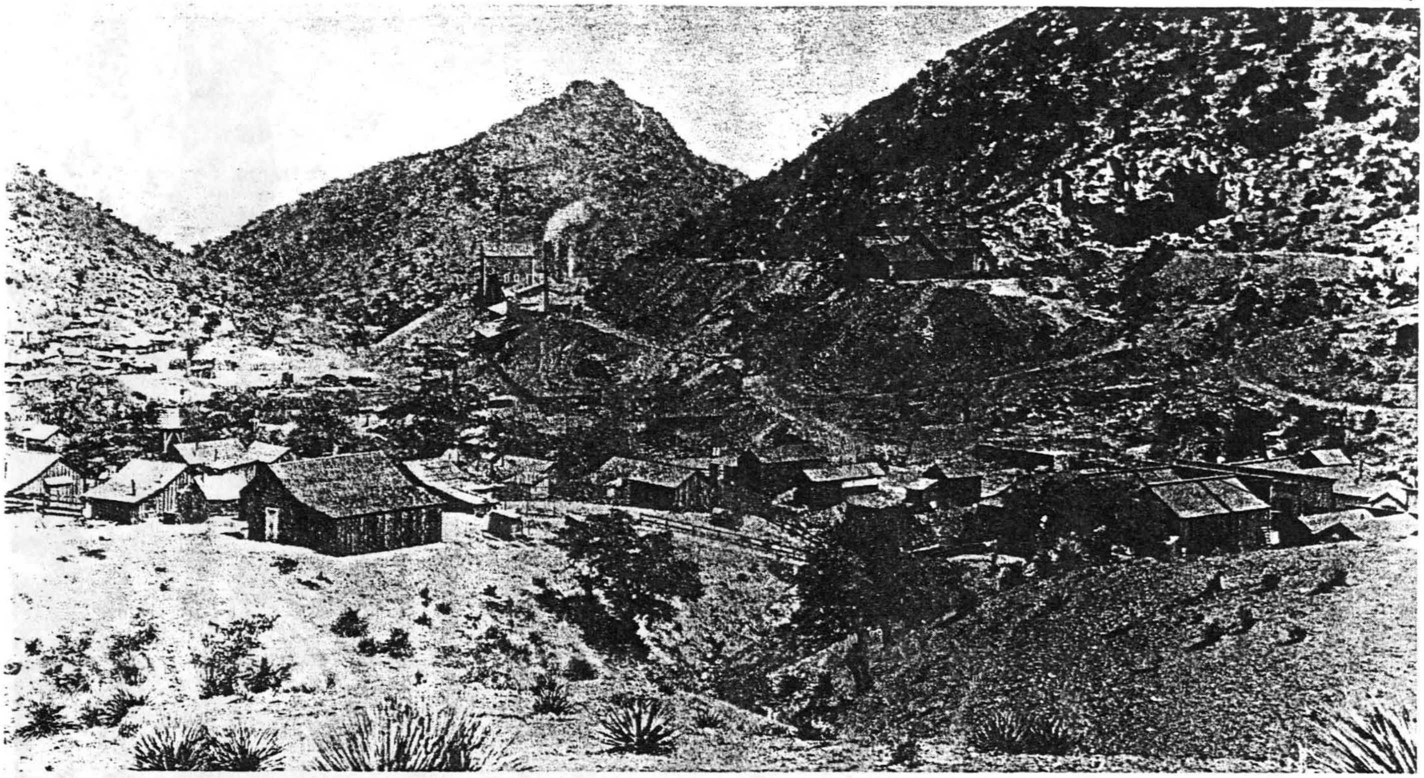
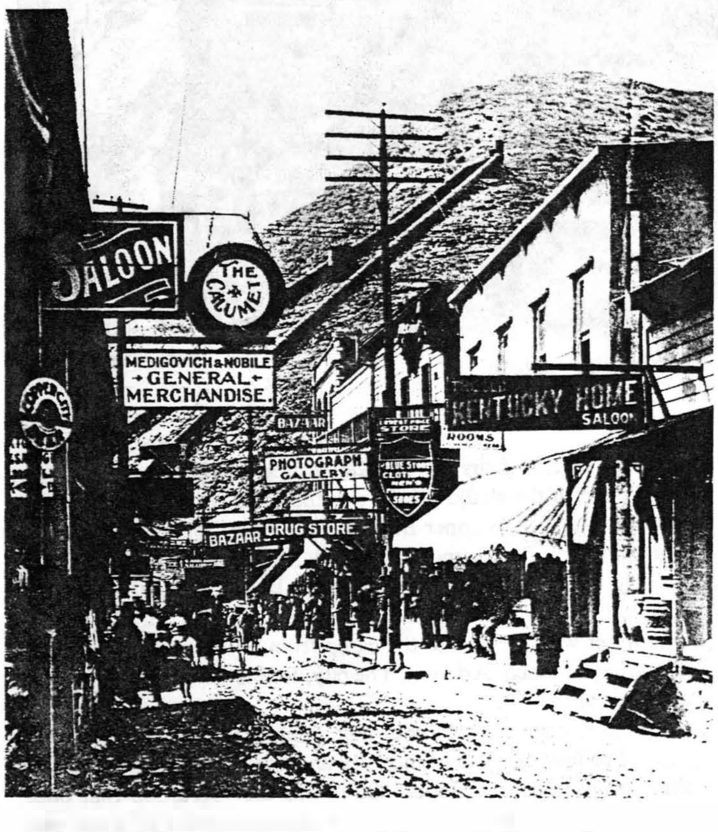


Figure 7. **Bisbee in 1887. The large opening at the right is the open cut of the Copper Queen mine, where Bisbee residents barricaded themselves when Apache Indian raids were threatened.**



Arizona Historical Society

Figure 8. **Brewery Gulch, Bisbee, in 1898. The stack of the Copper Queen smelter lays across the hillside in the distance.**

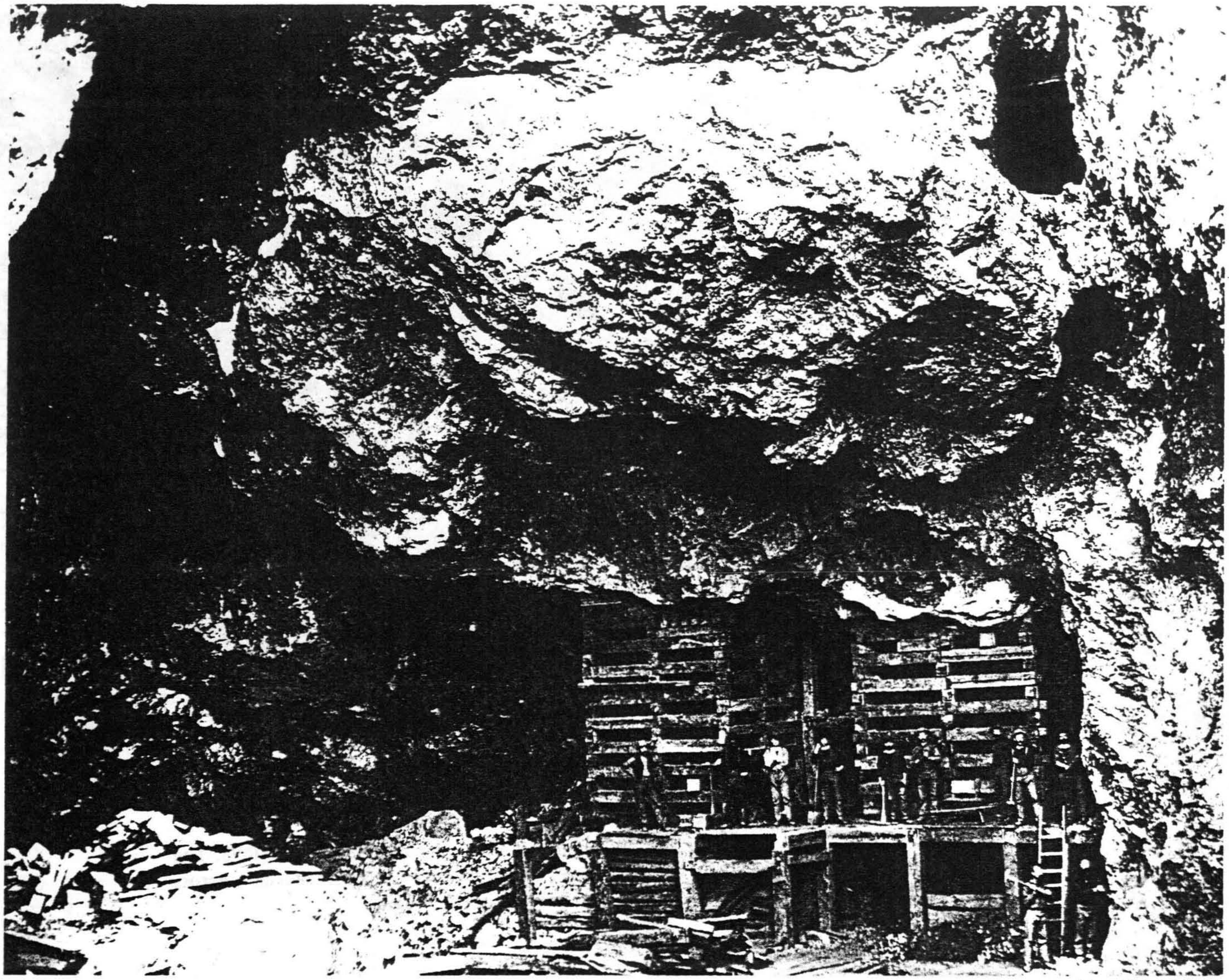
Another lynching by the citizens of Bisbee had an unusual and lasting effect. Hung for the killing of a defenseless man in the Can Can Restaurant over the affections of a woman, the body of the murderer was still dangling from a tree at the base of Castle Rock when a New York director of Phelps, Dodge, and Company came to see the mine. The director was horrified and convinced that such barbarism could only be the result of unenlightened minds. After returning to New York he sent books and a librarian to Bisbee. Thus Bisbee's library was started, in the hope of encouraging a more cultured, civilized community. Phelps Dodge continued to render this service for 90 years.

By the very early 80's, the ground for a great distance around the Queen had been located (claimed). However, besides the Copper Queen mine, only the Copper Prince had produced any ore to speak of, and even it closed before 1885 because of a depressed metal market.

The price of copper continued to fall and, by 1886, the metal from the Queen was selling for only eight cents a pound, down from 20 cents when the mine first opened. There was little profit in the 500,000 pounds a month the mine produced. At this same time, James and Dodge purchased those interests in the Queen held by Martin and Rielly, thereby achieving control of the mine. Not only did they have the courage to buy, but also to advance the company adequate funds with which to build a new smelter with a capacity of 1,000,000 pounds a month. The hope was that increased production would enable the Copper Queen Company to make a profit. For almost a year the mines were shut down until the new smelter became operational. Only some exploration work and de-watering were carried on at this time.

Even the new, more efficient plant was not the total answer. The need for cheap transportation was even more pressing. Finished copper from the smelter had to be transported out, and 10,000 tons of coke and more than a million board feet of timber for the mines needed to be brought in each month.

Late in 1887, Douglas called upon a Mr. Nickerson, then President of the Atchison, Topeka and Santa Fe Railroad, in hopes of bringing a railroad to Bisbee. Douglas was treated with supreme indifference. Only one course remained: the Copper Queen Company must build its own railroad.



Arizona Historical Society

Figure 9. **The Copper Queen mine glory hole in the early 1880's.**

Before the close of 1888, the Arizona and Southeastern Railroad stretched from Fairbanks, Arizona, to the mouth of the Bisbee Canyon, some 40 miles. The cost of freight dropped from $6.00 per ton to about $1.00, a significant savings on the 100 tons handled each day (Douglas, 1909). A futher dispute with the Santa Fe over the remark "that it was not running its railroad for the benefit of the Copper Queen" pushed the A. & S.E. to Benson where it tied into the Southern Pacific Railroad (Myrick, 1975).

A legislated change in 1901 moved control of the road from the Copper Queen mining company to a holding company, the El Paso and Southwestern Railroad. True to its name, the railroad tied into El Paso, then to the Rock Island Line at Tucumcari, New Mexico, and finally to Tucson for a full 772-mile route (Myrick, 1975).

The El Paso and Southwestern Railroad came to a voluntary end in 1924 with a favorable merger with the Southern Pacific Railroad. The shareholders of the E.P. and S.W. received stocks and securities worth more than $60,000,000 (Myrick, 1975).

More than economics and transportation troubled Bisbee. With the growing population crowding into the narrow canyons came sickness and disease, the insidious offspring of poor sanitation. From 1888 to 1890, hundreds died from typhoid fever. Stricken miners lay on canvas cots in Brewery Gulch and along Main Street, their uneasy but brave partners fanning them to reduce their fevers (Cox, 1938).

It was several years before the source of contamination was found. One of the shallow wells was the cause of this disaster. Fortunately, one well in upper Brewery Gulch was found to be free of contamination. So for more than a dozen years the precious fluid was sold house to house, carried on the backs of burros in canvas bags, and priced at 5¢ a gallon. Shortly after the turn of the century, water was pumped to the camp from a fine well field about 9 miles away at Naco, Arizona. The city, to this day, is served by this same system.

The hills, once covered with oak, juniper and manzanita, were stripped to feed the fires of industry and home. With each summer, came heavy rains and floods. Gone was the vegetation that once held the water in check. The sudden torrential flows of water carried everything in its path in the narrow canyon bottoms. Many lives were lost before a subway was built to channel the angry waters.

In 1892, James Douglas and his son Walter went to Europe to investigate the Mankes-Bessemer smelting process. So impressed with the principle was he that immediately upon his return he had one designed for the Copper Queen Company. By 1894, after a number of modifications, Douglas had perfected a method of smelting sulfides that forever changed the way these difficult ores were handled. To a large degree, this method is still basically the one by which most of the world's copper is smelted.

Bisbee Mining and Historical Museum

Figure 10. **Surface fissures formed by subsidence due to the oxidation and later mining of copper deposits below, in the Copper Queen mine.**

After the change in techniques, copper production doubled in two years and by 1899 more than 3,000,000 pounds per month were being produced. Unfortunately though, the crowded conditions at the smelter site next to the Czar shaft precluded any expansion.

A new smelter was a must; the flow of ore from the Copper Queen mines seemed limitless and quite able to support a new facility. The principal owners of the Copper Queen mine had also acquired the mines near Nacozari, some 70 miles south of the Mexican border. Therefore, the logical place for a new smelter was where it would handle the ore from both mines. A site in the lower end of the Sulphur Springs Valley, right on the Mexican border was selected. Here was limitless water and space. A townsite was laid out to support the new facility and it was appropriately named Douglas in honor of the man who had so ably led the Copper Queen Company for 20 years. The new works had a capacity of 10,000,000 pounds per month and cost $2,500,000 to build (Douglas, 1909). Late in 1903 it was blown in, and the old Bisbee facility was completely scrapped.

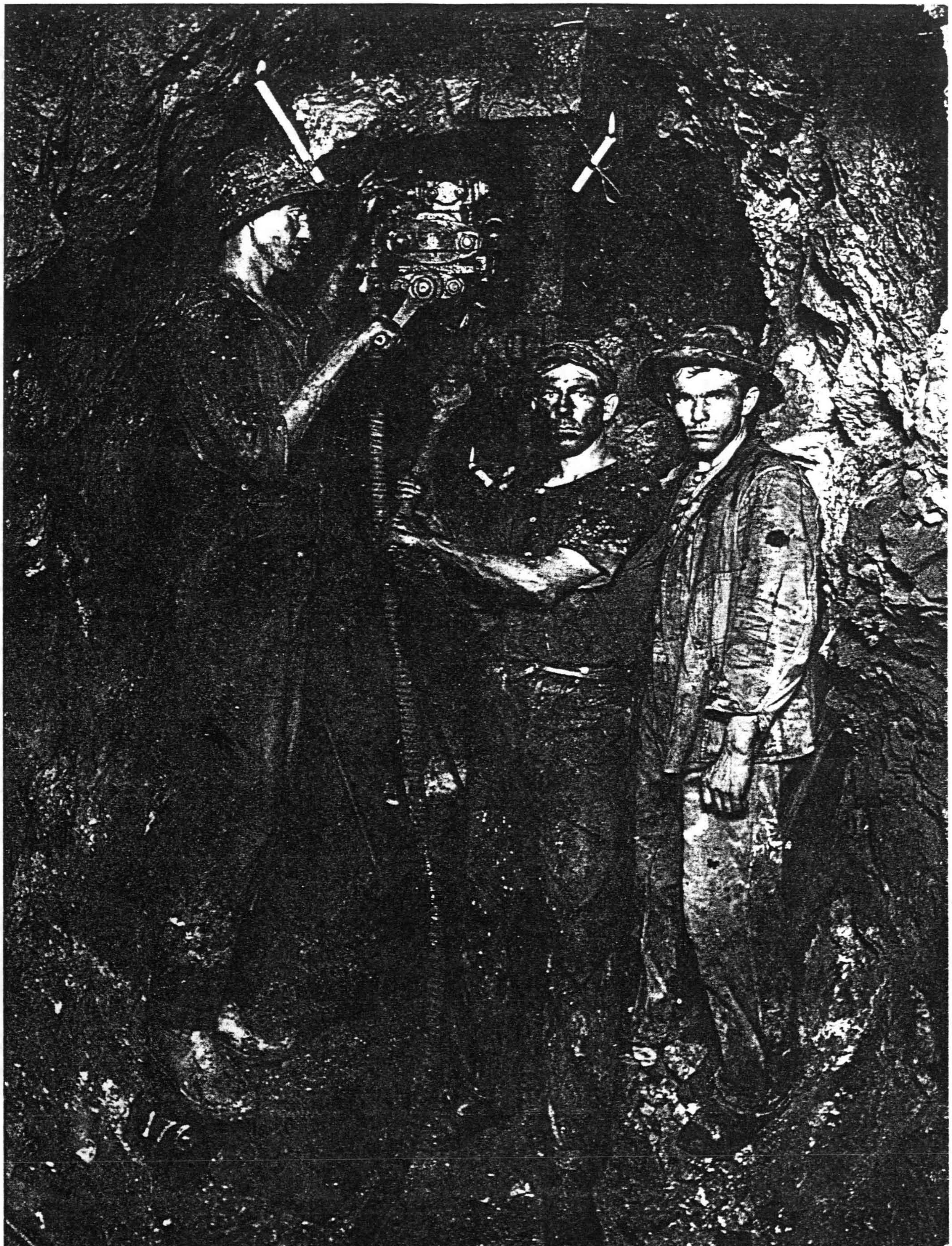
While Dr. Douglas had always been a proponent of an aggressive acquisition policy in the district, there was one opportunity that was lost, though under peculiar circumstances. The Irish Mag claim, named for a woman of the red-light district in upper Brewery Gulch, lay far to the east of any known ore and was generally considered to be of little value. A group of eight other claims and the Irish Mag were owned by a miner named Daly. Evidently of unsound mind, he had threatened the life of Ben Williams and told Douglas that he had been hired by a group of conspirators to kill him. Shortly afterwards, Daly offered his claims to Douglas for $10,000, a proposal which Douglas was anxious to accept. Williams, however, thought it would look like they had succumbed to blackmail and threatened to resign if the purchase was made; so it was declined.

Soon afterwards, in April of 1890, Daly shot and killed W. W. Lowther, a deputy sheriff who was trying to arrest him for assault. The last seen of Daly was when he fled up the side of Sacramento Hill (Douglas, 1913).

As Daly was a fugitive, there was little chance that he would return to claim his property, so a host of claimants suddenly appeared including a "wife" and "son." Daly's common-law Mexican wife, Angela Diaz, had advanced him money to do assessment work; for this reason title was vested by the Supreme Court of the United States to her in 1899. During the long legal battle, she had

Bisbee Mining and Historical Museum

Figure 11. **Ore teams of Jimmy Carr, returning to Bisbee with a load of coke. Early 1880's.**



Bisbee Mining and Historical Museum

Figure 12. **Drilling holes underground around 1905. Note candleholders.**

sold her interest to Martin Costello, a Tombstone saloon keeper, for $1,800 (Cox, 1938). After the favorable decision, Costello sold the property for $500,000 to the Lake Superior and Western Development Company.

Long before the legal battle was over for the "Mag's" ownership, the potential value of Daly's claims became well known. Development on the 800 level of the Spray shaft had found fine orebodies near the Irish Mag sideline. Captain Jim Hoatson came to the district looking for a good property to purchase on behalf of the Lake Superior and Western Development Company. Nothing looked as good to him as the barren, hard limestone knob called "Mag Hill."

In the Calumet, Michigan, area, everyone knew Cap'n Jim and respected his knowledge, so before long he had the money to buy the claim and sink the needed shaft. But for all his knowledge, Hoatson failed to realize just how deep the ores really were, and that it would cost much more to mine the Arizona limestones than it did the rocks in Calumet. On the ragged edge of bankruptcy, Cap'n Jim went back for more money, money to sink just a little deeper, where the ores must surely lie. So it was, on the faith of an uneducated miner, that some of the great names in the steel and iron business invested many thousands more. Their confidence in Jim was rewarded. After finding small bunches of ore on the 850 and 950 levels and building a modest smelter, a fabulous orebody was cut on the 1050 level in 1902 by the Northeast drift (C. & A., 1916). Before the story of the Irish Mag was finished, nearly $10,000,000 in dividends were paid from the 15 acres that made up the claim.

The Calumet and Arizona Mining Company absorbed the Lake Superior and Western Mining Company and set about to develop its vast holdings of favorable ground. It could all have been for naught save for the wisdom and absolute honesty of James Douglas and the partners of Phelps, Dodge and Company.

The law of the apex had been firmly established in the west by the famous Eureka and Richmond ruling. This law, simply put, means that whoever owns the apex of a continuous vein, lode, or formation, has the right to claim ownership of all ores on its dip, even if the vein passes under other claims at depth. There is little doubt that the Copper Queen Company could have claimed for its own all of the ore found by C. & A. and been upheld in court. This would, of course, have been allowed only after bitter litigation at enormous expense. But Douglas said, "We must decide which industry is to prosper here—that of mining or that of lawyers" (Langton, 1940).

So the common boundary law was mutually agreed upon and Bisbee was spared the grief and hatred that so scarred many other districts. Along with the agreement, free access to each other's mines was granted so that the discoveries of one could help the other. Thus began the cooperation between companies and their respective engineers which was heretofore, unknown. Those in the profession today are still reaping the benefits of the shared technical progress that this spirit has brought to the industry. Perhaps this is the greatest contribution Dr. James Douglas made.

Once the future of the Calumet and Arizona Company had been assured by the riches that flowed from its mines, Tom Cole, its president, set out to buy all the ground he possibly could. Douglas, not to be outdone, paid a fortune for property he could have had for a trifle just a few years earlier. In the ensuing scramble, absolutely undeveloped ground went for as much as $40,000 an acre. Stakes were high in this copper game; even after purchase, hundreds of thousands of dollars had to be spent sinking a shaft of up to 2000 feet before the value (or lack of) could be determined.

With no more land to buy, the mining companies set about building the fortunes of their investors. They also spent large amounts building the community and developing safer working places until the camp had no parallel.

To this point, Bisbee had been singularly free of labor troubles, due principally to the efforts of the mining companies to provide a safe work environment, a pleasant community to live in, and wages comparable to what miners elsewhere were receiving. But in early 1917, just 2½ months after America's entry into World War I, a group known as the "Industrial Workers of the World" called a strike in Bisbee without a vote of the miners. Under threat and intimidation, by the third day about 80 percent of the 4,500 men employed underground were staying off the job (Loyalty League of America, 1917). However, members of the mechanical trades never gave any support to the agitators from the I.W.W., and within a few weeks half of the men were back at work underground. But the "Wobblies," as they were called, persisted in their efforts to stop the mines with increased amounts of harrassment. At this same time, most of the other mines in Arizona and Butte, Montana, had also been closed by this group.

With the vital war requirements of the red metal threatened by the effects of the strikes, it was obvious that nothing short of drastic action would end the work stoppage. Convinced that a strike in a time of unprecedented national crisis could only be directed and supported by people of treasonable inclinations, a deportation plan was conceived. Secretly, 2,000 men from every profession in the camp gathered before dawn on July 12, 1917, to begin what they truly saw as their patriotic duty. At the same time, the telephone exchange and Western Union were occupied by interests favorable to the "Loyalty League," as the group called itself. The morning edition of the *Bisbee Daily Reivew* delivered to all homes in the pre-dawn hours, warned that women and children should stay off the street that day.

From house to house, combing every street and alley, the armed and deputized forces of the "Loyalty League of America" swept the whole camp. Every known striker, agitator, or sympathizer was removed and marched to the Warren Ball Park. Here a court questioned each man: "Are you working? Do you want to work? Who can vouch for you?" A great many answered the questions appropriately and were released. However, 1186 men were detained, loaded into cattle cars, and taken to a siding near Columbus, New Mexico. They were left with the warning that, should any return to Bisbee, they would most certainly be killed. The strikers were then abandoned by their guards.

For almost a month, the "Loyalty League" controlled the town until it was completely purged of the anarchistic "Wobblies." There was then and is now little doubt that what was done was for the best: a truly patriotic act. A subsequent investigation ordered by President Woodrow Wilson and conducted by Felix Frankfurter found no federal offense, while the Supreme Court of the United States determined that the participants had acted to enforce "the law of necessity."

During the post-WWI years, Bisbee continued to hold its position as the greatest of copper camps. This was helped by the development of the Sacramento pit. One of the earliest open pits in the world, it produced for most of the 1920's.

The great depression found the two main companies in markedly different positions. The Copper Queen Company, now known as Phelps Dodge Corporation, after mining for some 45 years, had nearly depleted its reserves and had less than one year's-worth of ore left. However, because of its high standard of operating efficiency it was in a very good cash position. On the other hand, the Calumet and Arizona Company had incredible reserves; the Campbell orebody was just being delineated. But because of a too-liberal dividend policy, insufficient funds were available to carry them through this difficult time.

A merger between the two great companies was effected in 1931, with Phelps Dodge Corporation the survivor. Even though copper hit price levels as low as those of the late 1880's, the richness of the

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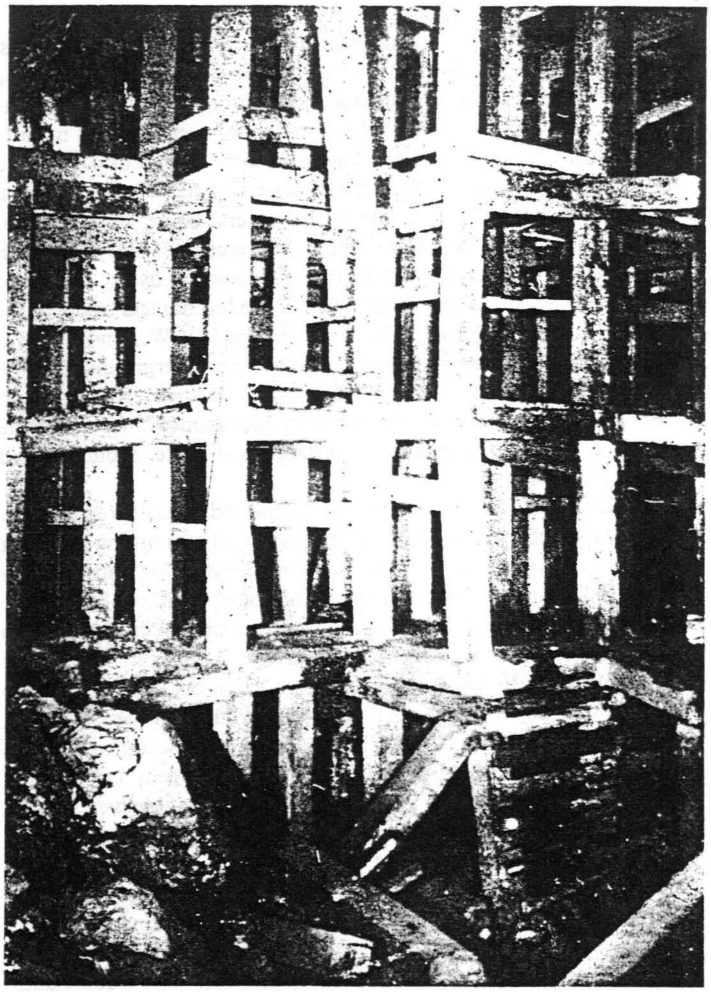


Figure 13. **Square-set timbering in the southwest stope of the Copper Queen mine.**

sulfide bodies in the Junction and Campbell mines kept the camp alive.

By the late 1900's, production was again up to pre-Depression levels. Lessees who had played a significant role in production since 1912 were producing as never before. Several years after the merger, Phelps Dodge leased much of the remaining tonnage in the mines that they themselves had operated for so long. Areas in the Southwest, Czar, Holbrook, and other mines were being exploited by low-overhead lease operations, often at a very handsome profit.

When World War II's need for copper arose, Bisbee was prepared. Though the mines were already operating at near capacity, contracts were entered into with the government on the "Metals Reserve Account" to augment production by mining lower grade ores. Manpower shortages were partially alleviated when several hundred soldiers with mining experience were assigned to work in Bisbee.

With the end of the War, came a sharp drop in copper demand. Lead and zinc ores had often been exploited during the life of the district, but now they became the life's blood of the camp. While important amounts of copper were recovered (some 123,500,000 pounds from 1945 through 1950), it was the rich lead-zinc orebodies in the Junction, Campbell, and the newly-acquired Denn that made the profit. During this time, 1,152,000 tons of mixed ores were mined yielding 105,400,000 pounds of lead and 235,000,000 pounds of zinc (Mills, 1958).

The last significant mining development in the district was the Lavender pit. Stripping started in April of 1951, but it was not until July, 1954, that any ore was shipped to the concentrator. The pit, which was closed in December of 1974, is still a source of copper. Water is continually sprayed into the pit and collected in the nearby Junction shaft for use in a leach operation, a process that will continue to provide copper for many years.

Soon after production from the Lavender pit ended, all operations stopped. The end to this truly great mining camp came in mid-1975 when the underground workings were closed. After nearly a century of providing mankind with one of its most essential elements, Bisbee fell, an early victim to problems never before encountered by the industry. The regulatory zeal that swept the country adding cost after cost, killed her. And too, the flow of cheap copper from half a dozen other countries was also responsible.

But what of Bisbee's future? Hundreds of millions of pounds of copper are still in the ground, as are lesser amounts of lead, zinc, and other metals. Whether they will be mined is doubtful, at least under today's conditions. However, leaching has long been an important aspect of the Bisbee operation. Now this clean, efficient, but painfully slow hydrometallurgical process is still recovering important amounts of copper from the Lavender pit, the dumps, and the underground mines. How long this will continue to be economic is anyone's guess, but perhaps it will last for many years.

Bisbee today remains the quiet picture of a small town, lost in time. Those colorful memories of days gone by hover among the winding streets. Lingering shadows of past mines creep up the steep hillsides, and nature carefully disguises her secrets of what might remain.

With Bisbee's new approach, catering to tourism and retirees, its survival seems assured, but only after near Herculean efforts by many of the residents. The most impressive fruit of their labor and cooperation is the "Queen Mine Tour." Winding through these tunnels and stopes, one quickly becomes part of the exhilarating environment the early miners once experienced. So it seems that Bisbee remains determined to continue activity in the subterranean world of Queen Hill, where more than a century ago the legend began.

Mining Methods

The ores and their host rocks in the Warren mining district were remarkably variable in character. To a large degree, this was a function of supergene action; rocks which had undergone more oxidation were softer. In some areas, notably those near the Czar and Holbrook mines, the rocks were so soft and plastic that they defied all attempts to mine them underground.

For the softest ores that could be mined, a technique developed in England called "top slicing" was used (Hodgson 1914). Starting at the top of the ore, a horizontal slice was mined and heavily timbered. Once all the ore was recovered from this slice, the timber would be blasted, causing the area to cave in. Then a second slice below the tangled mat of timber would be taken, and the new timber blasted again. The resulting timber mat was usually strong enough to support the increasing weight as mining progressed downward. One distinct disadvantage of this method is that the country above is badly broken. So it must first be ascertained that no ore is above such a stope.

The vast majority of mining was done using what is known as the "square set" method. It was continually used from 1881 until the mines closed in 1975. This name was derived from the configuration of the timber. As each 6 x 6 x 8-foot block was mined, a rectilinear set of timber was installed to support the opening. After a predetermined number of sets had been mined, the stope would be gobbed (backfilled with waste rock) for additional support.

Many of the primary sulfide ore bodies were very competent, and could be mined with considerably less timber, perhaps even none. Cut and fill mining was important in the extraction of such ores from 1916 (Wilson, 1916) through mid-1975. Here, the usual approach was to start at the bottom of the ore and remove as much as conditions would allow, then gob the hole and start over on top of the fill.

Shrinkage mining was only of limited value in Bisbee because of the generally irregular shape of the ore bodies. But when used a considerable savings in labor and timber was experienced. With this method, the ore would be broken, but only part of it removed, so that the remaining material would serve as a floor for mining. Once all the ore had been blasted, the stope would be emptied and usually gobbed.

Block-caving is an approach whereby a large block of ground is developed with numerous raises and closely spaced parallel drifts. Then, using large amounts of explosives, the entire block is shattered. The many raises funnel the broken ore down from the block. This technique is successful only under a limited set of circumstances; most important are homogeneity of both the rock and ore grade. The porphyry of Sacramento Hill met these criteria and was mined by this method with limited success.

Mining Equipment

A full cycle in mining consists of drilling, blasting, mucking, timbering, and (in drifts) advancing track and pipelines. The evolution of the equipment used to perform these steps is in itself an interesting story.

Drilling blastholes in the workings was originally done by handsteel. This involved using chisel-bit steel bars of varying lengths, starting with the shortest, and a hammer. A one-man set-up involved using a single jack (4-pound hammer) and drilling a short hole. Most drilling, however, involved two men and a double jack (8-pound hammer), usually drilling a 6-foot hole.

Handsteel drilling was a very popular competition in all of the western mining camps. Intercamp competition soon developed, with granite from Gunnison, Colorado, as the standard medium. On the 4th of July, 1903, the world's record of 38⅜ inches in 12 minutes was set in Bisbee by a two-man team from the Copper Queen Company (Cox, 1938).

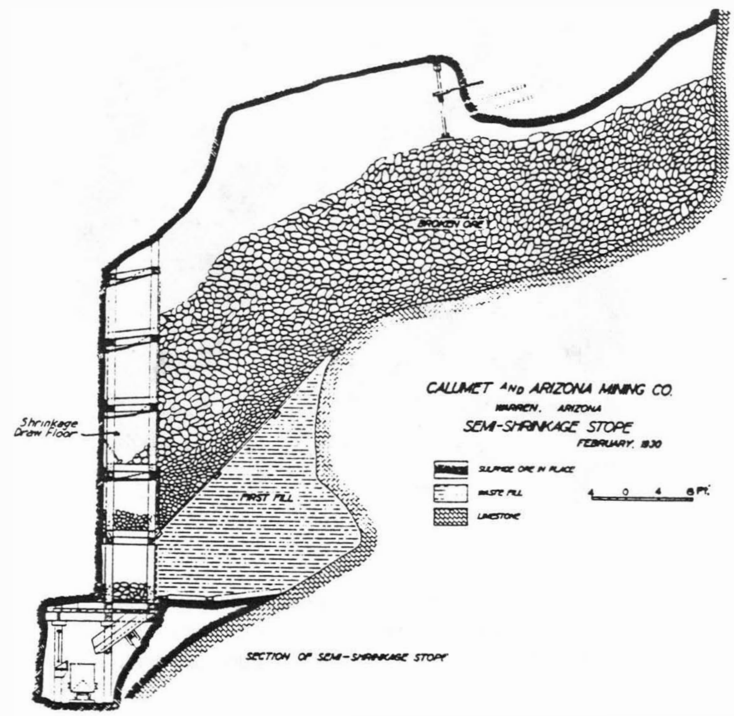


Figure 14. **Construction of a semi-shrinkage stop (Lavender, 1930).**

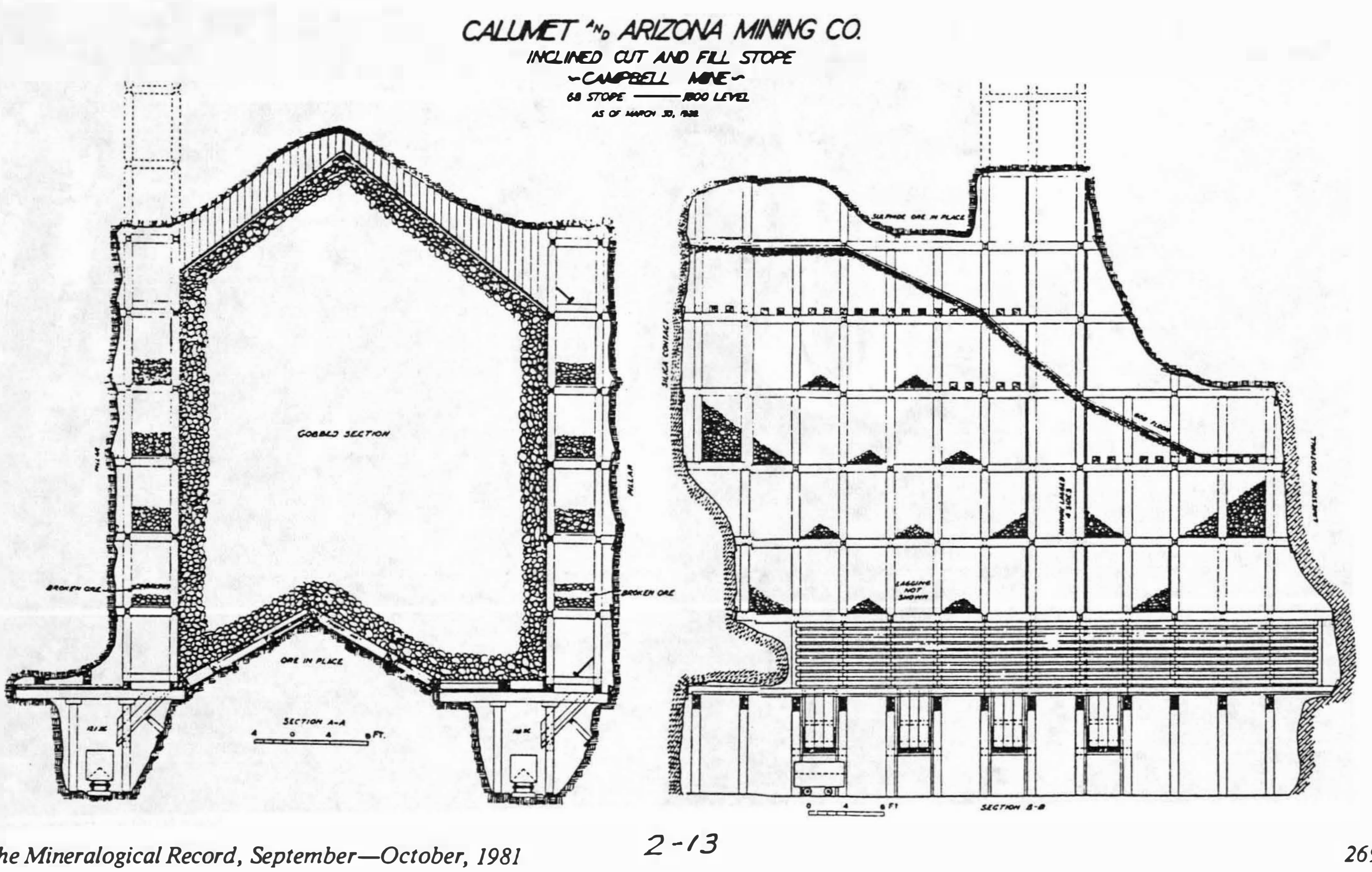


Figure 15. **Timbering scheme used in the Campbell mine. The square sets are tightened with wedges. (Lavender, 1930).**

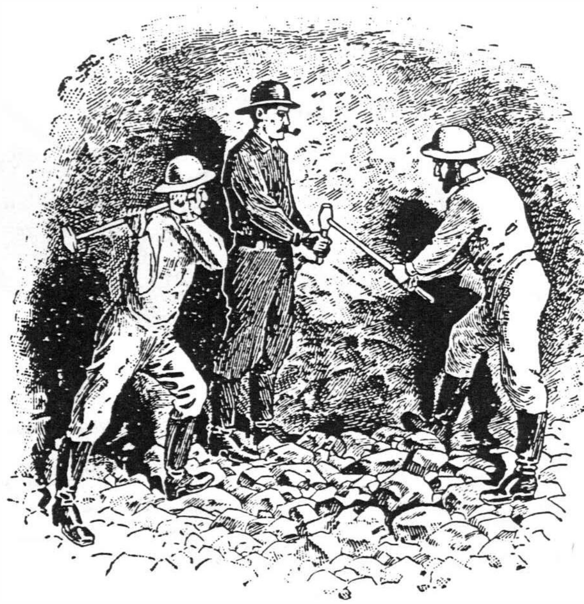


Figure 16. **Three men double-jacking. The center man holds and turns the drill steel while the other two strike it with 8-pound hammers.**

The first pneumatic drills were introduced in 1905. While cumbersome by today's standards, they completely replaced handsteel by 1908.

Blasting in the underground changed very little for many years. Dynamite and fire fuses were used until the mid-1960's when a pneumatically loaded ammonium nitrate and fuel oil mixture came into use.

Mucking, or the moving of broken rock, was done totally by hand before 1933. The ore was manually shoveled into half-ton mine cars. In stopes these were trammed (pushed) by hand to a central raise and dumped for transfer to haulage cars on the level below. In small or irregular stopes wheelbarrows were in common use.

These time and labor intensive techniques were replaced by slushers. A slusher is a two-drum (or more) winch arrangement that pulls a bucket-like rake back and forth over the muck pile, carrying small amounts to wherever needed, usually a raise. A few years before closing, several small, rubber-tired, front-end loaders were used in some of the larger stopes.

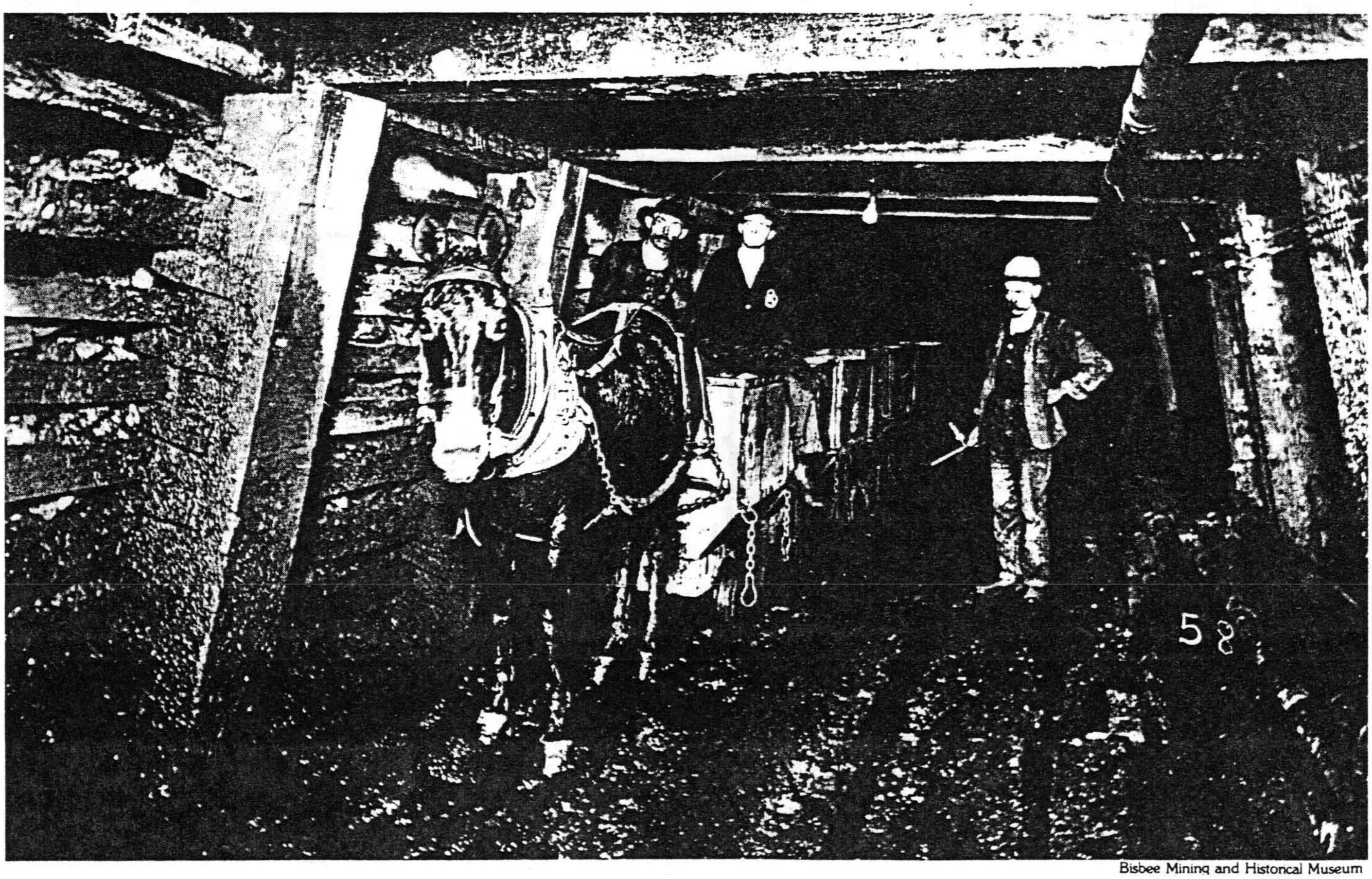
The transition from hand to mechanical mucking in the tunnels and drifts occurred in 1934 (Mills, 1958). Pneumatic loaders were introduced that traveled on rails and would literally throw the rock into a coupled mine-car.

Prior to 1907, all movement of the mine-cars, both loaded and empty, was by hand; then mules were brought into the mines (Mills, 1958). While a man could only tram a single car, a mule could pull five. Often treated like pets, these animals were well cared for. Each level had a "mule barn" in a dry, well-ventilated area.

Electric trolley haulage was introduced in 1908; however, it was not until 1930 that the mules were totally displaced. From then on trolley and storage battery locomotives (or motors, as they were called) moved all rock and supplies.

Electric lights were put in all of the main haulage drifts in 1907, but personnel lighting was by candle as it had been for 30 years. The holders for these candles were commonly works of art in themselves. Consisting of a spike, a hook, a handle, and a candle-holding loop, they were usually forged from a single piece of steel. The thumb-tab for loosening the grip of the candle-loop came in various designs; birds and animals were common motifs, but the

Figure 17. **Mules such as this one in the Czar mine, 1908, pulled ore cars at Bisbee for many years.**



Bisbee Mining and Historical Museum

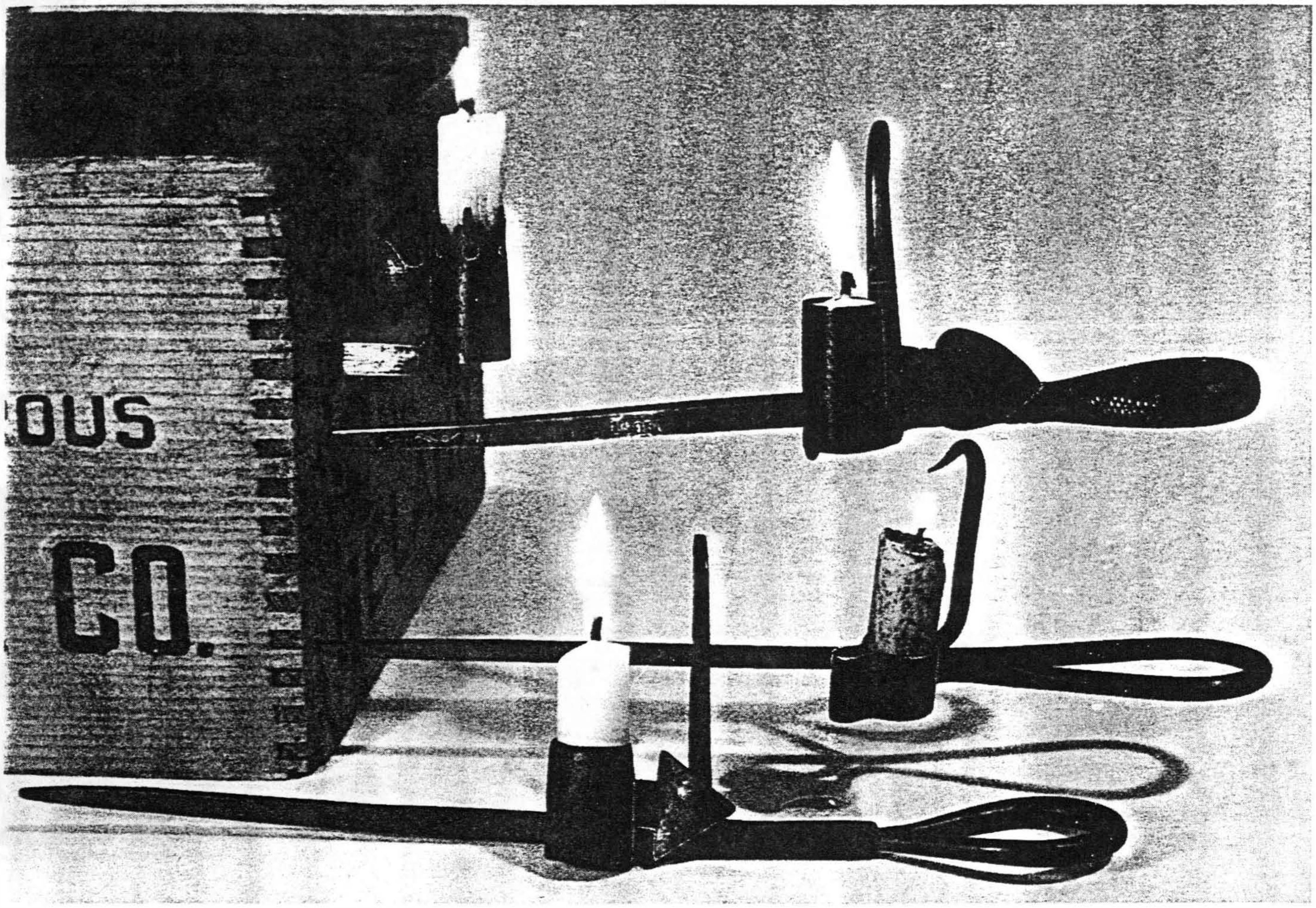
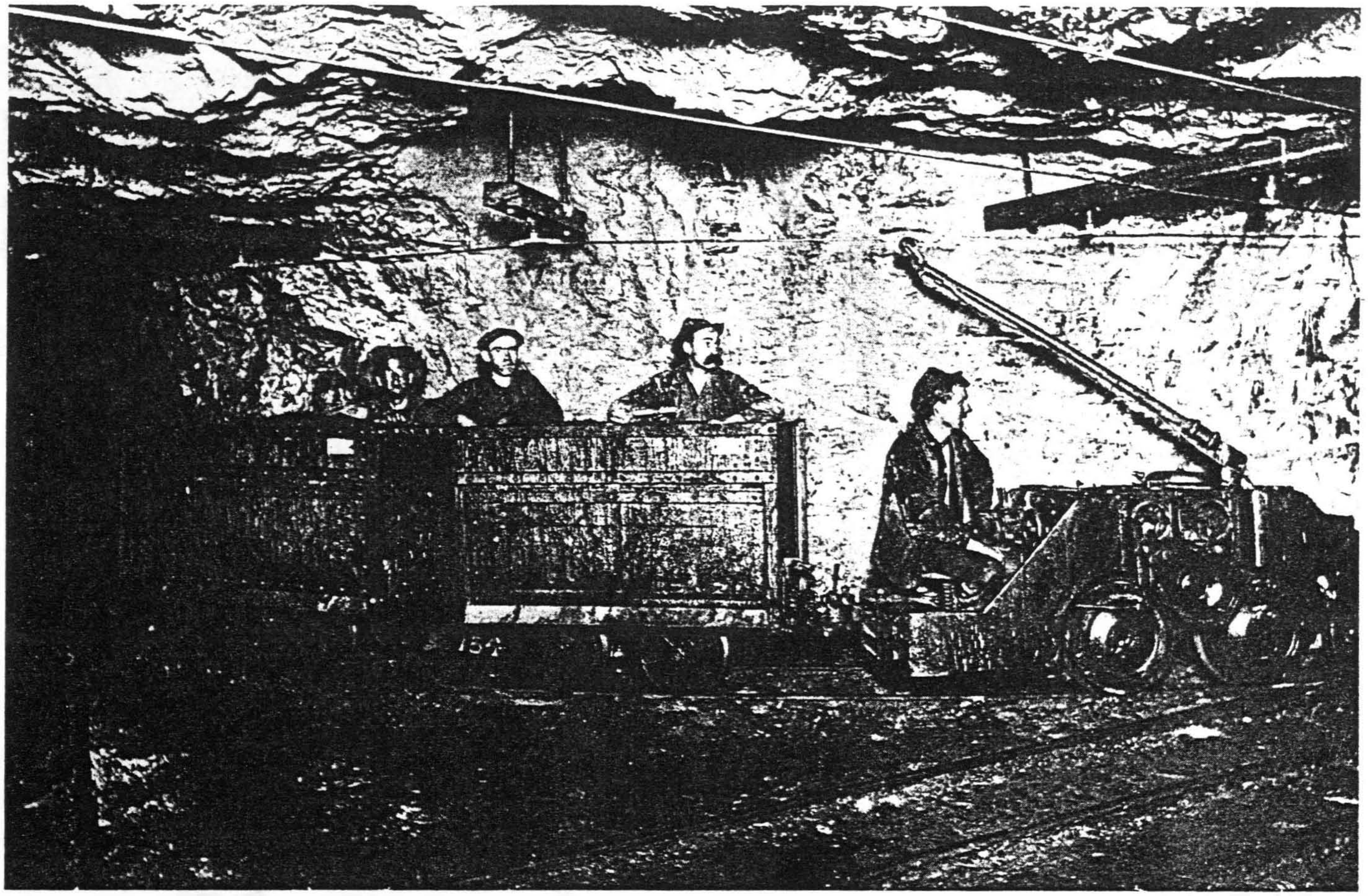


Figure 18. Miners' candleholders used at Bisbee. The small one was found in the attic of a mining family in Bisbee; old-timers questioned about it confirmed that such small holders were used, either stuck in a notch in the cap or into a timber (Melvin Elkins collection). The Varney-style candleholder (center) was made for the Copper Queen Consolidated Mining Company by a local blacksmith, and bears the initials "C.Q.C.M.CO." (R. Graeme collection). The upper holder is inscribed "L.M. BARBAROS. BISBEE. ARIZ. 1905." and was probably a presentation item to honor a miner (Richard Hauck collection). The holder with the triangular thumb-tab (bottom) is marked "D.E. DAVES," who was a Cornish "cousin jack" miner in Bisbee (Wendell Wilson collection).

Figure 19. A mint-condition example of the famous Copper Queen carbide lamp. When the Justrite Manufacturing Company in Chicago received an order for several hundred lamps in 1912, they removed the usual name "Little Giant" from their cast aluminum lamp and replaced it with "Copper Queen" for the Copper Queen Consolidated Mining Company. (Nancy Van Scriver collection.)



Bisbee Mining and Historical Museum

Figure 20. **This electric trolley was introduced at the Holbrook mine in 1909; it is now on display in front of the Bisbee Mining and Historical Museum.**

most popular was a well-shaped woman's leg, complete with bloomers and shoe.

The use of candles began to fade in 1911 when carbide lamps appeared. Late in 1912, the Copper Queen Company ordered several hundred large, cast aluminum lamps from the Justrite Manufacturing Company, each of which had "Copper Queen" embossed on its side. These make interesting collectors' items today. However, it was not until 1916 that the transition to carbides was complete.

Miners were responsible for purchasing their own lamps and seemed to prefer brass to the cast aluminum type. Two styles of brass lights were in general use: a small cap lamp that would last 2 hours before recharge, and the larger stope lamp that was made to hang from timber on the wall. The latter would usually burn for about 4 hours before refilling was necessary.

Electric cap lamps were first introduced in Bisbee at the Junction and Campbell divisions in 1938 (Mills, 1958). Here again, it took a number of years for one lighting method to replace another. While these lamps were provided by the company, it was not until late in 1944 that all of the miners were using the Edison lamps.

Mines

During the years that Bisbee sent forth its impressive flow of fine minerals, more than 30 separate mines were involved. A great many specimens are improperly labeled as far as actual locality is concerned. Undoubtedly, the majority of those labeled "Copper Queen mine" or "Calumet and Arizona mine" are actually from some lesser known mine.

This problem developed because all of the mines operated by the Copper Queen Consolidated Mining Company, as well as its successor Phelps Dodge and Company and Phelps Dodge Corporation, have continually been referred to as the Copper Queen mines. By the same token, all of those developed by the Calumet and Arizona Mining Company have been called by the name of the controlling company.

In an effort to help collectors who wish to be more specific in their labeling and to know the general time-frame during which specimens were recovered, the following summary of mines is offered. The characteristics shown by various minerals from many of these mines are described further on, in the section on minerals. Together these sections may assist collectors in attributing more specific locality details to their Bisbee specimens, and will provide background for those lucky collectors whose specimens already have detailed but unfamiliar notations on the labels.

Atlanta shaft, Atlanta claim, 400 feet in depth, sinking started in 1884. It was this mine that sent Phelps Dodge on its way to becoming a major force in domestic copper. The Atlanta orebody was cut from just below the 200 level to the 400 level. Because it was in ore and a small shaft, it was abandoned in 1886 and replaced by the more efficient Czar. In 1917, dumps from the Southwest, 5th level, covered the Atlanta shaft.

Baxter tunnel, Baxter claim, started in 1889. Driven by the Copper Queen Company into Queen Hill from the east side to the prospect above the Southwest orebody. Unstable ground and only modest amounts of ore forced abandonment about 1900. Lessees

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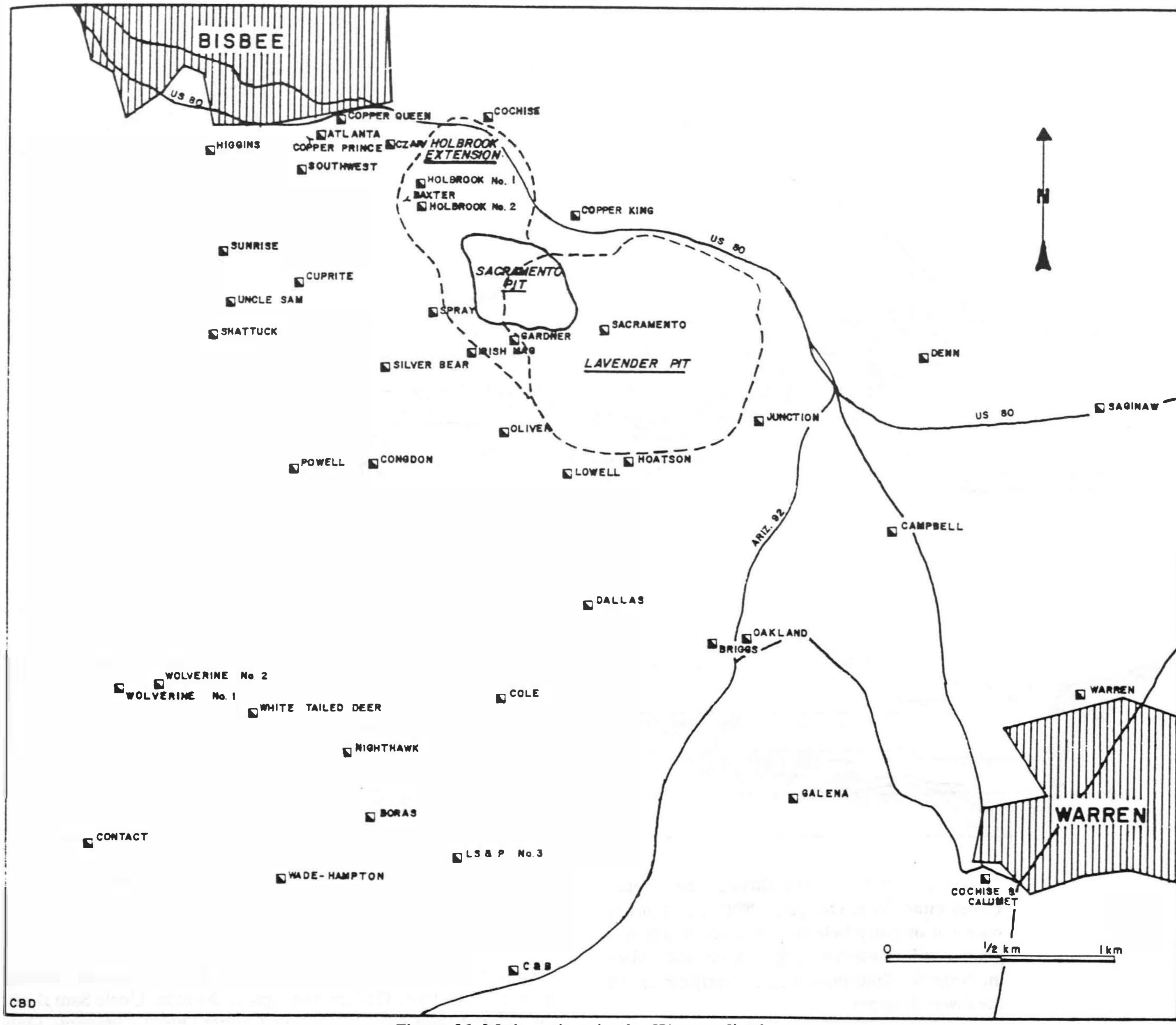


Figure 21. **Major mines in the Warren district.**

removed a small amount of highgrade ore in the mid-1930's.

Boras shaft, Boras claim, 1034 feet in depth, sinking started in 1917. Developed by the Copper Queen Company for lessees, substantial reserves of carbonate ores were opened up on the 400 and 600 levels in 1919. Operations continued until 1926 when it was closed. A small amount of mining was done by lessees from 1938 until 1944, most of this below the 800 level.

In the early 1950's, it was reconditioned for an emergency escape way and ventilation shaft for the Cole shaft. It served in this capacity until the cessation of operations.

Briggs shaft, Hard Cash claim, 1630 feet in depth, sinking started in 1902. Named for Charles Briggs, a banker in Calumet, Michigan, and president of the Lake Superior and Western Development Company, part of the Calumet and Arizona. No ores were shipped from here until 1910 because of water problems. During 1908 and 1909 work was suspended until a drainage drift from the Junction was completed (C and A, 1916). Mostly supergene ores were mined with a few primary sulfides. Operations were suspended in 1922 until 1935 when it was leased. This lasted until mid-1944 when it was permanently closed. The shaft was filled and the dumps leveled in 1949 to make room for a company housing development.

Campbell shaft, Regular claim, 3332 feet in depth, sinking started in 1927. Developed by the Calumet and Arizona Mining Company, it was named for Gordon R. Campbell, an early investor in the company. The original purpose of this shaft was to serve as a ventilation opening in the mining of the ores, east of the Junction shaft. This all changed when in 1929 the magnificent Campbell orebody was discovered; it was the largest mass of ore ever found in the district, containing well over a million tons. Stretching from above the 1600 level to below the 2200 level, this orebody helped make the Campbell the most productive mine in the district. Also, this is the only mine that operated without interruption. The deepest mine in Bisbee, it produced vast amounts of lead and zinc, in addition to copper.

Cole shaft, Triangle and John P. Jr. claims, 1563 feet in depth, sinking started in 1902. The Lake Superior and Pittsburg Development Company, an arm of the Calumet and Arizona Company, sank this shaft. Named in honor of Thomas F. Cole, a heavy investor in the mines of the district. At the time he was manager of the Oliver Mining Company, a subsidiary of United States Steel.

A truly great mine, its first ores were shipped in 1905 and the last in 1975. During this period, it was closed from 1929 until 1934 and again from 1944 through 1947. Operations were resumed at full

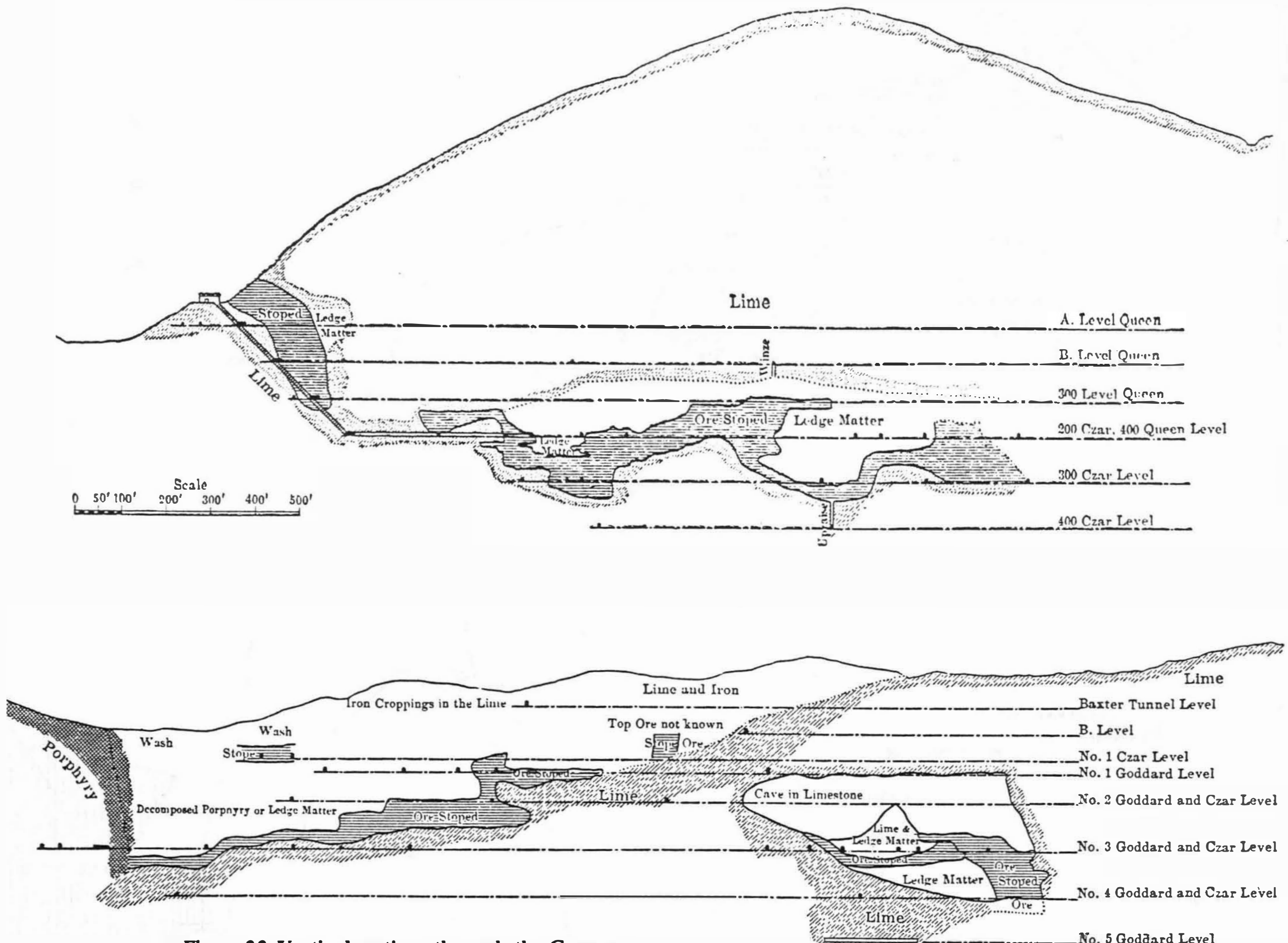


Figure 22. **Vertical sections through the Copper Queen mine (from Douglas, 1899). The famous open cut or glory hole shown in the upper diagram is still in existence, though partially filled in. Note the limestone cavern overlying ore in the lower diagram.**

scale in 1953. Ores from the Oliver, Powell and White-tailed Deer areas were tapped from the Cole.

Copper Prince mine, Copper Prince claim. A contemporary of the Copper Queen mine, mining began there in 1882 and lasted through early 1884. Both a shallow shaft and a tunnel were used to exploit the near-surface ores mined by the Arizona Prince Copper Company. This property was acquired by the Copper Queen Company in 1885 to preclude trespass litigation against the Prince for their mining excusions onto Copper Queen Company ground. The portal to the tunnel is visible today just above the post office, while several stopes have been cut by the highway that bypasses Bisbee.

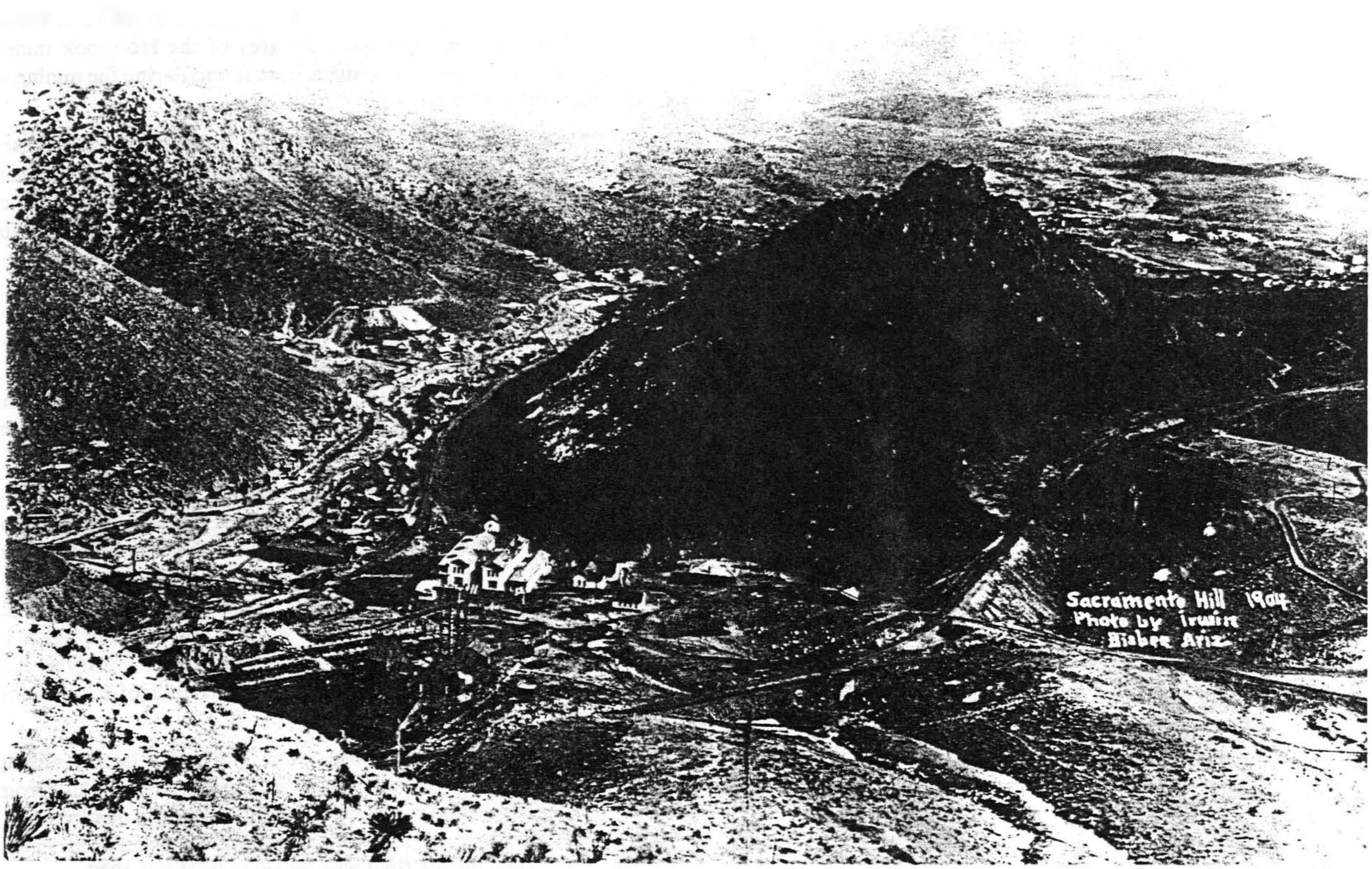
Copper Queen mine, Copper Queen claim, 400 feet on inclined depth, sinking started 1881. The original work was done through an open cut and two very shallow vertical shafts in 1880 by the Copper Queen Mining Company. These were replaced by the 45-degree inclined shaft, cut some 200 feet to the east of the original discovery site. Mining through the Copper Queen ceased in 1888 when workings from the Czar reached the Atlanta and John Smith orebodies. It was re-opened in 1913 for exploration and a little mining and closed again that same year (Mills, 1958). A fire destroyed the upper 150 feet of the shaft in 1958. Today the Queen Mine Tour affords a good view of the lower portions of the shaft.

Cuprite shaft, Brother Jonathan claim, 911 feet in depth, sinking started about 1905. Designed to replace the older Uncle Sam shaft, the Cuprite shaft was sunk by the Copper Queen Company. Only modest amounts of ore were removed from here, with most of it hauled to the Czar for hoisting. Closed in 1929, it was turned over to lessees in 1934 and was mined sporadically until 1942. From then until mid-1944, low grade ores were exploited for the "metal reserves contract" using furloughed soldiers (Mills, 1956). The shaft was filled in 1968 and covered with dumps from the Lavender pit.

Czar shaft, General claim, 440 feet in depth, sinking started in 1885. This shaft was the first sunk by the Copper Queen Company. During its nearly 60 years of production, this shallow mine yielded more fine mineral specimens than any other in the camp. Little other than carbonate ores were mined from here and its proximity to the Dividend fault zone as well as the stock afforded it a unique geologic environment.

Operated by Phelps Dodge until 1931, it was then leased. In 1942, as at several other shafts, the company resumed operations to support the war effort. The final closing of this very wet, cold mine was in 1944.

In an effort to stop trespassing, a concrete cap was poured over the shaft in 1961. This also stopped the flow of air needed to preserve the shaft timbers from decomposition. As a result, in 1973 the head-frame collapsed and the shaft was filled. The site of this mine is 250 feet east of the main building of the Queen Mine Tour.



Arizona Historical Society

Figure 23. **Sacramento Hill, Bisbee, as it appeared in 1904. Today virtually the entire hill has been removed and the site taken over by the Lavender and Sacramento open pits, as shown in Figure 26. The Holbrook shaft buildings are in the foreground.**

Dallas shaft, Des Moines claim, 2032 feet in depth, sinking started in 1911. Production from 1913 until 1916 was significant, but only modest amounts were mined from 1920 through 1929; it served as the main hoisting shaft for the Gardner and Lowell ores while the Sacramento pit was in operation. The shaft was reconditioned in the late 1940's and re-opened in 1950. The Dallas become an important producer and remained in use until all operations ceased in 1975.

Denn shaft, Robert E. Lee claim, 3157 feet in depth, sinking began in 1907. The Denn and Arizona Copper Company, later part of Shattuck Denn Company, was the developer of this mine. It was named for Maurice Denn who, along with Lem Shattuck and Joseph Muheim, owned the 13 claims developed by this working.

Sunk along the Dividend fault, water was a problem from the start. By 1909 a fine series of oxide ores was found extending from just below the 1000 level to the 1800 level, parallel to the Mexican Canyon fault. Production was continuous until 1920, when large amounts of water were hit by development headings on the 1800 level and the mine was flooded (Bronson and Wilcox, 1930).

Because of depressed metal prices, no attempt was made to dewater the mine until the merger with Shattuck and Arizona in May, 1925 (Mills, 1956). From then, production was continuous to 1944, including large tonnages of zinc-lead silver ores. Phelps Dodge purchased the property in March 1947 and mined some 95,000 tons (Mills, 1956). Later, the shaft was deepened and used to serve the development of the 3100 level.

Gardner shaft, Gardner claim, 1457 feet deep, sinking started in 1890. Purchased by the Copper Queen Company with some reservation in 1890 (Douglas, 1909). Early development work soon dispelled anv concerns when it was found that the limestones and the associated halo of ore extended farther to the east than anyone had thought. Also, it was here that the first important primary lead-zinc ores were found. Mining was continuous until the merger with the Calumet and Arizona Company in 1931. Reopened by lessees in 1935, mining continued on a reduced scale until its final closure in 1944. The shaft site was assimilated by an expansion of the Lavender pit in 1968.

Goddard shaft, Goddard claim, 510 feet in depth, sinking started in 1887. Only a modest producer during its short life, it was named for John Goddard of New York who was the owner. The property was acquired in 1888 by the families who controlled Phelps Dodge and was transferred to the Copper Queen Company in 1892. In 1900, when workings from the nearby Holbrook reached the ores developed by the Goddard, it was abandoned. The exact location of this shaft is unknown. Because of the poor ground, the shaft soon caved, and all surface signs were gone by 1909.

Hoatson shaft, Del Norte claim, 1500 feet in depth, sinking started in 1905. Captain Jim Hoatson was a man of unusual faith and mining expertise. It was on these qualities that the early investors in the Irish Mag put their money. To acknowledge that success, the Hoatson was so named. Most of the ores mined here were rich oxides from the great Hoatson orebody that reached from the 1200 level to below the 1400. By 1912, all mined materials were taken to the Junction for hoisting, and the Hoatson became just a service shaft. The mine was closed in 1922.

Higgins mine, Webster claim, shaft 300 feet in depth, collared in 1902, tunnel started 1904. Originally stated by Thomas Higgins, for whom it is named. Early development work was discouraging and the mine was closed in 1906. However, it was leased in 1914 and good ore was found in July of that year (Elsing *et al.*, 1922). Leasing continued until 1916, when mining was taken over by the Higgins Development Company, the owners of the property.

The mine was closed in 1920, when the reserves were nearly depleted, and was sold to Phelps Dodge in 1922 (Mills, 1956). Subsequent work by the new owners developed additional ore, and mining by the company was carried out until 1927. Leases were then given to several individuals who mined it until 1930. The mine again operated under lessees from 1934 to 1944 when it was finally closed. In 1933 the shaft burned; the remaining hole was filled in 1962. The tunnel entrance in Uncle Sam Gulch caved in about 1955 and the Bisbee side was sealed in 1980 to stop trespassing.

Holbrook shafts, old Goddard claim, 525 feet in depth, sinking started in 1889, new Baxter claim, 645 feet in depth, sinking started in 1906. The original shaft was sunk by the Holbrook and Cave Development Company, a group owned by the families that controlled Phelps Dodge. The properties were transferred to the Copper Queen Company in 1892. A producer of principally oxide ores, the Holbrook yielded a great many fine mineral specimens. Before sinking was completed the soft, ever-moving ground caused problems with the shaft alignment. By early 1906 it had become impossible to keep open so it was abandoned and a new shaft was started some 400 feet to the south.

The New Holbrook, as it was called, was a much better and deeper facility providing access to ores below the 500 level. While it, like its predecessor, produced many fine specimens, all of the ores were hoisted at the Sacramento, so an obvious chance for confusion as to source exists. Both shafts were swallowed by the Holbrook extension of the Lavender pit in 1969.

Irish Mag shaft, Irish Mag claim, 1393 feet in depth, sinking started in 1900. The first venture in the district by the Calumet and Arizona Mining Company, this was an incredibly rich though short-lived mine. The main orebody was hit in 1902 on the 1050 level, with some 325 feet of 9-percent copper ore being cut (C and A, 1916). Work was then continuous until 1913, when it was turned over to lessees. In 1917, the mine was closed and the surface facilities removed. The site was covered by dumps from the Lavender pit in 1968.

Junction shaft, Waddel claim, 2727 feet in depth, sinking started in 1903. A Calumet and Arizona property, it was one of the most productive mines in the district. Early in its life, many oxide-zone minerals were mined here, including some very fine specimens. Later only sulfides were produced including substantial amounts of zinc and lead. The Junction was an extremely efficient mine with five concreted compartments and a very fast hoist. For many years it was the central hoisting and pumping facility for the other mines. It still serves as the pumping shaft for most of the district with pump stations on the 2700 and 2200 levels for normal waters and one on the 1800 level for handling acid waters. Active mining and hoisting was stopped in 1958 with the remaining Junction ores being mined through the Campbell. The massive headframe for the operation still stands on the eastern edge of the Lavender pit.

Lavender pit. Harrison Lavender began his career with the Calumet and Arizona Mining Company as a miner in Bisbee. By the time of the merger with Phelps Dodge in 1931, he was the chief engineer. Retained by Phelps Dodge, he eventually became responsible for all of their western operations. He was instrumental in the development of the porphyry ores that resulted in the pit named in his honor following his death.

Initial stripping began in 1950, with the first ores milled in 1954 (Mills, 1956). Continually mined until its closure in 1974, 94,400,000 tons of ore and 281,600,000 tons of leach material and waste were removed for a total of 376,000,000 tons (Phelps Dodge, personal communication, 1975).

The Holbrook extension to the pit was started in 1967 and was so named because it encompassed the area of the Holbrook mines. Many truly fine mineral specimens were found during the mining of this segment of the pit.

Lowell shaft, Galena claim, 1603 feet in depth, sinking started about 1903. The Lowell exploited a group of claims that was purchased by the Copper Queen Company from Senator Clark of Montana in 1903 during the race with Calumet and Arizona for property. No ores were cut in the first 1000 feet and those found later were almost all sulfide. This mine had the questionable distinction of having the first sulfide mine fire in the district. Such fires plagued the Lowell for most of its productive life and a few fires continued to smolder for many years after its closure in 1931. From 1935 to 1940, this mine was operated by lessees. No work was done after 1940 in the Lowell itself; however, some ores were mined from the Dallas. The site was covered by Lavender pit dumps in 1969.

Neptune tunnel, Neptune claim, started in 1881. Actually an adit, not a tunnel, it was the most important producer for the Neptune Mining Company during its short life. The property was sold at a Sheriff's sale in 1886 to interests favorable to the Copper Queen Company and title was transferred to the Queen in 1892. Mining was done only during the years 1881–1882 and again in 1913. The exact location of this mine is uncertain. However, it is believed that it was situated on the western flanks of Sacramento Hill.

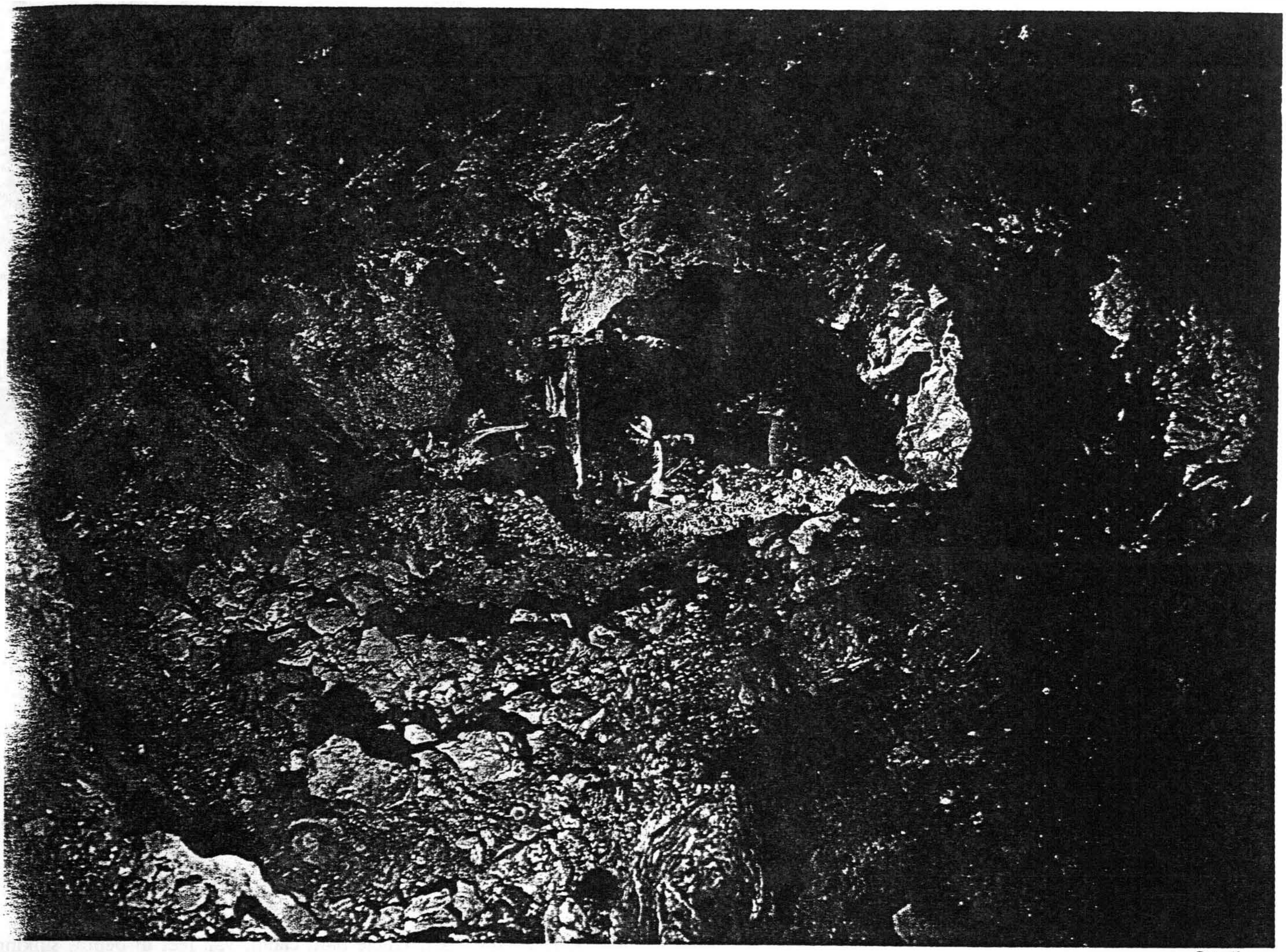
Nighthawk shaft, Nighthawk claim, 749 feet in depth, sinking started about 1911. This mine was developed by lessees and from 1923 to 1930 produced significant amounts of mostly oxidized ores. A very modest and unsuccessful operation was undertaken in the mid-1930's. The mine's final closure came in about 1938.

Oakland shaft, Oakland claim, 1380 feet in depth, sinking started in 1916. Developed by the Calumet and Arizona Mining Company to prospect areas east of the Briggs shaft. Even though some ore was found, most was exploited through the larger and more efficient Briggs or hauled to the Junction for hoisting. The Oakland served as a ventilation shaft until 1947 when it was filled to control the exhaust gases from the Campbell fire.

Oliver shaft, Senator claim, 1477 feet in depth, sinking started 1903. An early development of the Calumet and Arizona Mining Company, the mine was named for Henry W. Oliver, a principal investor in the company. Mining was continuous from 1904 to 1922 when it was closed for several years. Re-opened by lessees, the Oliver operated sporadically until 1940. Many types of ore were mined here, using several mining systems (C. and A., 1916). In 1965 the headframe was dismantled and the shaft was filled. Dumps from the Lavender pit covered the mine site in 1969.

Sacramento pit. One of the earliest open pit copper mines, stripping for the Sacramento started in 1917. Mining was done using 3½-cubic-yard steam shovels that ran on standard gauge railroad. Haulage was all on rail with 0–4–0T Porter locomotives pulling 20-cubic-yard cars (Ziesmer and Mieyr, 1923). Ore production started in 1923 and continued through most of 1929 with some 9,000,000 tons delivered to the smelter or mill. Waste and leach materials totaled 23,000,000 tons, for an overall production of 32,800,000 tons (Phelps Dodge, 1938). The resulting pit was just over 700 feet in depth. Mining in the Holbrook extension of the Lavender pit assimilated the Sacramento pit.

Sacramento shaft, Stars and Stripes claim, 1795 feet in depth, sinking started in 1904. Sunk on the eastern flank of Sacramento Hill, the "Sac" was one of the most important mines developed by the Copper Queen Company. For many years, it served as the main



Peter Kresan

Figure 24. **A portion of a stope in the Copper Queen mine, excavated in the 1880's.**

hoisting facility for all of their operations. While it produced mostly sulfide ores, important amounts of oxides were also mined. It operated from 1904 until the merger with the Calumet and Arizona Company in 1931 when operations were suspended. Mining resumed in 1935 and lasted through 1944 with low grade ores being mined for the wartime "metals reserve account" during the last two years (Mills, 1956). The mine was consumed early in the operations of the Lavender pit.

Shattuck shaft, Iron Prince claim, 1139 feet in depth, sinking started in 1904. One of the most productive and profitable operations in the district, it was named for Lem Shattuck, the owner of the group of claims it exploited. This mine was developed by the Shattuck and Arizona Copper Company. Ores from the Shattuck were transported to a railroad loading bin near the Holbrook by a 3300-foot aerial tramway on an 18-degree slope. Principally oxides were produced including large amounts of lead. Operations by the company continued until 1925 when lessees took over. They mined it until 1947 when it was closed. A fire set by children in 1952 destroyed the surface plant and burned out the shaft.

In 1973 Phelps Dodge purchased the property and erected a headframe that had been moved from the Cochise and Calumet shaft. A hoist was installed and the shaft opened up to about the 800 level by the time work was suspended in early 1976.

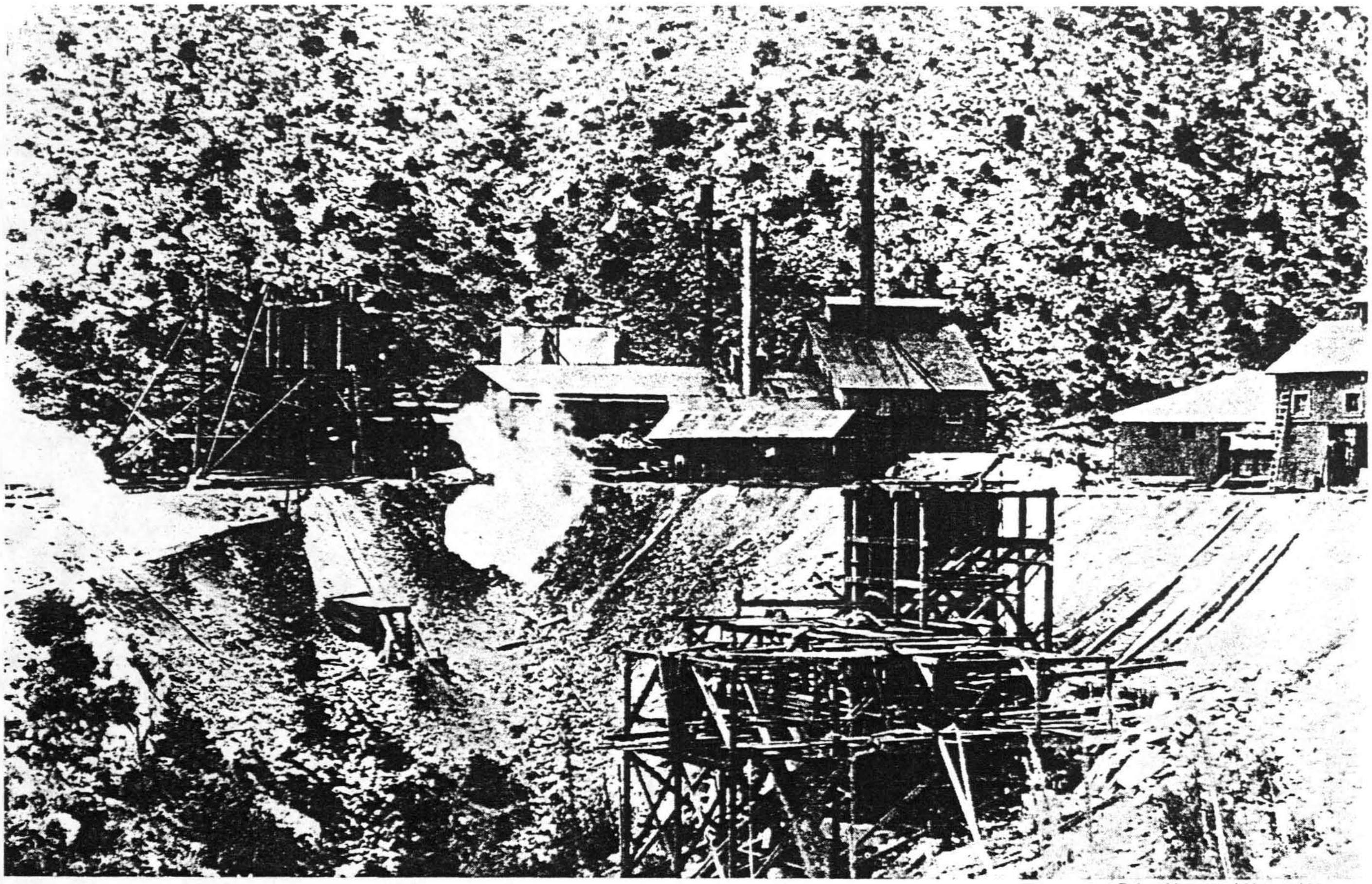
Silver Bear shaft, Silver Bear claim, 1052 feet in depth, sinking started in 1912. Originally intended to prospect the ground south of the Spray, this Copper Queen Company project was only moderately successful. Small amounts of oxide ore were developed and mined from the 400, 600, 700 and 800 levels. Most of this was near the Irish Mag claim. Mining was discontinued in 1922 and the surface facilities removed in 1942. The site was covered by dumps from the Lavender pit in 1968.

Southwest mine, Atlanta claim shaft, 493 feet in depth, sinking started in 1911. The Southwest, a Copper Queen Company property, was used to exploit Queen Hill above the collar of the Czar shaft. Three principal adits and two interior shafts, one a replacement of the other, serviced this expansive mine.

The Southwest mine is unique in the district in having its levels designated according to elevation above sea-level. The bottom level was the Queen tunnel at an elevation of 5300 feet; thus it was called the 3rd level. Correspondingly, the Southwest tunnel at the 5500-foot elevation is the 5th level and so on upwards to the 10th level at 6000 feet. All other mines in the district have levels numbered according to the depth in feet, measured from the collar at the surface downward.

An incredibly rich mine, it exploited the New Southwest orebody which contained nearly a million tons of 10-percent copper ore, all oxides. The ground was unusually competent, and the resulting opening was referred to as "the ballpark."

Mining was continuous in the Southwest until 1931 and was resumed by lessees in 1934 who worked into mid-1944. Important amounts of lead were mined in addition to the copper during all phases of its operation. Today, the Queen Mine Tour uses part of



Bisbee Mining and Historical Museum

Figure 25. **Headframe of the Shattuck shaft on the Iron Prince claim, opened in 1904.**

the 3rd level as its pathway. The newer of the Southwest shafts is visited in the course of the tour.

Spray shaft, Silver Spray claim, 1060 feet in depth, sinking started in about 1889. Development was started by the Holbrook and Cave Mining Company and turned over to the Copper Queen Company in 1892 before any ore had been found. By 1894, the Silver Spray, as it was then known, was a major producer. It was the impressive orebodies developed east of the shaft that inspired Jim Hoatson, on the advice of John Graham, to purchase the Irish Mag and start the C. and A. Company on its way.

Reserves were depleted in the Spray by 1913 and it was leased until 1918 when all of the surface facilities were removed. The shaft was bulkheaded at the collar and covered by dumps from the Sacramento pit. During the early 1930's, a lessee reclaimed the lower part of the shaft from the Holbrook, then raised up through 80 feet of loose dump material, an extraordinary feat. A small wooden headframe served the mine until its final closure in 1940. The site was covered by the Lavender pit dumps in 1968.

Sunrise shaft, Golden Gate claim, 734 feet in depth, raising started in 1919. A unique facility in many ways, the Sunrise was developed by the Copper Queen Company to service the Southwest mine. This shaft was a series of connected raises from the Queen tunnel or 3rd level to its collar at 6000 feet in elevation.

Because the hillside it surfaced on was so steep, no conventional headframe hoist system could be used. So a four-storied structure was erected over the opening with the hoist on the top floor situated over the shaft. The cage was the only one in the district large enough to accommodate a mule. This interesting structure still stands on the south facing slopes of Queen Hill. Its periods of operation are the same as those of the Southwest mine.

Uncle Sam shaft, Uncle Sam claim, 932 feet in depth, sinking started about 1893. Originally developed by the Copper Queen Company to prospect favorable horizons south of the Holbrook. However, nothing of interest was found, principally because of insufficient work, and the mine was abandoned in 1895.

Encouraged by finds in the nearby Shattuck, exploration was resumed by the company in 1905. Ore was found later that same year. Mining continued from that time through early 1923 with the last few years under lessees. The shaft was reconditioned in 1934 and lessees resumed mining off and on until 1942 when the mine was abandoned. Its headframe was removed and sent to Tyrone, New Mexico (Mills, 1958). The shaft was filled with waste from its own dump in 1966.

Wade Hampton shaft, Black Hawk claim, about 400 feet in depth, sinking started in 1913. Sunk on a small showing of lead, silver and gold, only very minor amounts of which were recovered; the mine was abandoned by 1915.

White-Tailed Deer shaft, White-Tailed Deer claim, 602 feet in depth, sinking started in 1911. A Copper Queen Company mine, it was sunk on the strength of encouraging finds in the southern portions of the nearby Cole. By 1913 it was producing a significant amount of ore, principally oxides. Mining by the company continued until late 1920, when it was turned over to lessees who did relatively well. In 1941 Phelps Dodge resumed control of the mine and brought it into production once more to assist in the war effort. The shaft was filled during the summer of 1964.

Wolverine shafts, both on the Broken Promise claim, number 1 was 670 feet in depth and number 2 was 700 feet in depth. Sinking started on number 1 in 1903 and on number 2 about 1912. The sole property of the Wolverine and Arizona Mining Company, it was

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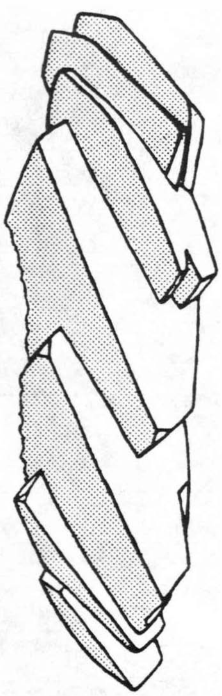
Figure 26. **The Lavender pit (foreground) and connected Holbrook extension behind it today occupy the site of the former Sacramento Hill (and have assimilated most of the Sacramento pit), as seen in this aerial photo taken from the opposite direction as Figure 23.**

operated only during times of high metal prices. Most of the ores mined were oxides from a southern extension of the Shattuck deposits. A lease on the Higgins tunnel was secured from Phelps Dodge in the late 1920's and the remaining Wolverine reserves were removed through this opening using an interior shaft. Phelps Dodge acquired the property in 1949 for its "nuisance value" (Mills, 1956). The number 2 shaft burned in 1974.

Unsuccessful exploration mines. As in every district a number of mines were developed in the never-ending search for new ore. Many of these were successful while others were not. Sometimes, though, even the latter produced a few fine specimens. For that reason they are listed here:

Bisbee Queen shaft
Bisbee West shaft
Cochise shaft
Cochise and Calumet shaft (developed by Phelps Dodge for water to be used in the Sacramento concentrator)
Congdon shaft
Contact shaft and adit
Copper King shaft
Galena shaft
Glance shaft
Hedberg tunnel
Houghton tunnel
Ivanhoe shaft
Kentucky tunnel
Lake Superior and Boston shaft
Lone Star shaft
Powell shaft
Saginaw shaft
Warren shaft



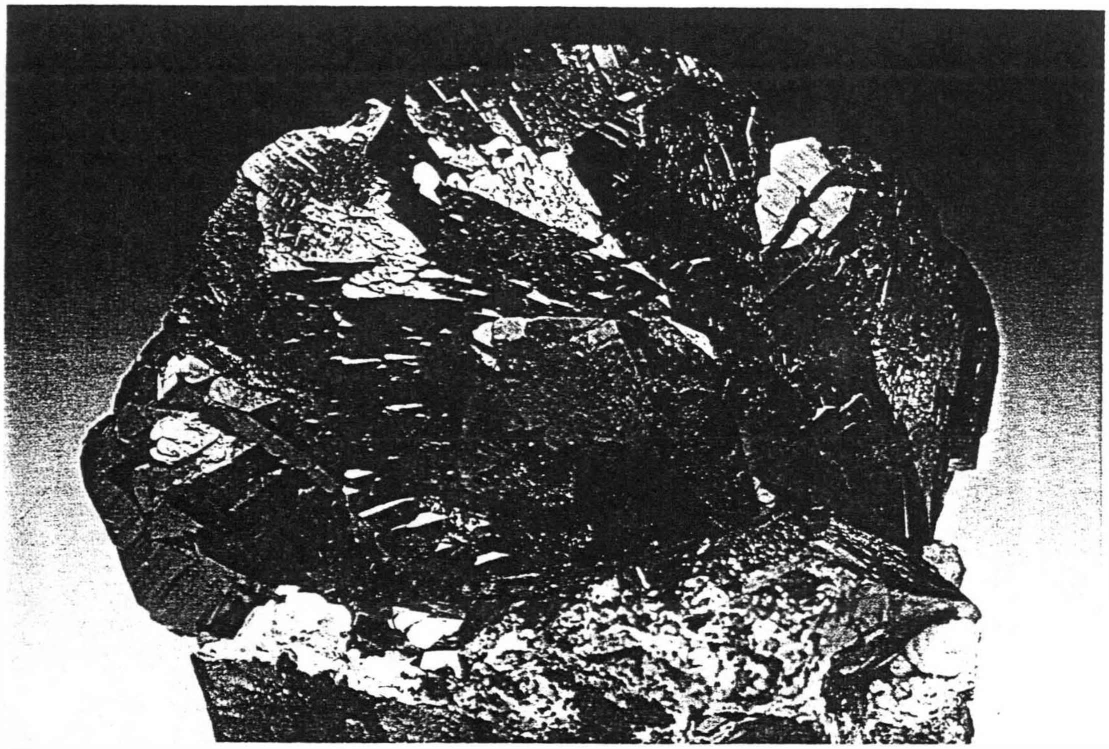


Figure 30. Azurite "pinwheel" growth, composed of seven individuals offset from each other by rotation approximately about the *c* axis. Sketch at left shows a top view. About 3 inches across, from the Sacramento shaft. Note that the interior of the crystals is a malachite pseudomorph, overlain by a thin secondary growth of azurite. Graeme collection.

Figure 31. Azurite crystals on a matrix 4⅓ inches tall, from the Sacramento shaft. Arizona-Sonora Desert Museum collection.

Geology

General Geology

The geology of the Warren district has, over the years, received several very fine treatments. For the most part, the interpretations and hypotheses of these workers have stood the test of time. Ransome's classic professional paper (1904) is still the basis for most of the work done in the area. Other important papers that have expanded on Ransome's work include Bonillas, Tenney, and Feuchere, 1916; Trischka, 1938; and Bryant and Metz, 1966. Because of these fine discussions of the district, only an overview will be presented here.

The rocks of the district consist of a basement Precambrian quartz sericite schist overlain by 5500–6500 feet of generally calcareous Paleozoic sediments. These were all intruded during Jurassic times and subsequently mineralized. Erosion then removed an unknown thickness of the sediments and instrusives, bringing the upper mineralized zones in both units near the surface. At this time, supergene enrichment occurred along a relatively level plane.

During lower Cretaceous times, some 5000 feet or so of principally clastic sediments were deposited on this surface. Later, tilting of about 30° to the east and erosion again exposed the western end of the mineralized area to a supergene environment, resulting in what exists today.

Rock Units

Precambrian Rocks

Pinal schist

This Precambrian basement unit is of unknown thickness and has been dated at 1.7 billion years old. Essentially a fine-grained, fissile, quartz-sericite schist, it is probably metamorphosed sediments. Most of the hills north and west of the stock are composed of this unit. While locally mineralized, the Pinal schist has never been known to host ore.

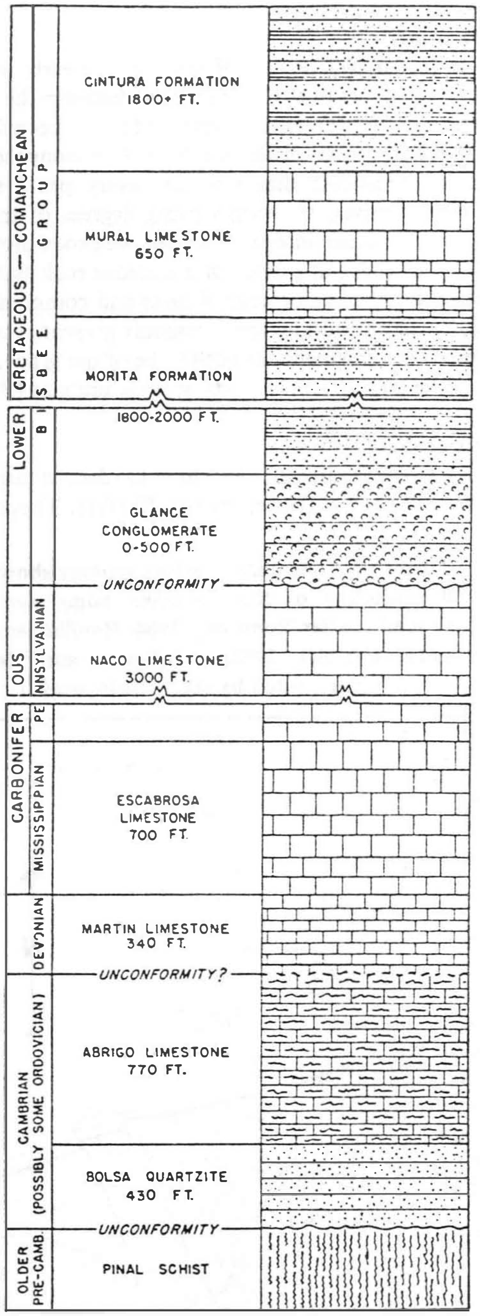


***Figure 32.* Generalized geologic section (from Hogue and Wilson, 1950; after Ransome, 1904).**

Paleozoic Sediments

Bolsa quartzite

Cambrian in age, the oldest member of this unit is a basal conglomerate grading into arkosic grits and finally into crossbedded quartzites. Locally it achieves a thickness of 430 feet. The Bolsa may be pyritic in some areas, but has never been an ore-bearing horizon.

Abrigo limestone

Also Cambrian in age, the Abrigo limestone rests conformably on the Bolsa with a total thickness of 770 feet. It is a thin-bedded, cherty, impure limestone with some calcarous shales and local manganese oxide staining. During the early years of mining, the Abrigo was considered to be of limited potential. Only the top 100 feet or so were explored to any degree. It wasn't until the mid-1950's that its true value as a host for ore was realized. From then until the cessation of mining it was the mainstay of the underground operation.

Parting quartzite

This unit rests atop the Abrigo with no apparent unconformity below or above. Only an average of 8 feet thick, its value lies in its use as a marker bed. Bonillas *et al.* (1916) felt it represented the Silurian, while Ransome (1904) assigned it to the Abrigo.

Martin limestone

While this Devonian unit is only 340 feet thick, it has produced more ore than any of the other limestones. It is a dark gray, dolomitic, compact, fossiliferous unit of moderately thick beds.

Escabrosa limestone

The second most productive horizon in Bisbee, this unit is some 700 feet thick and is of Mississippian age. Generally light in color and thick-bedded, the Escabrosa rests conformably on the Martin and is often a cliff-former. The separation between the overlying Naco and this horizon is indistinct. Based on fossil evidence, the contact is imperceptable in the field.

Naco limestone

Of Pennsylvanian-Permian age, an average of 1500 feet remains. It rests conformably on the Escabrosa and a pre-Cretaceous erosional surface forms its top. This limestone is moderately thick-bedded and quite fossiliferous. Only modest amounts of ore have been discovered in the Naco.

Mesozoic Sediments

Cretaceous sediments, Bisbee group

These units rest on an uneven erosional surface of schist, Paleozoic sediments and granite. They include the Glance, a basal conglomerate; the Morita sandstone; and nearly pure Mural limestone; and the Cintura sandstone-shales for a total thickness of at least 4900 feet. Because these units are post-ore, they are of little relevance and will not be discussed.

Intrusive Rocks

Juniper Flat granite

This unit is most prominent to the north and west of the productive zone. The rock is a coarse-grained mass, pink to purplish gray in color, composed principally of two units: a quartz monzonite and a granodiorite. Microcline, or orthoclase and quartz as well as a little biotite and plagioclase are the most common constituents. Usually fresh and free of alteration, it has been dated at 177 million years (Creasery and Kistler, 1962). Economically, only a few small but rich pockets of gold have been found in it. These were in quartz veins associated with fluorite.

Sacramento stock

This intrusive mass is actually composed of two distinct units. They are known as the granite porphyry and the younger granite porphyry. The older unit is a highly altered quartz porphyry. It was intensely silicified and pyritized by early hydrothermal fluids and is almost totally devoid of ore minerals. This, perhaps, was a result of being effectively sealed during early alteration, rendering penetration by later, ore-bearing fluids impossible.

The younger granite is described as a quartz-feldspar porphyry. It has been moderately altered by both hypogene and supergene fluids. This same unit also occurs as numerous dikes in the underground mines and was the ore host for both the Sacramento and Lavender pits. Both intrusions comprising the Sacramento stock are dated at about 180 ± 3 m.y. (Phelps Dodge, personal communication, 1972). However, Lowell and Guilbert (1970) have ascribed an earlier date of 163 m.y. to these units.

Breccias

Breccias are included here because of their wide distribution and their important relationships to the ores. Many types of breccias are recognized in the district. In decreasing order of respective volumes, the terms applied to them are: intrusion, intrusive, silica, igneous, fault, and protoclastic. Of these, only the first three are of major significance and are all pre-ore.

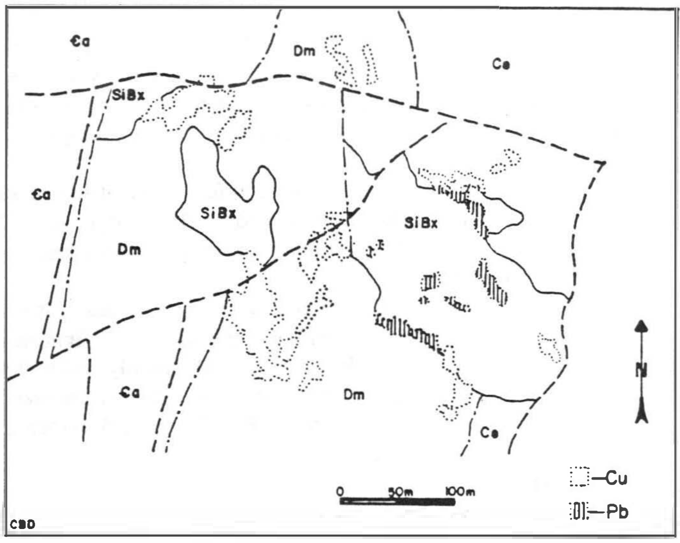


Figure 33. **Silica breccias (SiBx) and their relationship to copper and lead orebodies in the Southwest mine. Note their apparent restriction to the upper Paleozoic units.**

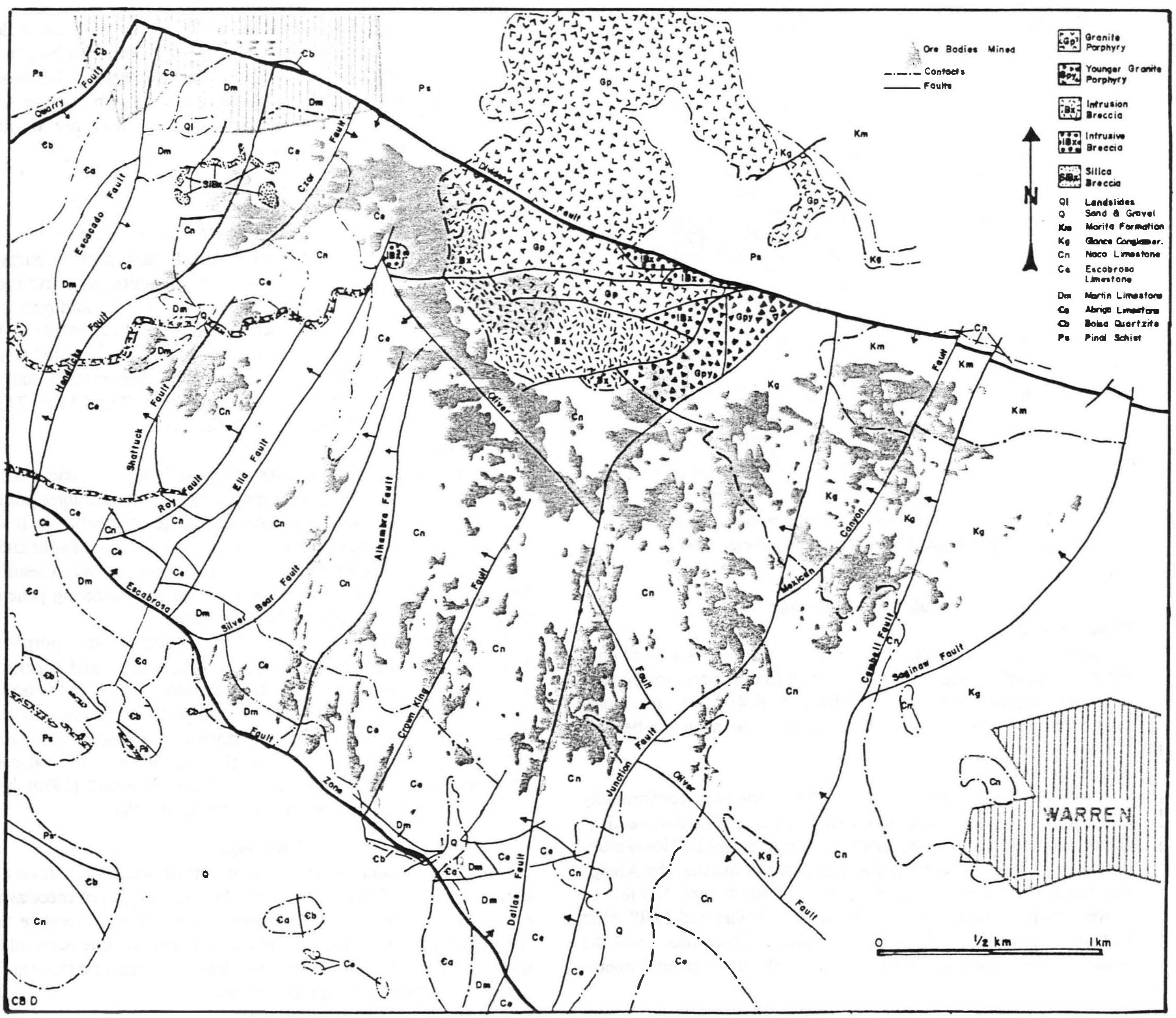
Intrusion breccia

This is the contact breccia of some of the early workers. Most commonly it occurs in the contact zone between the older granite porphyry and the sediments. It appears to have been formed by the active intrusion of the earlier porphyry. It is composed of angular to rounded fragments that represent every pre-Cretaceous unit except the intrusives, showing varying degrees of transport. The breccias usually grade into undisturbed wall rock along the edges. The matrix of this unit consist of a siliceous rock-flour containing small fragments of the brecciated units and commonly significant sulfides. Sufficient sulfides are commonly present as a replacement of the matrix or fragments or both to be of ore grade. This usually occurs in the more siliceous parts of these breccias (Bonillas *et al.*, 1916).

Intrusive breccias

These breccias are found throughout the district ranging in thickness from less than a quarter inch to 500 feet. They are a hetero-

Figure 34. **Generalized surface geology showing a projection of the orebodies mined underground. (After Ransome, 1904; Bonillas *et al.*, 1916; Trischka, 1938; and Bryant and Metz, 1966; supplemented by recent field work.)**



geneous mixture of all pre-Cretaceous units in a matrix of rock flour. Amazingly free of alteration, the fragments are angular to rounded and have been found up to 100 feet in diameter, frequently, hundreds of yards from their closest known source. The breccias are usually quite continuous over long distances, and pinch and swell, readily changing from dikes to sills. Bryant (1968) ascribes a fluid intrusion origin and estimates they have a total volume of 800 million cubic feet.

Silica breccias

As the name suggests, these are highly siliceous units. Composed of angular fragments of completely replaced limestone, they have a matrix of cryptocrystalline quartz and specular hematite. Relict fossils representing all of the fossiliferous units can, on rare occasion, be found. Judging from these, movement of the units appears to have occurred downward as well as upward. Indications of lateral movement are found in fragment orientations along their edges. These units are invariably pipe-like and physical connection with porphyry dikes is common (Bonillas *et al.,* 1916). Also, they appear to have been restricted to the Shattuck, Southwest, and the Higgins ore zones. Their importance to ore implacement, because of their permeability, cannot be overstated. Trischka (1932) felt that over 90 percent of the ore mined in the aforementioned areas was in physical contact with the silica breccias. The accompanying illustration shows the typical relationship between these breccias and the associated oxide ores of both copper and lead. The origin and mechanics of these units are still uncertain. Trischka (1928) proposed that they are limestone breccias of fault origin that were later silicified. They closely fit the solution and replacement breccias described by Butler (1913) and Kuhn (1941). As they are restricted to the post-Cambrian Paleozoic sediments, the silica may well represent a remobilization of their abundant cherts (Keith Coke, personal communication, 1973).

Structural Geology

The Dividend fault is the most important fault zone in the district. It is an ancient structure that has experienced numerous periods of activity. A normal fault, it trends northwest with a southwesterly dip of from 60° to vertical. Displacement ranges from 4900 feet at its eastern most exposure, to in excess of 2000 feet near its western end. Underground, this zone is from 39 feet to more than 240 feet thick. It divides the Mule Mountains along their major axes from the mouth of Mule Gulch to the beginning of Tombstone Canyon, where it terminates against the Quarry fault.

The Quarry fault is the westernmost and one of a series of north-northeast trending fault zones that are more or less perpendicular to, and south of, the Dividend fault. Among these faults are: the Quarry, Escacado, Shattuck, Czar, Silver Bear, Mexican Canyon, and Campbell. Most terminate at the Dividend zone. Generally these faults dip steeply to the west. Some 2½ miles to the south and sub-parallel to the Dividend zone is the Escabrosa fault zone. It is here that most of the north-northeast faults end. A few sinuous structures with a generally northwest trend complete this summary of the important breaks in the productive zone. The end result of all this faulting is a series of blocks bounded by major fault structures.

Geologic History

Little can be reconstructed of the Precambrian other than to say that, after metamorphism was complete, the schist was intruded by several basic dikes and then peneplained. Onto this level surface were deposited nearly 1200 feet of Cambrian sediments as it subsided, rapidly at first, then at a much slower rate.

Then there is a hiatus, leaving no record from the late Cambrian until Devonian times. The record resumed as the Devonian seas deepened and dolomitic sediments developed. During the Mississippian period and deposition of the Escabrosa limestone, the seas were much more shallow, as indicated by numerous reef formations. Deposition of limestone lasted through Pennsylvanian into Permian times when uplift occurred. The Paleozoic sediments had by then reached a total thickness perhaps greater than 6500 feet and were undergoing erosion. At some point during late Triassic or early Jurassic times, while still relatively flat lying, the sediments underwent extensive faulting, and activity along the Dividend fault zone occurred.

How quickly intrusion followed is unknown, but about 180 million years ago a quartz porphyry followed the Dividend fault through the schist into the overlying sediments. Extensive peripheral breccias were formed along the contact with the wall rocks.

Subsequently there came intense silicification of both the intrusion and the sediments. The Paleozoic rocks were locally silicified as much as 2½ miles from the locus of intrusion. This was closely followed by heavy pyritization in the porphyry, schist, and silicified sediments. Large replacement bodies of pyrite were scattered throughout the limestones.

Following the same path along the Dividend fault and close in time came a second intrusion. It forced its way through the schist, earlier porphyry, and the now-silicified sediments. Numerous dikes intruded the limestones, commonly for great distances. Soon thereafter, intrusive breccia dikes and sills also invaded the sediments, while an irregular pipe-like mass of breccia 500 feet in diameter pushed its way into the stock. The silica breccias probably also formed during this time.

As a result of the intrusive and breccia complex nearly a mile across in their midst, the adjacent sediments became irregularly metamorphosed for a short distance. Replacement by garnet, diopside, wollastonite and vesuvianite near the porphyry shortly gives way to tremolite, actinolite, and edenite indicating only minor effects of high temperatures. This assemblage in turn soon grades into recrystallized limestones followed by unaltered rock. In all, a contact metamorphic halo of little more than 1500 feet developed around the stock.

Metamorphic effects in the limestones are also noted along many, but not all, of the porphyry dikes. Generally, quartz is the most abundant mineral, followed by epidote and garnet. No truly definitive pattern is obvious in these instances because of the overlapping nature of the aureoles, and also the irregular and erratic development.

Paragenesis

When the mineralizing fluids were introduced is still being debated. Bain (1952) suggests 104 million years ago, Bryant (1968) 130 m.y., while others (Anthony *et al.,* 1977) feel the mineralization is quite close in age to the porphyry or 180 m.y.

Following the oft-used channels in the limestones, the fluids formed hundreds of widely-scattered replacement bodies without evident connection. The size of the replacement orebodies was quite variable, ranging from several thousand tons to a few exceptional masses of more than a million tons. Bryant and Metz (1966) report that possibly two-thirds of the ores mined came from masses of 25,000 tons or less.

Ground preparation was the key to their deposition. Aside from structures, silicification was the most important of the controlling features. The immense aureole of ore around Sacramento Hill in the contact zone illustrated this. Here, replacement by ore is apparently restricted to the more siliceous areas. In the limestones away from the contact influence, large barren zones are found with every feature of ore areas except silicification. Yet, seldom are silicified masses of any size found that are not mineralized.

Other features found in areas hosting ore include intersecting structures, breccias and/or porphyry, and alteration minerals such as epidote and garnet. Massive pyrite, and recrystallization of the country rock are also common.

In spite of all of these clues, prospecting for new orebodies has always been exceedingly difficult. While, as stated, many of these features are present in ore zones, the breccias, porphyry, and structural characteristics are much larger and far more widespread than the ore. Therefore, their presence simply indicates a favorable area with no guarantee of economic mineralization. Alteration is much the same. Finding it only indicates that mineralizing fluids could have been there, not that they have been or, if so, that any ores were deposited. So elusive are the orebodies that just inches away from them there is little if anything to betray their presence. Because of this a continual prospecting program was essential. At no time in the near-century of mining has there ever been more than just a few years of ore in sight.

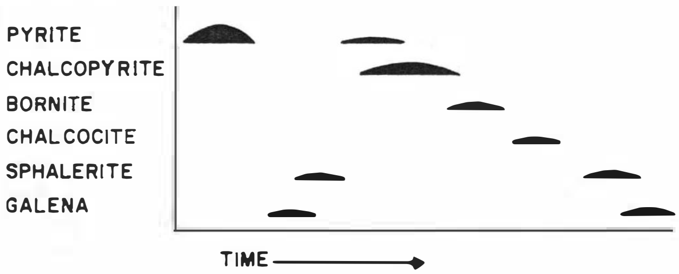


Figure 38. **Hypogene (primary) paragenetic sequence.**

Hypogene Paragenesis

Lead and zinc mineralization seem to have occurred during several separate periods. Additionally, it is often highly localized. Consequently the overall hypogene (primary) paragenesis may be confusing, with the apparent sequence dependent upon the area being studied. Bain (1952) suggests that the sequence was: pyrite→galena→sphalerite→chalcopyrite→bornite. Schwartz and Park (1932) found it to be: pyrite→chalcopyrite→bornite→chalcocite→sphalerite→galena, while Tenney (1913) indicated pyrite→sphalerite→galena→chalcopyrite→bornite to be the sequence. No doubt each of these workers is correct in the context of the specimens examined. Perhaps, then, a combination of all of these more closely represents the actual sequence.

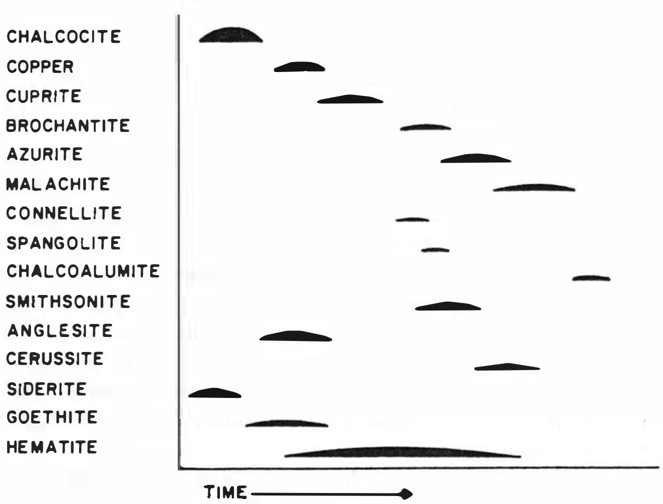


Figure 39. **Generalized supergene (secondary) paragenetic sequence.**

Supergene Paragenesis

At some point in pre-Cretaceous times activity along the Dividend fault was renewed. The north or footwall side was uplifted an unknown amount and all the sediments were removed. There is no reason to suspect that they had not been mineralized to the same extent as those that remain. What may have happened to that copper has long been debated. Some suggest that perhaps the unusually rich supergene deposits along the Dividend may well be relics of these ores (Bonillas *et al.,* 1916).

Also during this period, enough of the overlying units were removed from the hangingwall or south side to subject these sulfides to supergene (secondary) enrichment. A deep canyon was cut along the Dividend fault line from the stock to the east, giving even further access to fluids which caused enrichment. By Cretaceous times, an enriched zone more or less parallel to the surface had formed. Boulders of gossan and stream-worked secondary minerals in the lower Glance conglomerate confirm this enrichment period. The deposition of more than 3900 feet of sediments in the shallow Cretaceous seas effectively sealed the ores from further attack. Later uplift, almost doming, around the old Juniper Flat intrusion tilted the beds about 30° to the east. Erosion again uncovered some mineralized areas. This time, only the western part was exposed.

An interesting aspect of many of Bisbee's supergene minerals is that their source within the district is easily determined. So distinctive are they, that not only the mine but the ore zone and frequently even the stope can be recognized. No two areas were subjected to the same set of conditions so specimens from each area are somewhat different. The principal differences are morphology, associated species, color and hue, and paragenetic sequence.

Because of their significance to the mineralogy of the district, a discussion of some of the supergene characteristics is instructive. A marked difference is apparent between those areas that underwent more than one period of supergene activity and the sections that did not. If a north-south line were drawn in the vicinity of the Spray shaft it would come very close to separating the two areas.

Supergene assemblages vary in the relative proportions of minerals they contain. For example, to the west malachite is by far the most abundant secondary product, followed by azurite, cuprite, copper and chalcocite. Here, chalcocite is very much in the minority when compared with any of the other minerals. In the eastern sector, exclusive of the porphyry ores, chalcocite is the most common, then cuprite, copper, azurite and malachite. This, of course, is a function of the degree of supergene activity.

A comparison of the morphologies of azurite in the two areas reveals that western specimens are most frequently massive, reniform and stalactic. While large crystals are unusual, pseudomorphs of malachite after azurite up to 1½ inches were not uncommon. To the east, very few reniform or massive groups were found. Here, almost all azurites were well crystallized, commonly exceeding 2 inches. Well-formed pseudomorphs of malachite after large azurite crystals abound in this area.

A few stalactites of azurite in the Sacramento shaft and malachite in the Campbell shaft, when found, had a non-vertical orientation indicating formation prior to tilting. Conversely, in the western area stalactites, horizontal fluid level lines and precipitated minerals inevitably show a post-tilting growth orientation.

The depth to which the supergene fluids penetrated was, of course, a function of permeability. Along major structures secondary minerals were found at unusual depths. In the Campbell shaft, wulfenite has been found in the 2566-foot level along the Campbell fault. This is some 1170 feet below the pre-Cretaceous surface. No primary ores were cut in the Denn shaft, along the Dividend fault, above the 2000-foot level, or 975 feet below the old surface (Bronson and Wilcox, 1930). To the west, the Hoatson orebody was oxidized for over 1365 feet below the present surface along the Junction fault.

In the areas affected by post-Cretaceous supergene action, nearly total oxidation took place at depth. In the Shattuck, for example, no sulfides, primary or secondary, were found above the 800-foot level.

Supergene gangue minerals

Enormous volumes of acids were generated by alteration of pyrite during supergene activity. One of the several features attributable to this is the huge amount of clays, principally halloysite and kaolinite. Derived, for the most part, from the porphyry and metamorphic feldspar minerals, tens of thousands of tons were formed. So pervasive are the clays that along the west and south sides of the stock, erosion developed low-lying areas, indicating the lack of resistance to weathering.

Quite plastic in nature, these clays were both a boon and bain to the miners. Almost always heavily iron-stained, they would frequently contain enough disseminated copper minerals to constitute an ore. While easily removed, keeping the workings open often proved impossible. Ground opened one day would be completely closed the next, crushing the largest of timbers. The Holbrook shaft was lost in 1906 to these clays.

A common product of early supergene activity was siderite. Commonly found in large masses with boxwork structure, it frequently occurred under or adjacent to chalcocite orebodies. Carbon dioxide filled the voids in the boxwork. Further exposure to supergene fluids altered the siderite to limonite (Trischka, *et al.*, 1929).

Oxidation Caves

Perhaps the most interesting, yet least known, oxidation feature is the caves accompanying many of the secondary orebodies. A significant reduction in volume accompanied the total oxidation of the primary sulfides. This, coupled with lesser amounts of limestone removed by the acids generated during this process, has left voids above the oxides.

The host limestones compensated for the removed support in several ways. If the beds were thin or broken, they would slump and fill the opening with rubble that usually became cemented with calcite. Numerous crystal-filled pockets would in some areas develop between the broken limestone boulders. These effects can often be identified as much as 1000 feet above and have served as guides to ore (Wisser, 1927). When slumping occurred less than 300 feet from the surface, a roughly conical depression formed. Such features dot the hills in the Czar, Southwest, and Shattuck areas.

In the thicker bedded, more competent horizons where most of the district's ores occurred the effects were somewhat different. Instead of complete collapse the beds would spall off leaving a stable, often somewhat domed ceiling. Many hundreds of such caves were found in the district. Typically of very large size, they would have a floor of limestone boulders immediately overlying an oxide orebody. The accompanying illustration from Douglas (1899) shows these features (Fig. 22).

The largest of these caves was in the Shattuck mine. Crescent-shaped, it curved around a silica breccia, attaining a maximum height of 275 feet, a width of 340 feet, and a total length of 600 feet. It contained many large boulders. One end of the cave was over copper ore, while the other was over cerussite. So closely associated with the ores were the caves that Wendt (1887) was of the opinion that the copper carbonates in the Queen and Atlanta areas had been deposited as such in pre-existing openings.

Associated with both the complete filling by rubble and the doming structures were sag caves. Formed as the beds sagged over the openings or rubble, they are usually small. Seldom more than 6 feet high, they may be as much as 100 feet in length and width. Because they invariably occur peripheral to the other openings, only very rarely do they contain any minerals other than calcite and aragonite.

As a source of fine minerals, Bisbee's caves were exceptional. Ransome describes some of them in his 1904 paper: "The walls of these caverns were covered with velvety moss-green malachite and sparkled with the blue crystals of azurite, while from the roofs hung translucent stalactitic draperies of calcite, delicately banded and tinted with the salts of copper."

An equally fascinating account of a small cave hit in the Southwest orebody before 1900: "A room, not too big, perhaps 50 feet in curved length and 20 feet high and 15 or so feet wide. The walls were all manner of irregular lumps of black azurite dotted with

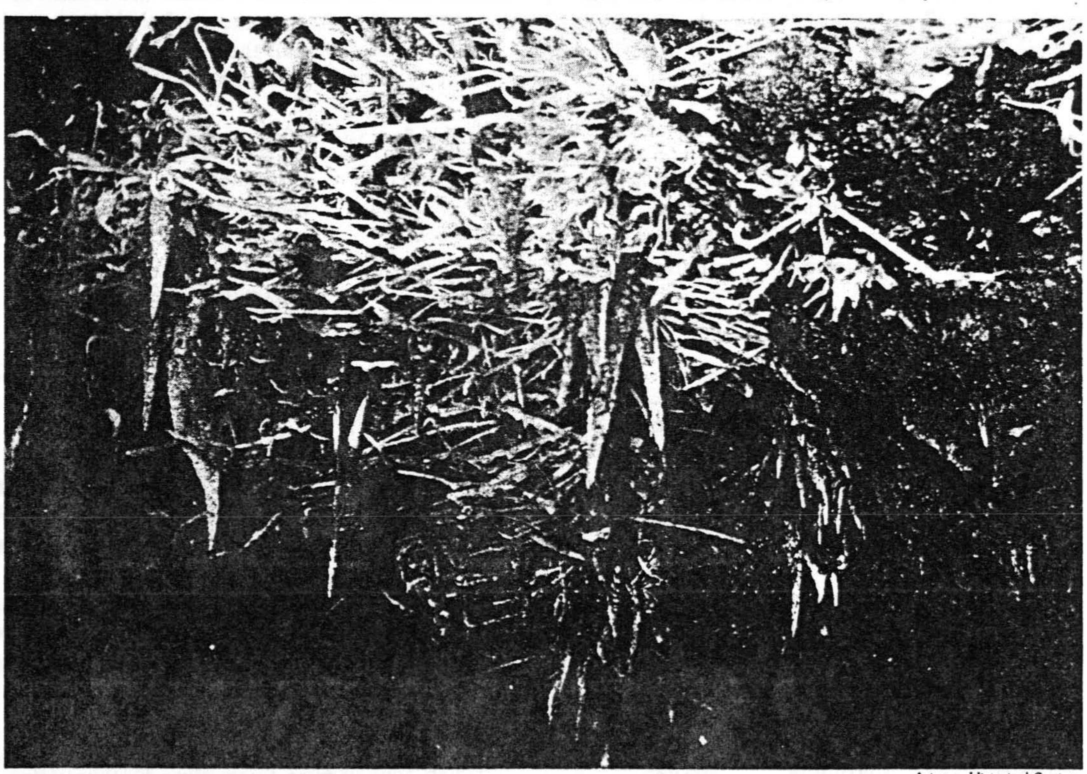


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Figure 40. **Calcite cave growths, probably in the Southwest mine.**

malachite. From the back (ceiling) hung limonite stalactites with azurite crystals here and there on them. The floor was mostly a thin crust of blue on malachite" (M. J. Cunningham, personal communication, 1952).

In 1907 a cave-like opening 20 feet in diameter, with drusy stalactitic cuprite, was hit above the 1050-foot level of the Irish Mag shaft. The Junction shaft has a series of caves up to 65 feet across between the 2200 and 2566 levels. These are filled with iridescent stalactitic and botryoidal siderite.

The most common cave minerals are calcite, aragonite and gypsum. The carbonates are commonly tinted by copper and iron. It is in these caves that their loveliest forms are attained. Occasionally, a cave would fill with calcium carbonate-rich water after stalactites and other growths had developed. The result would be single-crystal stalactites of up to 20 inches and oriented crystal overgrowths on many of the formations. At the water line, sunburst-like crystal groups of up to 3 feet across would develop around the tips of the stalactites.

Other minerals found in Bisbee's caves include cerussite, conichalcite, descloizite, goethite, hematite, mimetite and smithsonite.

Minerals

Herein lies the enduring fame of Bisbee. There are at least a dozen copper deposits worldwide whose metal production has or will exceed that of the Warren mining district. But no mine or district other than Tsumeb can claim such an abundance of remarkably fine specimens. In spite of the simplicity of the mineralizing fluids and the relatively modest effects of hydrothermal alteration, an impressive assemblage of minerals developed. A total of 214 species have been confirmed. In addition, 17 more are either reported but unconfirmed or are represented by specimens whose identity or origin is in question. Of the confirmed species, paramelaconite, shattuckite, bisbeeite, chalcoalumite, graemite and almost certainly spangolite were originally described from Bisbee.

In a general way, all of the minerals found can be categorized by origin. These categories are: rock forming, alteration, hypogene, supergene, and post-mining. Obviously there is some room for overlap between the classes. But it seems most beneficial to list such minerals only in the group that most typically represents their mode of occurrence.

Table 1. Rock-forming minerals at Bisbee.

albite	calcite	labradorite	orthoclase
allanite	celadonite	microcline	rutile
andesine	dolomite	muscovite	sanidine
apatite	enstatite	oligoclase	titanite
augite	hornblende	olivine	tourmaline
biotite			zircon

Table 2. Alteration minerals at Bisbee.

(This group includes both hydrothermal and metamorphic products.)

actinolite	chrysotile	halloysite	rhodochrosite
allophane	clinochlore	illite	scapolite
alunite	clinochrysotile	kaolinite	scheelite
anatase	clinozoisite	laumontite	sepiolite
andradite	diaspore	magnesite	stevensite
anhydrite	dickite	magnetite	talc
antigorite	diopside	natrolite	thomsonite
barite	èdenite	prehnite	tremolite
bixbyite	epidote	pumpellyite	vesuvianite
brucite	fluorite	pyrophyllite	wollastonite
chamosite	forsterite	pyrrhotite	zoisite
chromite	grossular	quartz	

Table 3. Hypogene (primary) minerals at Bisbee.

aikinite	cosalite	greenockite	sphalerite
alabandite	digenite	marcasite	stannoidite
altaite	djurleite	molybdenite	stromeyerite
bornite	enargite	polybasite	tennantite
canfieldite	famatinite	powellite	tetrahedrite
chalcopyrite	galena	pyrite	uraninite
cinnabar	gold	rickardite	wittichenite

Table 4. Supergene (secondary) minerals at Bisbee.

anglesite	chrysocolla	hisingerite	pyrolusite
antlerite	claringbullite	hydrohetaerolite	pyromorphite
aragonite	conichalcite	hydrozincite	rosasite
atacamite	connellite	ilsemannite	sengierite
aurichalcite	copper	jarosite	shattuckite
azurite	covellite	langite	siderite
bayleyite	cuprite	leadhillite	silver
beudantite	cyanotrichite	lepidocrocite	smithsonite
bindheimite	delafossite	linarite	spangolite
bisbeeite	descloizite	malachite	stibiconite
boehmite	devilline	manganite	stolzite
braunite	dioptase	mimetite	sulfur
brochantite	embolite	minium	szomolnokite
bromargyrite	fornacite	mottramite	teineite
carbonate-	gibbsite	murdochite	tenorite
cyanotrichite	goethite	osarizawaite	tilasite
cerussite	graemite	paramelaconite	turquoise
cesarolite	graphite	paratacamite	tyuyamunite
chalcoalumite	groutite	pharmacosiderite	vanadinite
chalcocite	gypsum	plancheite	variscite
chalcophanite	hausmannite	plattnerite	willemite
chalcophyllite	hematite	plumbojarosite	wulfenite
chalcosiderite	hemimorphite	pseudomalachite	
chlorargyrite	hetaerolite	"psilomelane"	

There is little doubt that most of the minerals classified as post-mining in their formation have also formed in some places prior to mining. However, because of their known readiness to form as post-mining minerals their earlier, supergene formations have probably gone unrecognized as such.

Table 5. Post-mining minerals at Bisbee.

anthonyite	epsomite	kornelite	rhomboclase
basaluminite	fibroferrite	lime	roemerite
bianchite	goslarite	melanterite	rozenite
botryogen	halotrichite	matavoltine	siderotil
chalcanthite	hexahydrite	pickingerite	voltaite
copiapite	hydrobasa-	ransomite	
coquimbite	luminite		

Catalog of Occurrences

The following catalog of Bisbee mineral occurrences is based principally on field observations made by the author over the last 25 years, coupled with a study of thousands of specimens in collections both great and small. Nearly all of the species identifications resulting from this work have been confirmed by X-ray analysis, and such confirmation is indicated by an asterisk (*) following the locality of the analyzed specimen under each species heading. This information has, of course, been augmented by the extensive literature as cited and as listed in the bibliography. Perhaps the most important and perishable data preserved through this study are the accounts of occurrences, environments and associations which have been so freely given by those miners and professionals who personally collected many of Bisbee's finest specimens.

Acknowledgments

No work of this nature, regardless of scope, is possible without uncommon amounts of assistance from others. It is with pleasure and deep appreciation that I acknowledge the immense and often protracted help so unselfishly given. I say thank you to:

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Bisbee Mining and Historical Museum

Appendix 3

Bisbee, Arizona's Dowager Queen of Mining Camps
A Look at Her First 50 Years

by Richard W. Graeme

History of Mining in Arizona
Volume I
Chapter 3
1987

Chapter Three

Bisbee, Arizona's Dowager Queen of Mining Camps
A Look at Her First 50 Years

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Introduction

The Warren Mining District, or Bisbee as it is better known, produced a tremendous amount of metal during its century of operation. Through 1981 a production of nearly 8 billion pounds of copper, 324 million pounds of lead, 355 million pounds of zinc, and 28 million pounds of manganese had been recorded (Keith, et al., 1983). In addition to these important base metals 2,792,000 ounces of gold and 102,215,000 ounces of silver came from these mines (Keith, 1983).

This means that Bisbee has produced more gold, silver, and lead than any other district in Arizona. There are, however, several areas in the state that have exceeded Bisbee's copper production.

The Bisbee of today remains a town of unique charm, a place almost suspended in time. Memories of the early years of this century line her winding streets, anxious to be discovered by the curious. Along the steep limestone hills colorful dumps can be seen, now but a shadow of the great industry that gave the town a reason to be.

My intent here is not to present a framework of endless numbers but rather to add color to those faded early years when this very special camp was young.

Ore is Discovered

The Mule Mountains, that nondescript range of hills ho sting Bisbee, are typical of many in the basin and range province. Rising 3,500 feet above the surrounding broad valley desert plain, they achieve an ultimate elevation of 7,300 feet. These elevations gave the promise of water and game among the tangled oaks and pines.

History has chosen not to remember who the first non-Indian that entered the canyon called Mule Gulch may have been. But he almost certainly was someone seeking either refuge from the desert or mineral wealth.

It has been suggested that the presence of ore in the Mule Mountains was known as early as 1876 (Mc Clintock, 1916), a year before the discovery of nearby Tombstone. For what was to become Bisbee, however, the time was not yet at hand. Confirmed discovery came early in the summer of 1877 when a scouting party from Fort Bowie made their way into the mountains.

Their search for Indians and need of water took this group to a spring among the rust-colored hills. Not surprisingly, the water here was disagreeable.

The following day, John Dunn, a member of the party, went further up the gulch in search of good water. Finding a fine spring near a massive limestone cliff, he began his return trip to the group. Along his way back to camp he discovered a small outcrop of cerrusite (lead carbonate). Once back in camp, Dunn reported his find to Lieutenant Rucker, the officer in charge.

Dunn, along with Rucker and one T.D. Byrne, located the first claim in what was to become the Bisbee area. Even though these men were the first to stake a claim, they shared little in the success that was to follow. Given all they had to choose from, they selected badly, twice. First their original claim, the Rucker, was later shown to be largely on barren ground. Secondly and most unfortunately, Dunn chose to grubstake George Warren. He was to locate additional claims in the area, naming Dunn in each. Warren accepted the grubstake, but never honored his agreement.

George Warren

George Warren had, by this time, suffered such that fate was compelled to deal him a good hand, but George being his own worst enemy was unable to play it right.

As a boy, Warren lost his mother quite early and at about 10 years of age joined his father, a government herder in New Mexico. While attending a herd of horses, the Warrens were attacked by Indians. The father was killed while George, though wounded, was taken captive.

He was their prisoner for 18 months when some prospectors traded 15 pounds of sugar to the Indians for him. Warren remained with these men for sometime, learning the "art" himself. (Hart, 1926).

After his agreement with Dunn in the late summer of 1877, Warren and several acquaintances from Tombstone went to the Mule Mountains, located a number of claims and established the Warren Mining District (Hart, 1926) None of the fortune that was to flow from the Copper Queen, one of the world's greatest mines, was to be for George.

Having located the dozen or so claims in the district along with others, Warren had but a one-ninth interest in the Copper Queen. This, according to legend, he lost in a race sometime in 1879. Warren and a George

Atkins had been drinking in Charleston, the milling town for the Tombstone area.

Warren claimed he could run a hundred yards, turn a stake driven into the ground, and run back faster than a man on horse back, a trick he had seen the Apaches perform as a youth. There was just one problem, drink had changed the distance to be run, in his mind. The race was lost and with it his share of the Queen, a loss that may well have been worth several tens of millions of dollars (Duncan, 1911).

After this, things only got worse for George. The remainder of his property was taken into "protective custody" by some unscrupulous associates when he was charged with insanity. Once relieved of his remaining property he was released. The cure obviously occurred only when his money was gone.

Warren then went into Mexico where he sold himself into peonage for money to work his latest discovery. Judge G.H. Berry, hearing of this went to his rescue, paid the indebtedness and returned George to Bisbee. Here, he earned a precarious living with some help from the Copper Queen Mining Company. Most of the time he spent doing odd jobs around saloons for a drink of whiskey.

He died in about 1895. The object of pity and disgust, he was soon forgotten.

The Copper Queen

It has been often said that great mines are made, not found. If this is true, the high grade mass of ore in the Copper Queen did little to slow down the making of this truly great mine. High grade, it seems even then, could cure a host of ills.

It didn't take long for the scattered, small showings of cerrusite to be worked out. The interest of the miners quickly turned to the copper stain on the hillside. An open cut four feet wide and ten feet in length was made. Rich ore was cut at its end and one-half ton was removed that assayed 22% copper (Duncan, 1911).

In spite of this good showing these early owners lacked faith in the Copper Queen. James Douglas, whose role in this marvelous mine will be described later, remarked in an address given in 1912:

> "The men who opened the cut, acted the fool, as most prospectors do they made a hole and ran through rich ore at the end of the hole, and so they thought it wiser to stop and get what money they could rather than spoil the prospect altogether [by mining through the ore] and get nothing and therefore, the Copper Queen mine was sold for $20,000." (Douglas, 1912).

His condemnation was not total, however, as he continued:

> "I could not have thought well of it at that time, because we professional men thought that [ore in] limestone was invariably a fake and was simply placed there by Providence in order to delude us . . . Somehow or other, I have a certain faith in Providence and feel that it doesn't play jokes . . . I took quite a liking to the Copper Queen."

In spite of his "liking", faith in the value of this extremely remote, unusual deposit remained shallow in the owners' minds. They had but one thought in mind and that was to sell.

So it was that in the spring of 1880 the Queen was optioned to Edward Riley for $20,000. Riley, a lawyer by profession, had made a number of unsuccessful mining investments just before this and had no money of his own. As Douglas put it "[he] was worn down to where there was hardly any soles to his feet, and he had to borrow some money from Zeckendorf in order to go to San Francisco to see if he could float this mine in the Mule Mountains" (Douglas, 1912).

In San Francisco he succeeded in selling the Copper Queen to Messrs. Martin and Ballard, through the mining firm of Bisbee, Williams & Co. for $20,000, taking his remuneration in half interest. Bisbee, Williams & Co. were prepared to recommend the purchase, in as much as Mr. Lewis Williams of the firm had already seen the property.

With this change in ownership mining began in earnest. To this point, the ore had been hauled to the West Coast by 24-mule team, then sent to Wales for smelting. To eliminate this terrible expense, a small smelter was erected under the direction of Lewis Williams, while his brother Ben assumed responsibility for the mining.

With good management in place and an ore grade of 23% copper (Douglas, 1909), the mine was an immediate success. The little furnace at the bottom of the hill was yielding almost one pound of copper for every four pounds of ore treated.

Two other mines had also briefly operated during the very early years of Bisbee. The Copper Prince Mining Company had several claims adjacent to the Copper Queen to the north and west. Here the Prince exploited one of the very few outcrops of ore in the district. Over all, the grade and tonnage of this mine were low compared to the Queen, but the operators were aggressive. Using the hated law of the Apex, the Copper Prince followed the ore well into Copper Queen ground. They were finally stopped by a suit. The controversy was settled with the purchase of the Prince property by the Copper Queen.

The other mining effort was by the Neptune Company. While the ground they held was eventually shown to be very rich, the Neptune produced little copper. Much of the capital owned by the company had been spent on a smelter 15 miles away, on roads, and a pretentious house (called the Castle) for its superintendent, Colonel Herring. With little money left for exploration the company could not meet its obligations. The property was disposed of at a sheriff's sale to interests favorable to the Copper Queen (Douglas, 1909).

James Douglas and Phelps, Dodge and Co.

Dr. James Douglas was a most unlikely figure to bring success and fame to Bisbee. A cultured man and a Canadian by birth, Douglas was educated abroad to be a Presbyterian minister, a role he never filled. His early years were spent in many occupations including working in a Canadian asylum (Langton, 1940). (Joralemon, 1973, suggests working with the insane prepared him for his Arizona experience.)

In any event, Douglas entered the mining business in 1872 by examining the California mine in Gilpin County, Colorado for some of its directors. From this point his life would be tied to mining until its end some 46 years

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later. To be sure the career of this most eminent "engineer" was not without its problems. Indeed, for the first decade there were no successes, just varying degrees of failure. The metallurgical plants he was in charge of in Quebec and later Phoenixville, Pennsylvania were total disasters.

Yet it was to this man that the principals of a New York mercantile house, Phelps, Dodge & Co., came for advice. Messers. Willis James and W.E. Dodge asked Dr. Douglas to investigate several mines in Arizona and advise them as to their value. The mines were the Longfellow near Clifton and the Atlanta claim adjacent to the Copper Queen.

Making the requested examinations, Douglas recommended the purchase of the Atlanta for $40,000 even though no ore was on the surface or in any of the very shallow workings. He did, however, caution his employers "that the risks were too great to be taken by a purchaser who was not able and prepared to lose all that he had invested" (Douglas, 1909). James and Dodge accepted the risk, a move that they would, for the short term, regret.

Douglas himself was placed in charge of exploration on the Atlanta claim. An anomaly in this rough, primitive camp, he was well educated, cultured, and sensitive to the needs of others. Though often monetarily poor, he was a man of exceptional integrity. When asked about his fee for examining the Atlanta, and given the choice of cash or a share of the mine, he reflected, "the cash was greatly needed, but I told them that as I had advised them to take more than an average risk, I would share it with them. And on that sudden impulse and hasty decision depended my whole subsequent career—successful beyond anything I had ever dreamed of" (Langton, 1940).

For over two years Douglas searched and explored, sinking prospect holes on small bunches of ore wherever they could be found—two years of vexation and disappointment. Having spent $80,000 on these effects, James and Dodge were thoroughly disheartened—not a single car of ore had been produced.

It was now spring of 1884, the neighboring Copper Queen orebody had suddenly pinched out and only 90 days of ore remained. All efforts at the Copper Queen to find an extension of the ore failed. Douglas still could not believe that only one orebody was here—surely others were nearby. So it was that James and Dodge, with much misgiving, committed a final $15,000 for a 400-foot shaft on James Douglas' faith. Douglas reflected, "John Prout and I selected the site where the shaft was to be sunk. But long before it reached the 400-foot level, the gloom which hung over both companies had been dissipated, for at 210 feet from the surface the shaft penetrated a very rich orebody, which was almost simultaneously entered by the level being driven east from the foot of the Copper Queen incline. The Atlanta shaft was sunk for 200 feet through ore" (Douglas, 1909).

To preclude litigation over the ownership of these new ores, the Copper Queen and Atlanta companies merged into the Copper Queen Consolidated Mining Company. The terms were more favorable to the owners of the original Queen than they might have been had not Douglas' ill luck still been in place. A drift from the 400-foot level of the Atlanta was run into the hill through the only block of waste in what was to be the great Atlanta orebody. It was one of the largest and most productive masses of ore ever discovered in the region.

This aside, the Copper Queen Consolidated Mining Company (C.Q.C.M.Co.) began buying property to secure its future. Over the next several years even in the face of very low copper prices the C.Q.C.M.Co. invested all they could in the claims of the district, often with some misgivings as some of the properties purchased were well beyond the reach of the known ores. Even at this, though, their faith in the district was not strong enough.

Mule Gulch Becomes Bisbee

During these years, the camp now called Bisbee after DeWitt Bisbee of the firm Bisbee, Williams & Co. in San Francisco, had its problems. The threat of Indian attack was still very real. Often were the times when the mine whistle would sound the warning: Apaches had been sighted! Men would grab their rifles while the women and children sought safety in the Copper Queen mine where supplies of food and water were kept for such emergencies.

While the town itself was never attacked, many of the nearby ranches were. In June of 1885, Billy Daniels, a deputy sheriff of Bisbee, and several other men were ambushed at the mouth of Mule Gulch. Daniels was killed but the others escaped (Duncan, 1911).

The often savage acts by the Indians were no match for the heinous crimes the early citizens of Bisbee suffered at the hands of their own. From its first murder in August 1880 until the formation of a citizens vigilance committee for public safety, the "Forty-five-sixty" in March of 1891, nearly two dozen people were shot down. The "Bisbee Massacre" of December 8, 1883, was the most tragic of these crimes.

In hopes of getting the mine payroll, five masked men robbed the Goldwater and Castaneda store, where the payroll was to be deposited upon arrival. While three men went into the store, the others remained outside guarding the street. Johnny Tappiner, a splendid young man, stepped unawares from the Bon Ton Saloon and was shot. Coming out of Joe May's saloon at the same time, a man named Howard was shot. Tom Smith, a deputy, immediately commanded that the shooting stop. He was shot twice and killed. Mrs. Annie Roberts, an expectant mother, was killed when the outlaws fired through the open doors of her restaurant. Running out of the Azurite Saloon, J.A. Nally was shot and so seriously wounded that he died within a few days (Duncan, 1911).

For all their violent actions, very little reward was to be had; the payroll had not yet arrived. Taking all they could find, $600 and a gold watch, they fled to the east. The stage with some $7,000 in payroll money arrived less than an hour later.

A posse was formed and the trail of the outlaws found. Just outside of Mule Gulch, one John Heath, an early volunteer to the group, tried to persuade Deputy Sheriff Billy Daniels that the bandits had turned north. Daniels, unconvinced, led the posse across the Sulphur Springs Valley to the Chiricahua Mountains, while Heath and another man went north.

The outlaws had returned to a prospector's cabin where just a few weeks earlier they had planned the crime. Dividing the loot, they then separated. Daniels, after a discussion with a prospector, was told the names of these desperados and learned that the man who masterminded the whole affair had not returned with them; his name was John Heath. Daniels sent word to arrest Heath and continued on in pursuit of the others.

The outrage that followed the crime united many people in the effort to capture the remaining five. Within a few weeks, their work was finished and all were confined in the Tombstone jail. One was captured in New Mexico; two near Clifton, Arizona; one in Chihuahua, Mexico; and the last in Sonora, Mexico.

All five of the outlaws were tried together, found guilty of first-degree murder, and sentenced to be hung. Heath was tried separately, found guilty of second-degree murder, and sentenced to life imprisonment. This so angered the people of Bisbee that a group went to Tombstone, removed Heath from the custody of the sheriff, and lynched him from a telegraph pole. To the end, Heath swore his innocence. The general acceptance of this action is shown by the coroner's jury verdict that: "We the undersigned, a jury of inquest, find that John Heath came to his death from emphysema of the lungs—a disease common in high altitudes—which might have been caused by stangulation, self-inflicted or otherwise" (Hankin, undated).

Another lynching by the citizens of Bisbee had an unusual and lasting effect. Hung for the killing of a defenseless man in the Can Can Restaurant over the affections of a woman, the body of the murderer was still dangling from a tree at the base of Castle Rock when a New York director of Phelps, Dodge and Company came to see the mine. The director was horrified and convinced that such barbarism could only be the result of unenlightened minds. After returning to New York he sent books and a librarian to Bisbee. Thus Bisbee's library was started, in the hope of encouraging a more cultured, civilized community. Phelps Dodge continued to render this service for 90 years.

Fire, Flood and Pestilence

Bisbee grew quickly once its success and future were assured. The main street was lined with buildings of every manner, housing merchants, restaurants and saloons. The great majority of the structures were frame in construction, each as close to the next as possible often sharing a common wall.

Many of the hillsides had sprouted crops of miners' homes, stair-stepping their way up the steep slopes. Few had yards; space was just too valuable to be so frivolously used. Almost all the homes were made of wood.

The results of this close building were quite predictable if not inevitable. Here, the misfortune of one soon became the misfortune of many. Three times in its early years Bisbee was ravaged by fire and each was more devastating than the last.

In February of 1885 the first of these fires consumed much of the business district and threatened the smelter as well as the Copper Queen mine. Only determined, brave action saved the works and, of course, the jobs of the miners.

The second fire sowed the seeds of destruction in June of 1907. This time the closely packed shanties on Chihuahua Hill were consumed. Wind-fanned, the flames threw off such terrific heat that the fireman were kept at bay. Only when the miners used dynamite to cut fire breaks did the fire yield control. More than 100 houses were lost and 400 people were left homeless.

Lastly, in October 1908, Bisbee's most disasterous fire broke out again, in the business district. Racing along the canyon, every building on Main Street to Castle Rock was consumed. Once again dynamite had checked the path of the fire. A large part of the residential area on Clawson Hill was also swept clean with few houses escaping.

A full three-quarters of Bisbee had gone up in smoke. Hundards of people were homeless, but the process of rebuilding began immediately. As before, those structures lost were replaced by finer, more durable buildings. Brick and masonry work rose from the ashes in buildings much more handsome than the originals.

The steep hills that surround Bisbee were once covered with oak and juniper trees that gave way to Apache pines near the peaks. Once these trees were removed to fuel the fires of home and industry, the stage was set for recurring disasters.

Typically, the late weeks of July and all of August brought rain, rain that fell in torrents giving life to this normally dry land. But with nothing to check the waters the summer rains often brought death to Bisbee.

The narrow canyons were filled with homes and businesses, lining the road that was the only conduit for the rain waters. Down this pathway would come torrents of water, mud, and debris, often sweeping the frail houses from their pinnings. Several times the unfortunate residents of these homes were lost along with structures. Some were never found.

Finally, after a particularly destructive flood in 1908, a drainage channel was built along the canyon bottom. Cutting in some places, filling in others and covering parts with stores as well as homes, the ditch successfully brought this threat to an end.

With the growing population crowding into the narrow canyons came sickness and disease, the insidious offspring of poor sanitation. From 1888 to 1900, hundreds died from typhoid fever. Stricken miners lay on canvas cots in Brewery Gulch and along Main Street, their uneasy but brave partners fanning them to reduce their fever (Cod, 1938).

It was several years before the source of contamination was found to be in the shallow wells that lined the canyons. Fortunately, one well in upper Brewery Gulch was found to be free of contamination. So for more than a dozen years the precious fluid was sold house to house, carried on the backs of burros in canvas bags, and priced at five cents a gallon. Shortly after the turn of the century, water was pumped to the camp from a fine well field about nine miles away at Naco, Arizona, developed by the Copper Queen.

The Queen Builds A New Smelter

During the years immediatly following the merger of the two companies, the price of copper began to fall. By early 1886, it was selling for a trifle under eight cents a pound, down from the 13 cents a pound at the time of consolidation.

Production was at 500,000 pounds per month which was all two small 36-inch, water-jacket furnaces could produce. There was little profit to be had at this rate and at times a small loss was incurred. As a result, the company had insufficient monies to improve the facilities. At this time James and Dodge purchased the interest held by the original Copper Queen owner, thereby achieving control of the mines.

Not only did they have the courage to buy those interests, but they advanced the company the needed funds to build a new smelter with a capacity of 1,000,000 pounds per month. It was hoped the increased production would allow a profit. The mines were closed, except for some for dewatering and exploration work, for nearly a year.

By the spring of 1887, the new smelter's four furnaces were complete and blown in during May of that year. In all, the C.Q.C.M. Co. owed James and Dodge about $300,000 (Douglas, 1909). Were it not for the efforts of a French syndicate's efforts to control the price of copper, it would have taken a number of years to repay this debt. But, three years of sales were negotiated at 14¼, 13¼ and 12¼ cents. The $300,000 debt evaporated like the dew (Douglas, 1909).

A Railroad is Built

The new plant, while much more efficient, was not the total answer. A need for cheaper transportation was even more pressing. Finished copper had to be transported out and thousands of tons of coke for the smelter as well as a million board feet of timber for the mines needed to be brought in each month. A railroad to service Bisbee was the only answer.

Late in 1887, Douglas called upon a Mr. Nickerson who was then president of the Atchison, Topeka and Santa Fe railroad. His hope was to persuade the Santa Fe to build the line from Deming, New Mexico, via Bisbee to the port at Guaymas, Sonora. Douglas was treated with supreme indifference. The Santa Fe built a line south from Benson to reach the Mexican port.

There remained no option but for the Copper Queen to build a railroad. At first, a narrow gauge road with grades up to 10% crossing the mountains was considered. Wisely, it was rejected for a much longer, standard gauge route that skirted the mountains. By the end of 1888, the Arizona and Southeastern Railroad, as it was called, reached from Fairbank to the mouth of Mule Gulch, some 40 miles.

Later, a second dispute with the Santa Fe over the comment "that it was not running its railroad for the benefit of the Copper Queen" pushed the A.&S.E. to Benson where a connection was made with the Southern Pacific Railroad (Myrick, 1975).

A legislated change in 1901 moved control of the road from the Copper Queen mining company to a holding company, the El Paso and Southwestern Railroad. True to its name, the railroad tied into El Paso, then to the Rock Island Line at Tucumcari, New Mexico, and finally to Tucson for a full 772-mile route (Myrick, 1975).

The El Paso and Southwestern Railroad came to a voluntary end in 1924 with a favorable merger with the Southern Pacific Railroad. The shareholders of the E.P. & S.W. received stocks and securities worth more than $60,000,000 (Myrick, 1975).

The Smelter is Expanded

As before, the mines of the C.Q.C.M.Co. continued to expand, following the mineralization down dip. Here changes in the nature of the ore began. The early ores had been totally free of sulfur and were easily rendered in single-step smelting furnaces. Now, increasing amounts of sulfides were found mixed with the oxidized ore; also a number of unoxidized orebodies had been discovered.

As the quality of the black copper bars fell, the need for an improved smelting works became imperative.

In 1892, James Douglas and his son Walter went to Europe to investigate the Mankes-Bessemer smelting process. So impressed with the principle was he that immediately upon his return he had one designed for the Copper Queen Company. By 1894, after a number of modifications, Douglas had perfected a method of smelting sulfides that forever changed the way these difficult ores were handled. To a large degree, this method is still basically the one by which most of the world's copper is smelted.

After the change in techniques, copper production doubled in two years and by 1899 more than 3,000,000 pounds per month were being produced. Unfortunately though, the crowded conditions at the smelter site next to the Czar shaft precluded any expansion.

A New Smelter is Built

A new smelter was a must; the flow of ore from the Copper Queen mines seemed limitless and quite able to support a new facility. The principal owners of the Copper Queen mine had also acquired the mines near Nacozari, some 70 miles south of the Mexican border. Therefore, the logical place for a new smelter was where it would handle the ore from both mines. A site in the lower end of the Sulphur Springs Valley, right on the Mexican border, was selected. Here was limitless water and space. A townsite was laid out to support the new facility and it was appropriately named Douglas in honor of the man who had so ably led the Copper Queen for 20 years. The new works had a capacity of 10,000,000 pounds per month and cost $2,500,000 to build (Douglas, 1909). Late in 1903 it was blown in, and the old Bisbee facility was completely scrapped.

Another Mining Group Comes to Bisbee

While Dr. Douglas had always been a proponent of an aggressive acquisition policy in the district, there was one opportunity that was lost, though under peculiar circumstances. The Irish Mag claim, named for a woman of the red-light district in upper Brewery Gulch, lay far to the east of any known ore and was generally considered to be of little value. A group of eight other claims and the Irish Mag were owned by a miner named Daly. Evidently of unsound mind, he had threatened the life of Ben Williams and told Douglas that he had been hired by a group of conspirators to kill him. Shortly afterwards, Daly offered his claims to Douglas for $10,000, a proposal which Douglas was anxious to accept. Williams, however, thought it would look like they had succumbed to blackmail and threatened to resign if the purchase was made; so it was declined.

Soon afterwards, in April of 1890, Daly shot and killed W.W. Lowther, a deputy sheriff who was trying to arrest him for assault. The last seen of Daly was when he fled up the side of Sacramento Hill (Douglas, 1913).

As Daly was a fugitive, there was little chance that he would return to claim his property, so a host of claimants suddenly appeared including a "wife" and "son." Daly's common-law Mexican wife, Angela Diaz, had advanced him money to do assessment work; for this reason title was vested by the Supreme Court of the United States to her in 1899. During the long legal battle, she had sold her interest to Martin Costello, a Tombstone saloon keeper, for $1,800 (Cox, 1938). After the favorable decision, Costello sold the property for $500,000 to the Lake Superior and Western Development Company.

Long before the legal battle was over for the "Mag's" ownership, the potential value of Daly's claims became well known. Development on the 800 level of the Spray shaft had found fine orebodies near the Irish Mag sideline. Captain Jim Hoatson came to the district looking for a good property to purchase on behalf of the Lake Superior and Western Development Company. Nothing looked as good to him as the barren, hard limestone knob called "Mag Hill."

In the Calumet, Michigan, area, everone knew Cap'n Jim and respected his knowledge, so before long he had the money to buy the claim and sink the needed shaft. But for all his knowledge, Hoatson failed to realize just how deep the ores really were, and that it would cost much more to mine the Arizona limestones than it did the rocks in Calumet. On the ragged edge of bankruptcy, Cap'n Jim went back for more money, money to sink just a little deeper, where the ores must surely lie. So it was, on the faith of an uneducated miner, that some of the great names in the steel and iron business invested many thousands more. Their confidence in Jim was rewarded. After finding small bunches of ore on the 850 and 950 levels and building a modest smelter, a fabulous orebody was cut on the 1050 level in 1902 by the Northeast drift (C.&A., 1916). Before the story of the Irish Mag was finished, nearly $10,000,000 in dividends were paid from the 15 acres that made up the claim.

The Calumet and Arizona Mining Company absorbed the Lake Superior and Western Mining Company and set about to develop its vast holdings of favorable ground.

Once the future of the Calumet and Arizona Company had been assured by the riches that flowed from its mines, Tom Cole, its president, began to buy all the ground he possibly could. Douglas, not to be outdone, paid a fortune for property he could have had for a trifle just a few years earlier, had his faith only been stronger. In the ensuing scramble absolutely undeveloped ground went for as much as $40,000 an acre. Stakes were high in this copper game; even after purchase, hundreds of thousands of dollars had to be spent sinking a shaft of up to 2,000 feet before the value (or lack of) could be determined.

All the efforts of Cole and the C. & A. could all have been for naught save for the wisdom and absolute honesty of James Douglas and the partners of Phelps, Dodge and Company. The law of the apex had been firmly established in the west by the famous Eureka and Richmond ruling. This law, simply put, means that whoever owns the apex of a continuous vein, lode, or ore formation, has the right to claim ownership of all ores on its dip, even if the vein passes under other claims at depth. There is little doubt that the Copper Queen Company could have claimed for its own all of the ore found by C.&A. and been upheld in court. This would, of course, have been allowed only after bitter litigation at enormous expense. But Douglas said, "We must decide which industry is to prosper here—that of mining or that of lawyers" (Langton, 1940).

So the common boundary law was mutually agreed upon and Bisbee was spared the grief and hatred that so scarred many other districts. Along with the agreement, free access to each other's mines was granted so that the discoveries of one could help the other. Thus began the cooperation between companies and their respective engineers which was heretofore unknown. Those of us in the profession today are still reaping the benefits of the shared technical progress that this spirit has brought to the industry. Perhaps this is the greatest contribution Dr. James Douglas made to mining.

A third, though much smaller, company emerged about this same time. To the south of the Copper Queen lay a small block of claims controlled by a Duluth company. These claims were owned by Lem Shattuck, a long-time resident and proprietor of the Capitol Saloon.

Shattuck lacked the funds necessary to develop this property so, putting up the claims as his contribution, he joined others to form the Shattuck and Arizona Copper Company.

The venture was a risky one. A C.Q.C.M.Co. mine, the Uncle Sam, at the edge of the Shattuck ground had gone down 600 feet and drifted in all directions looking for ore with little success. Undaunted, the mid-western investors committed the necessary money.

Once again luck sided with outside capital. After sinking only a few hundred feet and driving a small amount of drifts, good ore was found. Continued development exposed more and more good orebodies. The success of a small but adventurous group of investors was assured.

A few years later this same group gambled once again. Everyone knew that the Dividend Fault cut off all the ore in the district (this largely is true), so any claim on the wrong side is, then, of little value, right. Not necessarily because the fault dips very steeply and there happened to be a concentration of ore along this massive structure. At the time of their activity this was not known.

The Denn Shaft was begun with full realization of the financial risk, but perhaps without an understanding of what nature had in store. Nearly a thousand feet of post-ore sediments covered the favorable unit, so a deep shaft was obviously necessary.

Bad ground from the massive faulting made sinking slow and expensive. Water was found in amounts that were never expected. Every round had the potential of breaking into a flow that would flood the mine and several did. Good ore was eventually found on the 900-foot level and this mine too became profitable under the name of the Denn and Arizona Mining Company.

By the mid-1920's the two were combined to form the

Shattuck-Denn Mine Company. While this company was never large it had two very rich mines that rewarded their investors.

Bisbee Comes of Age

By the first years of this century, Bisbee had become a substantial town with more than two decades of successful mining to its credit. But it takes more than jobs to make a town. Necessities came slowly to the western mining camps and amenites often not at all.

Early on, the responsiblilty for providing both those things needed and those wanted fell to the Copper Queen. First, a store was provided to see that the residents of Bisbee were able to buy food and clothing of quality at fair prices. Even though it was a "company store", none of the unfair, almost enslaving practices so commonly a part of other such groups were ever a part of the Copper Queen store or its successor, the Phelps Dodge Mercantile.

To counter the annual epidemics of typhoid, diphtheria, and smallpox, that killed hundreds over the years, the Copper Queen built and staffed Bisbee's first hospital. Just as important, James Douglas worked hard to educate the people of Bisbee about poor sanitation, the principal cause of the epidemics. However, it was after 1900 before the epidemics ended, finally yielding to the combination of understanding and a public water system.

As previously noted, the C.Q. provided a library. They also constructed a church, the Y.W.C.A. (indirectly) and built, as well as operated, a fine hotel.

Through the Bisbee Improvement Company, the Copper Queen brought electricity, natural gas and telephones to the town. Even a good daily newspaper was developed for the community by the Company. While the paper was often criticized as an instrument of the Company, it filled an important void.

Later, the Calumet and Arizona Mining Company carried on the tradition set by the Copper Queen. The C. & A. built and staffed a second hospital, provided the community with a fine Y.M.C.A. and developed a new townsite called Warren.

In spite of its remoteness and the ever-present evidence of corporate power, Bisbee was never truly a company town. The community and its people were not just allowed, but encouraged to govern themselves and seek their own destinies. This most certainly contributed to the good relations the mining companies had with their employees.

Labor Problems

To this point, Bisbee had been singularly free of labor troubles, due principally to the efforts of the mining companies to provide a safe work environment, a pleasant community to live in, and wages comparable to what miners elsewhere were receiving. But in early 1917, just 2½ months after America's entry into World War I, a group known as the "Industrial Workers of the World" called a strike in Bisbee without a vote of the miners. Under threat and intimidation, by the third day about 80 percent of the 4,500 men employed underground were staying off the job (Loyalty League of America, 1917). However, members of the mechanical trades never gave any support to the agitators from the I.W.W., and within a few weeks half of the men were back at work underground. But the "Wobblies," as they were called, persisted in their efforts to stop the mines with increased amounts of harrassment. At this same time, most of the other mines in Arizona and Butte, Montana, had also been closed by this group.

With the vital war requirements of the red metal threatened by the effects of the strikes, it was obvious that nothing short of drastic action would end the work stoppage. Convinced, and rightly so, that a strike in a time of unprecedented national crisis could only be directed and supported by people of treasonable inclinations, a deportation plan was conceived. Secretly, 2,000 men from every profession in the camp gathered before dawn on July 12, 1917, to begin what they truly saw as their patriotic duty. At the same time, the telephone exchange and Western Union were occupied by interests favorable to the "Loyalty League," as the group called itself. The morning edition of the *Bisbee Daily Review*, delivered to all homes in the pre-dawn hours, warned that women and children should stay off the street that day.

From house to house, combing every street and alley, the armed and deputized forces of the "Loyalty League of America" swept the whole camp. Every known striker, agitator, or sympathizer was removed and marched to the Warren ball park. Here a court questioned each man: "Are you working? Do you want to work? Who can vouch for you?" A great many answered the questions appropriately and were released. However, 1,186 men were detained, loaded into cattle cars, and taken to a siding near Columbus, New Mexico. They were left with the warning that, should any return to Bisbee, they would most certainly be killed. The strikers were then abandoned by their guards.

For almost a month, the "Loyalty League" controlled the town until it was completely purged of the anarchistic "Wobblies". The actions of the "Loyalty League" were largely supported by the people of Arizona and the patriotic citizens of America.

There were, of course, those who felt this was an imperialistic act of the absentee mine owners who feared a loss of exaggerated war time profits. This typically vocal group, though very much in the minority, pursued every avenue in their efforts to see justice done, at least their form of justice. It was of no use. Charge after charge went unsupported by the courts. An investigation ordered by President Woodrow Wilson and conducted by Felix Frankfurter found no federal offense, while the Supreme Court of the United States determined that the participants had acted to enforce "the law of necessity."

Even today this event causes debate. One recent author (Byrkt, 1983) has chosen to judge the past in the context of the present—an unfortunate error. Using carefully edited references and poorly disguised inuendos he has found guilty those who were exonerated by the people of the time. It can still be said that what was done was for the best, a truly patriotic act.

The Post World War One Years

To this point almost all of the copper mined in the Warren district had come from the high-grade replacement orebodies scattered throughout the Paleozoic limestones around Sacramento Hill. Now "Sac Hill" became the focus of activity.

Bulk mining and treatment of low grade ores by flotation had been profitably employed in several places in the West. Sacramento Hill had all the basic characteristics of these other deposits.

Phelps Dodge developed the Sacramento pit with pre-production stripping beginning in 1917. Ore was not produced until 1923 and continued through much of 1929.

The underground mines of the district continued to provide the bulk of copper produced. Phelps Dodge, Calumet and Arizona and Shattuck-Denn remained the dominant forces in the district, but their relative prominance had changed.

For nearly forty years the C.Q.C.M.Co., now the Copper Queen Branch of Phelps Dodge Corp., had mined the same ground and their reserves were nearly depleted. Much of the remaining tonnage was being mined by lessees in the Southwest, Czar and Halbrook mines.

The Calumet and Arizona had vast holdings of undeveloped ground. For them the twenties were golden years. Numerous fine orebodies were found in the Junction, Oliver and Cole mines. The best was yet to come. In the spring of 1929 an exploration shaft, the Campbell, far to the east of any known ore hit what was to be the largest orebody ever hit in the district. The Campbell orebody contained more than one million tons of 8%–10% ore.

As history has shown time and again, ore alone does not make a good mining company. The difficult times brought on by the great depression found the two major companies in very different positions.

Phelps Dodge, though with limited reserves, was in a very good cash position. This was the result of exceptional management and high operating efficiencies. The Calumet and Arizona on the other hand had been less conservative. Her treasury was depleted from an overly generous dividend policy.

As a result, a merger was affected with Phelps Dodge the survivor. Once again the district was in the hands of those who half a century before had gambled on her and held faith.

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Appendix 4

The Early Influence of Mining in Arizona

by Michael N. Greeley

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Chapter Two

The Early Influence of Mining in Arizona

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Terra Incognita

Aboriginal Mining

During the earliest centuries of human habitation, the native Indians occupied a region known later by the Spanish as "Terra Incognita." In a portion of that area, now named Arizona, mineral resources played a primitive role in the development of society. Early man restricted his mining primarily to surface outcrops of salt, clay, pigment materials, quartz, stone, turquoise, and other curiosities. These commodities were used to produce pottery, tools, and weapons.

Some aboriginal mines are known to be very old. Certainly the quarrying of ubiquitous chert and obsidian, and the manufacture of tools and weapons, must have preceded most other forms of mining by several thousand years.

Paints were prepared for body adornment and to color pottery. These pigments probably were obtained from numerous localities that had exposures of such relatively common minerals as hematite (red to reddish brown color), malachite (green), and possibly carnotite (yellow). Evidence of this very early mining was reported no later than 1598 by the Spanish Captain, Marcos Farfan de los Godos after investigating what is thought to be the mineralized district of the Jerome area. Capt. Farfan reported the presence of an old shaft in the area and described it as being perhaps 16 to 17 feet deep. He categorized a variety of minerals according to color.

In 1697, the Spaniards, Capt. Cristobol Bernal and Juan Mateo Manje, reported conversations with Apache Indians in which the Apaches described minerals similar to cinnabar and native mercury. The Apaches used the vermillion cinnabar (mercury sulfide) as a body paint; blebs and pods of liquid mercury are frequently found with the sulfide. Description of the location of these deposits, and later discoveries of Indian artifacts, strongly suggest the mercury minerals referred to are those located in La Paz county, on the south flank of Cunningham Mountain in the Dome Rock mountain range. Here the Cinnabar mine was re-discovered by American prospectors in the 1880's.

The Tohono O'odham (Papago) Indians and their antecedents apparently mined the hills of Ajo for centuries to obtain hematite. According to early American descriptions, the natural colors due to intense mineralization would undoubtedly have attracted the Indians. The Papago name for the area was "au'auho" which means paint; this word was probably transliterated to "Ajo" by the Spanish.

Two small turquoise ornaments, associated with the Vahki Phase and located at the ancient Indian settlement of Ska-kaik (Snaketown), on the Gila River northwest of Casa Grande, are dated sometime between several hundred years before Christ and 300 AD. This turquoise jewelry is the oldest found in the United States.

The most extensive turquoise mines operated by the aborigines in Arizona are those located southeast of Chloride in the Cerbat Mountains of Mohave county. Openings were cut 20 to 25 feet in solid rock on Ithaca Peak and abundant mine tools were discovered later by early prospectors. Major prehistoric turquoise mines occurred on Turquoise Mountain in the Courtland-Gleeson area of Cochise county and on the east side of Canyon Creek, in Gila county, just above its confluence with the Salt River. Centuries later, in the 1900's, Tiffany and Company of New York received shipments of the blue-green gem stone from the Chloride and Courtland-Gleeson areas.

Other materials mined by the early Indians include clay, asbestos, and garnet. One rather large salt mine was operated between 900 to 1200 AD. This mine, probably the same as reported near Camp Verde in Yavapai county, by the Spanish explorer, Antonio de Espejo, in 1582, apparently had at least four underground levels. Another interesting aboriginal locale of the Terra Incognita is the Black Mesa area of central Navajo county, where archaeological investigations show that by about 1200 AD, Indians were mining and burning coal. This utilization of coal as a source of fuel may actually predate a similar use in Europe. The largest coal company in the United States, Peabody Coal Company, currently produces about 1,000,000 tons of coal each month from this same area.

Spanish and Mexican Development

The preeminent role played by gold in attracting the Spanish to the New World is well recognized. Commands made by the Spanish throne to acquire this noble metal were often translated into bizarre acts of cruelty and barbarism. The conquistadors wanted to convert the natives to Christianity and to take their gold. No attempt was made by these early Europeans to mine gold and silver;

they wanted instant wealth handed over to them by the conquered Indian nations.

Although never confirmed, stories of seven cities of gold in the Terra Incognita prompted several Spanish expeditions into what is now northern Arizona and New Mexico. (Actually the eagerly-sought Seven Cities of Cibola turned out to be the somewhat more prosaic Zuni villages of stone and mud in northwest New Mexico.) The earliest explorations were led by Fray Marcos de Niza through the Santa Cruz Valley in 1539, by Francisco Vasques de Coronado through the San Pedro Valley in 1540, and by Alarcon who sailed his ship into the Gulf of California and up the Colorado River.

Antonio de Espejo began his expedition in 1582. His travels took him via the Rio Grande into north central New Mexico and then westerly into central Arizona and the vicinity of the San Francisco Peaks. Espejo is the first foreigner on record to have discovered a major metallic mineral deposit in Arizona. He reported that he found, on May 8, 1583, rich silver ore in an area to the south of the San Francisco Peaks. This is the same locality described about 15 years later by Farfan in which he reported workings dug by Indians for pigments.

Some authorities believe this mining location is what eventually became the famous United Verde deposit at Jerome (Yavapai county), at the head of Verde Valley. The stream in this valley was referred to by the local Indians with a descriptive name which meant "green", a name given in apparent reference to the occurrence nearby of the green copper carbonate, malachite. Spaniards later translated the Indian name to "verde". The United Verde mine, and what some consider to be its original cap, the United Verde Extension, comprise the single largest bonanza copper deposit in Arizona. To date the deposits combined have yielded over 3.7 billion pounds of copper, 52 million pounds of zinc, 55 million ounces of silver, and 1.5 million ounces of gold.

During the latter years of the 17th century, Jesuit missionaries, led by Father Eusebio Francisco Kino, began establishing Catholic missions in northern Sonora, or what is now southern Arizona. As the mission churches were established principally along the major streams, Gila, San Pedro, and Santa Cruz, small military posts were garrisoned to protect Spanish settlements on the rivers and their tributaries. Settlers, priests, and Indian converts started prospecting and mining shallow deposits of oxidized and enriched silver-bearing lead deposits. About 1700, Father Kino's writings state:

> "In these new nations and new lands there are many good veins and mineral lands bearing gold and silver; and in the neighborhood and even in the sight of the missions some very good new mining camps of very rich silver ores are now being established."

The areas bordering the Santa Cruz River and its tributary, Sonoita Creek, and the areas flanking Arivaca Creek appear to have been the most heavily mined and developed by the early Spanish settlers. "Antiguas", mine pits and shallow excavations overgrown with vegetation and large trees and the remains of numerous crude adobe furnaces and slag piles, provided ample evidence to the early Americans that miners had preceded them. With the discovery in 1736 of the unusual "planchas de plata" at Arizonac, prospecting in the region intensified.

Arizonac, or Arizona as the Spaniards later called it, was about a mile south of the eventual international boundary and about eight miles west of the old Mexican town, Sasabe, at a place now called Banera. Very large masses and sheets (planchas) of pure silver were dug essentially from the ground surface. Apparently one lump weighed 2,700 pounds; others weighed 200 to 400 pounds. Ultimately, 156 "arrobas", or a little over two tons of silver, were reported. It was a find that fired the imagination of later American prospectors.

Throughout this region of northern Sonora, designated Pimeria Alta (upper Pima land) by the Spaniards, small scale mining operations were pursued despite various frontier difficulties including Apache Indian raids and local Indian revolts. The level of mining activity reduced considerably, however, during and after the Mexican Revolution of 1810-1812. As the Spanish troops were withdrawn so was the military protection. The missions, mines, and settlements were destroyed or abandoned as Apache raids and outlaw depredations increased.

With independence in 1821, northern Sonora was now a frontier of Mexico. The presidio of Tucson was reoccupied, affording some protection to the farmers and miners living in the Santa Cruz Valley and nearby areas. Apache attacks continued, however, and little mine development actually took place. Not until the war between Mexico and the United States (1846-1848) was resolved and the Gadsden Purchase was approved (1854), was there a renewed vigor towards mineral exploration and development in the region of Arizona.

Negotiations to determine the final southern boundary of the land embraced by the Gadsden Purchase is a story in itself. An obvious attempt was made to include areas of mineralization but little other than hearsay was known to guide congressional planning. Reports of the colorful outcrops at Ajo by early prospectors and '49ers traveling to California, must have been transmitted to Washington. Tom Childs, Sr., and his group of 19 men, in 1847 launched an effort to locate the mysterious planchas de plata but were forced back north by unfriendly Mexicans. On their way to Tucson, they were directed to Ajo where the prospectors saw the copper mine, worked earlier by Indians and Mexicans. Childs reported that in addition to open cuts in the hillsides, there was an inclined shaft approximately 60 feet deep. The party found notched mesquite logs used as ladders and ore buckets made from rawhide. Later, in 1849, this area was very close to one of the southern trails, El Camino del Diablo (The Devil's Highway), from Altar to Yuma, traveled extensively to the California goldfields.

Contrary to the original plan, the international boundary between the Arizona section and Mexico, was established too far north to give the United States a seaport on the Gulf of California. This unfortunate fact later created obstacles to the early development of the mineral industry and other commercial enterprises in southern Arizona. The necessity for low-cost, secure means of transporting ores and goods led to the rapid, alternative construction of railroads into the territory.

For 10,000,000, the Gadsen Purchase added over 45,000 acres below the Gila River, and southern Arizona became a part of Doña Ana County, Territory of New Mexico. This southern acquisition later yielded the single largest primary silver district in the state, Tombstone, and several very large copper districts, including the rich, multi-metal cornucopia, bountiful Bisbee.

American Settlement

Mining in California exerted a major influence on the development of western New Mexico Territory. Providence may have played a role too.

In settlement of the war with Mexico, the United States acquired the vast territory of California, Nevada, Utah, New Mexico, portions of Colorado and Wyoming, and northern Arizona. For this enormous acreage, Mexico was paid $15,000,000 pursuant to the Treaty of Guadalupe-Hidalgo signed on February 2, 1848. Unknown to both governments, interestingly, gold was discovered at John Sutter's sawmill in northern California nine days *before* the signing. In 1849, a year later, California produced some $45,000,000 in gold. In the decade, 1848-1858, California's gold production amounted to $555,000,000.

Within a year of this gold discovery, 80,000 people had gone to California. Many more were to follow and many passed through northern Sonora on their way. Regardless of success in the goldfields, some men, looking for new challenges, returned to Doña Ana County. In the 1850's, a favorite watering hole was Tucson.

It was here in the Old Pueblo, 1850, that Tom Childs, Sr., reportedly met for the first time a fellow '49er, Peter Rainsford Brady. He told Brady about Ajo and that he was preparing to return to the green-colored outcrops.

Brady took employment with Colonel Andrew Belcher Gray who in 1854 surveyed a route on the 32nd Parallel for the Texas Western Railroad. In the meantime, another survey party was establishing the boundary between Mexico and the United States, including the southern border of what is now Arizona. On the Gray expedition, while resting in Sonoita (Sonoyta), in northern Sonora, Mexico, Brady had a Seri Indian guide take him to Ajo. He brought back copper specimens and, when released from his work in San Francisco, organized the first mining company to conduct business in Arizona.

This company, the Arizona Mining and Trading Company, born in August, 1854, was created specifically to mine the ores of Ajo. At least some of the organizers and employees of the new mining firm are listed below:

Major Robert Allen, President	John Killbride
_________ Bendel	_________McElroy
William Blanding	Jock McPherson
Capt. Peter R. Brady	Granville H. Oury
*Tom Childs, Sr.	Col. _________ Porter
Francis P. Clymer	Frederick A. Ronstadt, Sr.
_________ Cook	**Charles Schuchard
B. (Hill) DeArmitt	Clem Thompson
Edward E. Dunbar, Manager	Dr._________ Webster
George Graham	George Williams
Col. Andrew B. Gray	J. Downer Wilson, Sec/Tr
O. Charles Hayward	A. S. Wright
G. Kibber	Joe Yancy

*Tom Childs and some of the fellows joined the group in Yuma.

**Charles Schuchard, B. H. DeArmitt, Col. A. B. Gray, J. Killbride, F. P. Clymer, G. H. Oury, C. Thompson, and F. A. Ronstadt, Sr., apparently formed a subsidiary party of 12 men led by Schuchard, that explored south of the border for the fabled planchas de plata. Their search was successful, finding a piece of silver weighing four ounces on the surface and later unearthing a mass weighing 19 pounds in some old shallow pits overgrown with oaks. The group was driven north by Mexicans who claimed the property was in their country.

After opening the first wagon road in this part of Arizona, from Petato as Gila Bend was known in those days, to Ajo, the company hired local Papago Indians to help open the mine. Although reports vary, the miners apparently hand-sorted the first shipment of ore, comprised chiefly of beautiful ruby-red cuprite and native copper. The ore was freighted by ox team through Fort Yuma to San Diego, 300 miles across the desert, and shipped by boat to Swansea, Wales. At least one other shipment was sent by flat boat, from Yuma, down the Colorado River to Guaymas, in the Gulf of California, where it was transferred to a shipment bound for Wales.

The copper smelter of Swansea paid according to the grade of the ore. Apparently the Arizona Mining and Trading Company received between $360 and $500 a ton. Enroute one ore shipment reportedly sank off the coast of Argentina.

To improve its profit margin by shipping a higher grade product, the company attempted to smelt its own ore. A reverberatory furnace was constructed in 1856 at a cost of $30,000. Because of the expense of coke and charcoal and the lack of suitable flux, however, the furnace was not successful. Only 100 pounds of matte copper were produced.

The remote location of the Ajo mine, high costs of transportation, comparatively low grade, and scarcity of water forced the operation to cease by 1859. It is to the credit of these mining pioneers that their enterprise lasted five years. The choice of name for the state of Arizona was undoubtedly influenced by the name of the first mining corporation to operate in the territory.

Additional influences derived from this first mining venture in Arizona are found in the later activities of some of the men involved. Brady remained in the territory and became a prominent businessman and politician. He was elected in 1866 as the first sheriff of Pima county and eventually served several terms as a territorial legislator.

Tom Childs, Sr., operated a stage station on the Gila River and continued attempts to develop the Ajo mine. In 1884, he formed a partnership with Washington Michael Jacobs and reworked the copper deposit. The ore was shipped to the Selby Smelting Company of San Francisco. Although the operation apparently produced little copper, Childs, Jacobs, and later, other partners, held on to their mining claims and eventually sold them to other developers. Childs and his son, Tom, Jr., built a relatively large ranching business in the area. In Tucson, Jacobs continued operating an assay office, opened in 1880, that is still family owned.

Granville Henderson (Grant) Oury and his older brothers were very active in southern Arizona. Grant Oury was Chief Justice of the Supreme Court for the Provisional Government in 1860. He resigned the same year and eventually gained eminence as a lawyer and politician.

Frederick Augustus Ronstadt, Sr., sold his interest in the mine at Ajo for $25. His son, Frederick, Jr., established in Tucson a wagon shop that was expanded by the family into a major hardware and building supply firm. Another German by birth, Charles Schuchard, who had served as an artist on Col. A.B. Gray's railroad surveying expedition, left the Arizona Mining and Trading Company and, by 1857, had gone to work as an engineer in charge of smelting operations for another pioneer firm, the Sonora Exploring and Mining Company.

The Sonora Exploring and Mining Company was founded in 1856 by Charles Debrille Poston and Samuel Peter Heintzelman. As a result of an exploratory trip in 1854 with Herman Christian Ehrenberg and a party of 30 men, through northern Sonora and the Gadsden Purchase, Poston gained enough information and interest to help promote the general development of southern Arizona. After this trip, he returned east as the representative of California businessmen who were interested in promoting ventures in the Southwest.

Poston and Heintzelman, who was a major in the U.S. Army at the time, convinced the Wrightson brothers and other investors in the Cincinnati area of the merits of their proposed mining venture. The company was formally organized in March, 1856, with Maj. Heintzelman as President and Poston designated Commandant and Managing Agent. By the end of the month, "Col." Poston was on his way, via Texas, to Arizona.

In Texas, Poston hired men and purchased equipment. Herman Ehrenberg met the group in Tucson and by September, the company had established its main office at the abandoned Mexican presidio at Tubac. Within a few months, Sonora Exploring and Mining Company owned the 17,000-acre Arivaca Ranch and land around Tubac. On January 1, 1857, the "discovery" of the Salero vein in the Santa Rita Mountains was announced, and the annual report, dated September 1857, announced ownership of 80 mines. Of this total the lodes apparently considered the most important were:

Arivaca Ranch	**Cerro Colorado Area**
Amado	Amarillo
Arenia	Carlos
Basura	Cesario
Blanca	Guadalupe
La Purissima	Heintzelman
Los Tajitos	Longoreña
San Jose	Maria
Santa Margarita	Puertozito

Santa Rita Mountains

Ojero
Salero

The firearms inventor and manufacturer, Samuel Colt, became a major stockholder in the mining company. Eventually he was a director and in 1859, as chief stockholder, he replaced Heintzelman as president. Colt also invested in at least two other mining enterprises, the Sopori Land and Mining Company and the Arizona Land and Mining Company, companion corporations of southern Arizona.

Spun off from the Sonora Exploring and Mining Company, in 1858, was the Santa Rita Company. It was organized in Cincinnati by the founders of the parent company; the mines held and developed thus far in the Santa Rita Mountains were transferred into the new company. In May, Horace Chipman Grosvenor and Phocian Way, Cincinnati engravers, were sent to Arizona to establish headquarters and supervise the company's operations. The company offices were set up at the Hacienda de Santa Rita near the abandoned mission at Tumacacori. By the next year, seven mines were operating.

One of the Wrightson brothers, William, brought a printing press from Ohio to Tubac in January, 1859. With the blessings of the Sonora Exploring and Mining Company and the Santa Rita Company, he and his editor, Edward E. Cross, published the first newspaper in Arizona. The first issue of the *Weekly Arizonian* came out on March 3.

All the mine properties were difficult to operate. Heintzelman who supervised the mine operations in the Arivaca and Cerro Colorado areas from August, 1858, to January, 1859, was frequently discouraged by the unskilled labor, faulty, crude equipment, high costs for supplies and transportation, and difficulties with the smelting furnaces. The company appears fortunate to have had very competent, trained engineers, particularly the Europeans Frederick Brunckow, Herman C. Ehrenberg, Guido Kustel, and Charles Schuchard. Unfortunately, the number of mines they had to develop was probably too large and the variety of ores too great to treat uniformly.

Frederick Brunckow was a native of Prussia and a graduate of the Royal Mining Academy. He discovered the San Pedro silver mine, about six miles southwest of Tombstone and half a mile east of the San Pedro River, reportedly in 1857. Brunckow left the Sonora Exploring and Mining Company in 1859 to develop his property and was murdered on July 23, 1860, by his Mexican employees. Apparently, he was found at the bottom of a shaft with a drill steel through his body.

The mine which was commonly known as the Bronco influenced Ed Schieffelin in his prospecting during 1877 of the silver-bearing outcrops to the northeast. Later he and his partners apparently used the old Brunckow cabin as headquarters and assay lab while staking the bonanza area of Tombstone.

Herman Ehrenberg was born in Germany. He produced the first private map of the area encompassed by the Gadsden Purchase and, as an employee of the Sonora Exploring and Mining Company, he produced a plan of the company headquarters at Tubac and sketches of the silver regions around Tubac. In August, 1856, he helped draft a petition to Congress seeking separate territorial status for Arizona. By mid-1858, he resigned from the Sonora Exploring and Mining Company. As president of the Cahuabi Mining Company, he reopened the old Picacho silver mine in the South Comobabi Mountains. He continued his association with Sonora Exploring and Mining, however, by submitting several articles in 1859 to the "company" newspaper at Tubac.

Ehrenberg was perhaps the first and most persistent geographer and topographer of Arizona. While prospecting and carrying on mining activities in central and western Arizona during the early 1860's, he helped establish the La Paz Town Association and as secretary, organize and draft the mining laws of the Castle Dome mining district. He built a road eastward from La Paz toward the Walker and Weaver mining districts and on northwestward toward Fort Whipple and Prescott. When his productive life was cut short by murder on October 9, 1866, his good friend and early pioneer merchant of the area, Michael Goldwater, established the town of Ehrenberg in his memory.

Austrian-born Guido Kustel was educated as a metallurgist in Germany. He introduced and improved the barrel amalgamation process for the Sonora Exploring and Mining Company. Eventually he returned to California, establishing assaying and metallurgical firms, and he became a recognized authority on the treatment of precious-metal ores.

Poston was probably the first true mine promotor in Arizona. Although some of his statements regarding the mines held by the Sonora Exploring and Mining Company were exaggerated, there is no doubt of his sincere enthusiasm to see the mineral industry and general commerce develop in the Santa Cruz River valley. A statement by him describing his tenure in Tubac reflects this philosophy:

> "It is astonishing how rapidly the development of mines increases commerce. We had scarcely commenced to make silverbars—'current with the merchant'—when the plaza of Tubac presented a picturesque scene of primitive commerce. Packtrains arrived from Mexico, loaded with all kinds of provisions. The rule was to purchase everything they brought, whether we wanted it or not. They were quite willing to take in exchange silver bars or American merchandise. Whether they paid duties in Mexico was none of our business. We were essentially freetraders."

In the operations, Heintzelman was the detail man and Poston, the "big-picture" man. While Heintzelman complained frequently in his diary of Poston's absences and apparent lack of interest, Poston appeared to be relatively busy obtaining more financing, men, and materiel for the mining enterprise.

Poston's interests were varied. On his first trip into the region of the Gadsden Purchase, he and Ehrenberg platted the townsite of Colorado City (Yuma) and sold lots. Later, when he arrived from Texas and rejoined Ehrenberg in Tucson, he also helped with the petition to seek independent territorial status for Arizona. He continued his efforts and, with Heintzelman and others' help, he saw passage of the bill creating the Territory of Arizona in 1863. Getting the bill passed by Congress and signed by President Lincoln during the Civil War was particularly difficult because of the known southern sympathies in Arizona. Upon formation of the new territorial government, Poston was appointed first Superintendent of Indian Affairs. Already known as the "father of Arizona", the voters of Arizona Territory elected him as their first Congressional Delegate to Washington, D.C.

After this two-year term, Poston was not re-elected but he did hold various public offices for a number of years. He wrote of his experiences often and was a founder of the Society of Arizona Pioneers, a precursor of the Arizona Historical Society. Poston was a strong proponent of Arizona development. Unfortunately, he lived very close to poverty in his later years and was found, June 24, 1902, dead on the dirt floor of his dilapidated adobe home in Phoenix.

During the last half of the 1850's, in addition to the companies that Brady and Poston were associated with, there were several other mining organizations active in Arizona. Like Heintzelman, many of the mine developers were military men who were, or had been, stationed in Arizona. Maj. Robert Allen, who had gained experience mining with Brady at Ajo, attempted to rework the San Xavier mine. The San Xavier Silver Mining Company was organized in 1857 in San Francisco with a Mr. Breed as its director. It erected adobe furnaces on the Santa Cruz River at the Punta del Agua, about three miles south of the San Xavier mission, but apparently had problems with sickness (malaria?) among the men. The furnaces may never have been operated; in December, 1858, an agent of the company (Edward H. Belcher?) requested the Sonora Exploring and Mining Company to smelt the San Xavier ore.

Another military man, Col. Andrew B. Gray, was director of the Maricopa Mining Company. Apparently in the late 1850's, this firm attempted to develop the Collins silver mine near the mouth of Aravaipa Creek on the San Pedro River. Gilbert W. Hopkins, a mechanical engineer, was reportedly the chief engineer on the property.

Soldiers stationed at Ft. Buchanan, at the head of Sonoita Creek, prospected the nearby Santa Rita and Patagonia ranges. Captain Richard Stoddert Ewell, Lieutenants Richard S.C. Lord and Isaiah N. Moore, (Lieutenant Horace Randal?), "Colonel" James W. Douglass, and Richard M. Doss purchased the Corral Viego mine in 1858 from a Mexican prospector. The mine was re-named Patagonia; shafts were sunk and furnaces were built. A little ore was mined but the soldiers were probably ill-equipped in terms of training to develop the mine efficiently. Some of their ore was smelted by the Sonora Exploring and Mining Company.

After passing through ownership of Elias Brevoort, a sutler at the fort, and Henry Titus, a filibuster and manager of the Union Silver Mining Company, the Patagonia was purchased in the spring of 1860 by Lt. Sylvester Mowry. He paid $25,000 for the property soon to be known as the Mowry mine.

In 1856, a Lt. Humphries is said to have discovered base-metal and precious-metal deposits, apparently in the Castle Dome Mountains northeast of Ft. Yuma. A prospector named Halstead reportedly discovered the copper deposits of the central Buckskin Mountains north of Yuma in 1858. Neither one of these areas was actively mined, however, until about 1862.

Except for possible cursory placering for gold around the Las Guijas Mountains near Arivaca, the Quijotoa Mountains near Covered Wells, and in the Cañada del Oro near Tucson, important placer development by the Americans did not begin until the 1850's when several discoveries were made in western Arizona. It has been reported that gold was re-discovered as early as 1857 in the vicinity of the Red Hills, at the southwestern foot of the Chemehuevis Mountains. This area is about 18 miles southeast of Topock and is near modern Lake Havasu City. Other discoveries may have been made in the later 1850's in Burro Creek and nearby gulches about 18 miles northwest of Hillside, in the vicinity of Bagdad.

The first truly significant placer discovery was made in 1858 by Jacob Snively where the Gila River wraps around the north end of the Gila Mountains, about 12 miles east of Yuma. This placer ground, approximately two miles long, was the scene of a stampede and furious activity for several years. The most productive gravels were found near the mouth of Monitor Gulch where Gila City (Dome) developed. Within a few months of the announcement of this bonanza, over a thousand prospectors were in the area combing the gulches. Officials of the Sonora Exploring and Mining Company complained that their Mexican miners quit work and left for the new diggings. J. Ross Browne described the scene:

> "Enterprising men hurried to the spot with barrels of whiskey and billiard tables; Jews came with ready-made clothing and fancy wares; traders crowded in with wagons of pork and beans; and gamblers came with cards and monte-tables. There was everything in Gila City within a few months but a church and a jail . . . "

As prospectors and miners moved into the western portions of the Territory of New Mexico, settlers including farmers, traders, and teamsters followed. For protection, in addition to that offered by the Army troops garrisoned at Ft. Yuma in California, forts were occupied or established at Ft. Defiance (1851), Tucson (1856), Calabasas (1856), Ft. Buchanan (1856), Ft. Mohave (1859), and several lesser stations. Communication and transportation between villages and rural settlements were facilitated by strings of stage stations. Greatest of the stage lines was the Butterfield Overland Mail which, in Arizona, ran westerly through Apache Pass and Dragoon Springs to Tucson, turning north by Picacho Peak to the Pima Villages on the Gila River, and then heading west down the Gila to Colorado City.

Centers of civilian population were concentrated along the Butterfield route and in the fertile drainages of the Santa Cruz, Sonoita, and Arivaca washes and their adjacent mines. The aggregate population, excluding Indians, counted during the decennial census of 1860 for the Territory of New Mexico, County of Arizona (now state of Arizona) was 1,541. Tucson, with 623 persons, was the most populous locality; Tubac was second with 164. The eldest person recorded was a woman, Quiteria Murguia, 100 years old, living in Tucson; place of birth, unknown.

The general hostility of the new territory can be illustrated by reviewing the experience of Larcena Pennington Page. In 1860, Larcena was one of only 44 Anglo-American women over 16 years of age in the area. One day in March, while her husband was timbering in upper Madera Canyon of the Santa Rita Mountains, she was kidnapped from their camp by a band of Apaches. After forcing her to walk some distance, they pushed her down a hillside, stripped her of her clothing, speared her eleven times, and stoned her. Two weeks later, having lost blood and having subsisted on melted snow and wild plants, she crawled and stumbled into the lumber camp. Larcena survived this ordeal; in 1913, a year after Arizona became a state, she passed away in Tucson.

The population figures during 1860 for mining communities are:

Arivaca Mines	27	Longoreña Mines	4
Cahuabi Mines	2	Patagonia Silver Mines	5
Copper Mines (Ajo)	18	San Pedro Silver Mines	8
Gila City	58	Santa Rita Silver Mines	5
La Laguna	18	Cerro Colorado Mines	3

There were 47 men that listed their occupation as miner. Although this number represents about 7.5% of the total work force (624), many others who listed their occupations such as laborer, teamster, or blacksmith, undoubtedly worked for the mines.

When the Civil War erupted in 1861, most of the military was withdrawn. The net effect of this withdrawal was chaos as Mexican Nationals thought the American government had collapsed and the Apache Indians thought they had won their war with the American invaders. In April, the Butterfield Overland Mail Company discontinued services through Arizona. Operations at most of the mines in southern Arizona were terminated.

The headquarters at Tubac of the Sonora Exploring and Mining Company and its mines at Arivaca and Cerro Colorado were abandoned. John Lee Poston, younger brother of Charles and storekeeper at the Heintzelman (Cerro Colorado) mine, was killed by Mexican laborers in 1861. Horace Grosvenor, superintendent of the Salero mine, was murdered by Apaches on April 25, of the same year. (An earlier manager, F.N. Slack, was killed by the Apaches, probably in 1860.) The headquarters at the Hacienda de Santa Rita of the Santa Rita Company and its mines were abandoned by June 15, 1861. Within the next two years, all company operations were looted and devastated by the emboldened Indians and Mexicans.

After the war, William Wrightson returned to re-open the Santa Rita mines. He employed the prominent engineer and territorial legislator, Gilbert Hopkins. Unfortunately, Wrightson was murdered by Apaches on February 17, 1865; less than a month later, on March 1, they killed Hopkins.

Under the leadership of Lt. Mowry, however, the Mowry mine continued to prosper during the first stages of the Civil War. Production of lead and silver was maintained as the property was well equipped and well defended. Numerous settlers moved into the mining camp for security. Unfortunately, in June, 1862, Mowry was arrested by Union troops as a Confederate sympathizer and imprisoned at Ft. Yuma for six months. Union agents operated the mine, apparently without much success, until it was returned to Mowry reportedly with $40,000 in damages, in 1864. Mowry attempted to raise capital to rebuild the mine but died unsuccessful, in 1871, in London.

In contrast to the generally bleak and restricted conditions existing in the Santa Cruz River valley and its environs during the Civil War, prospecting and mining activities in central and western Arizona increased. This is due in large measure to the support given by troops stationed at Ft. Yuma and by officers such as the Union General, James H. Carleton, who provided military escorts to prospecting parties and influenced the location of Ft. Whipple established in 1863. Gen. Carleton recognized the value of gold as a means to finance the war.

Development of the Colorado River area and northeast into the Prescott area was rapid. Gold was the prime motivator.

During the fall of 1861, an Indian trapper reportedly brought into Colorado City an eagle quill full of placer gold and showed it to Pauline Weaver, one of the most respected American trappers and guides of the period. After confirming the find, Weaver organized a prospecting party of 40 men led by Jose Maria Redondo. They left in January, 1862, for the dry washes on the western slope of the Dome Rock Mountains, an area that is about seven miles east of the Colorado River. In a gulch named for him, Juan Ferra picked up a nugget that weighed 47.5 ounces.

The rush was on. A wave of prospectors from California and Sonora, Mexico, came in and by the end of 1862, La Paz, with a population of 1,500, was well established 2½ miles east of the river. The La Paz placer discovery greatly stimulated prospecting throughout the region and as far east as the Bradshaw Mountains. The Middle Camp and Oro Fino placers were discovered on the east side of the Dome Rock Mountains. Across the valley, eastward, are the Plomosa placers on the west flank of the Plomosa Mountains.

In 1863, Abraham Harlow Peeples organized a prospecting expedition at Yuma and hired Weaver as its guide. The party traveled up the Bill Williams Fork and its tributaries to Antelope and Weaver creeks, north of Wickenburg, where incredibly rich placer ground was found. On Rich Hill, Peeples is said to have picked up $7,000 in loose gold one morning before breakfast. In the same year, the lode-gold deposit of the Vulture mine was discovered by Henry Wickenburg, a member of the Peeples party. The enormous output of gold from this mine helped finance the U ion Army; by the end of the war there was a 40-stamp mill in operation.

While Peeples and his gold miners were busy in the Rich Hill area, Capt. Joseph Reddeford Walker led an expedition of about 34 prospectors into the Lynx Creek area near the future site of Prescott. A member of his party, Sam Miller, discovered gold in the creek. It has the honor of being the single most prolific placer drainage in Arizona.

As the regions between Yuma and La Paz and central Arizona grew, river boat traffic on the Colorado River increased. People, produce, equipment and supplies of all description were shipped up and down the river. In 1862, the first shipment from the Planet copper mine was made; 100 tons of selected high-grade ore was sent to the smelter. It is reported to have netted $100 a ton. In 1863, Capt. John Moss, accompanying Gen. Carleton's California Volunteers, discovered the Moss vein about 5½ miles northwest of the present town of Oatman. Although he reportedly shipped $240,000 in gold from his mine within the first year, Moss apparently died in poverty.

The story of Capt. Moss is not unusual. Although Henry Wickenburg discovered one of the richest gold mines in Arizona's territorial history, he did not reap its great financial reward. Within three years of his discovery, he sold the property and tried his hand at ranching. Unfortunately, he was not particularly successful and in 1905, tired at 85 years of age, he shot himself.

Others though, like Peeples, and later, Schieffelin, were successful and retained their prosperity. Regardless of the final outcome, however, it was the initial discovery and the excitement of that find that was transformed by numerous people into opportunity and enthusiastic endeavor.

Arizona Territory

Population Centers

Governor John N. Goodwin and his gubernatorial party formally proclaimed the independent Territory of Arizona on the afternoon of December 29, 1863, at Navajo Springs in what was to become central Apache county. On January 22, 1864, the group arrived at a new Army post, Ft. Whipple, only 18 miles northeast of the future city of Prescott.

In order that the new territory could be subdivided into judicial districts and a new legislature could be formed with fair representation, the United States Marshal for Arizona was instructed to take a census. During the spring of 1864, Marshall Milton B. Duffield and two assistants were given a military escort for protection as they traveled about the territory counting its citizens.

Within just four years of the first census, the population of the territory, excluding Indians, had grown almost 300%. The aggregate total in 1864 was 4,573 persons. Although Tucson (population 1,568) was still the largest community, other areas, particularly in central and western Arizona, were rapidly being developed. This development reflected primarily a shift in mine activity. Some of the settlements with a sizable group of miners are listed with their total population:

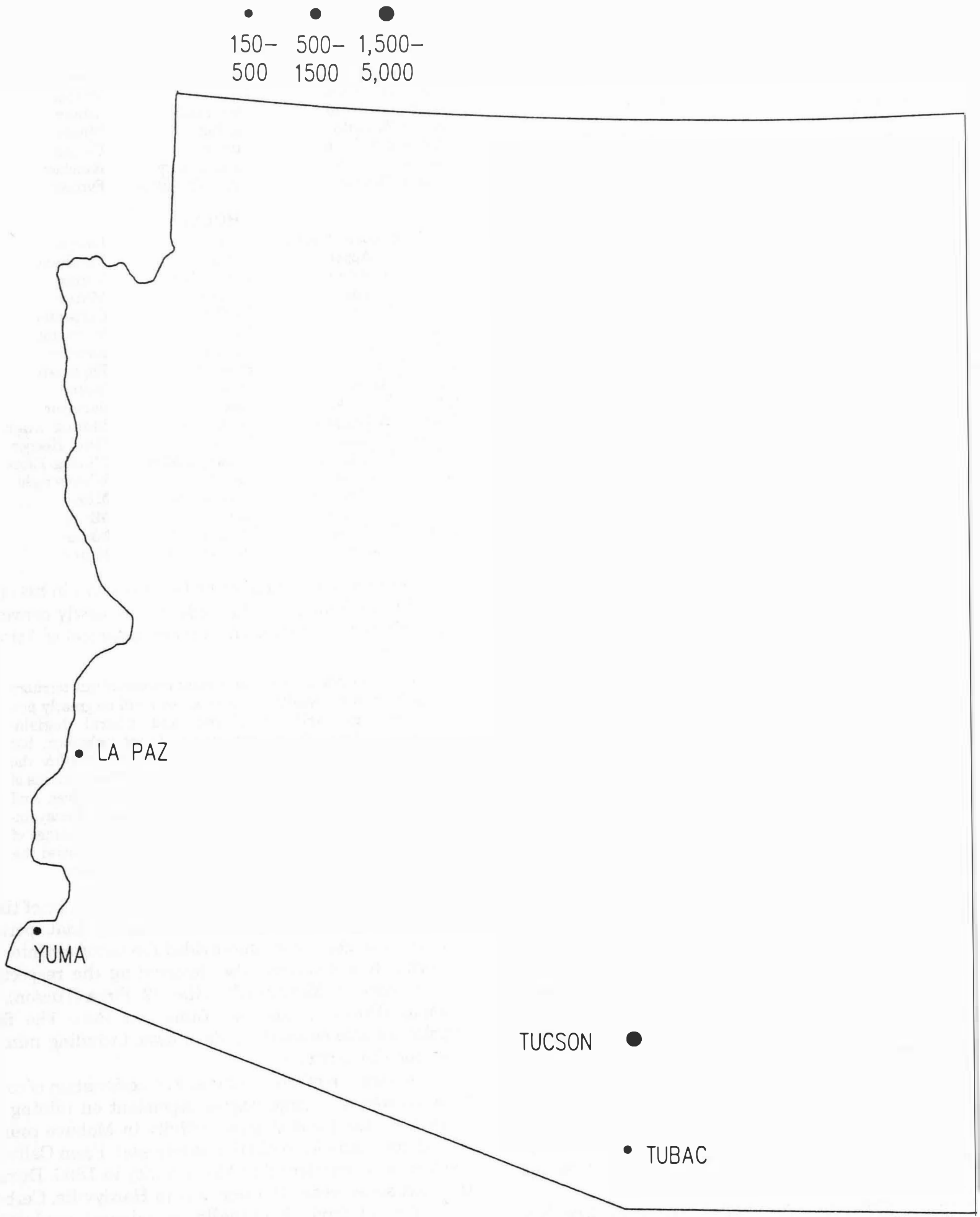
Apache Chief Mine	8	Los Posos	14
Apache Wide West Mine	3	Mineral City	16
Castle Dome	32	Mowry	252
Cerro Colorado Mine	45	New Water	61
El Dorado Canyon	90	Olive City	19
Fresnal	91	Picacho Mine	7
Fort Mojave	120	Plomosa Placers	14
Hardys Landing	32	Salizar Mine	5
Hughes Mines	54	San Antonio Mine	17
La Laguna	113	San Francisco District	62
La Paz	353	Scottie Mine	4

These villages including several others such as Arizona City (Yuma) and Tucson comprised the first and second judicial districts. The third district, actually enclosing most of the territory, contained Prescott and the mining centers of Antelope, Groom Creek, Lynx Creek, and Wickenburg. Population figures were not segregated by village in this district, but it is interesting to note that of the 761 working males (excluding soldiers), 435 of them, or 57%, gave their occupation as miner.

Practically one out of every four people in the Territory of Arizona in 1864 was a prospector or a miner. Of the total population, 53% (2,404) were working males, and of this group, 45% (1,080) were associated with mining. Jesus Angeilo, at 90 years of age, was the oldest person registered and he listed his profession as miner.

By the end of 1864, the first year of territorial government, Arizona had about 25 legally organized mining districts. Some of these, with their date of formation, are given below:

La Paz	Oct. 6, 1862
Castle Dome	Dec. 8, 1862
El Dorado Canyon	Jan. 1, 1863



POPULATION OF SELECTED ARIZONA CITIES

1864

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Pioneer	May 10, 1863
Weaver	Jun. 25, 1863
Yavapai	Sep. 28, 1863
San Francisco	Nov. 13, 1863
Quartz Mountain	Dec. 27, 1863
Eureka	Jan. 2, 1864
Cerro Colorado	Apr. 23, 1864
Walnut Grove	May 21, 1864
Wickenburg	May 21, 1864
Bradshaw	Sep. 14, 1864

Jacob Snively, of Gila City fame, was chairman of the Castle Dome mining district and Herman Ehrenberg was chosen as the District Recorder. The filing fee at his office in La Paz was $1.00. The Pioneer district was established by the "Walker" Prospecting and Mining Company and the Weaver district was named in honor of the old Tennessee trapper, Pauline Weaver. Henry Wickenburg was, appropriately, the first president of the Wickenberg district.

Politics

The fledgling government had many tasks before it. In addition to taking the census and creating three judicial districts in its first year, it located a capitol and elected the first territorial legislature.

In 1863, there were three principal centers of population: (1) the future site of Prescott and its neighboring mines, (2) La Paz, and (3) Tucson. The census taken the following year showed that the old Pueblo of Tucson had more inhabitants than all the people counted in either the second judicial district (containing La Paz) or the third district (containing the Prescott area).

Gen. Carleton, the commanding officer of the territory, was convinced that the area bordering Granite and Lynx creeks was rich in gold and he wanted to secure this wealth for the Union. He sought and received permission to establish Ft. Whipple in this area.

Carleton also apparently helped persuade Gov. Goodwin and his cabinet that a site for the capitol should be selected in central Arizona near the fort. There in a region of relatively abundant natural resources, including timber and water, and with relatively few Mexican or secessionist influences, the new seat of government could be protected and could thrive. A few months after Goodwin's party reached Ft. Whipple, the capitol was established a short distance to the southeast at a site on Granite Creek and named Prescott.

Election day, in 1864, was Monday, July 18. Voters selected nine members for the Council (now the Senate), eighteen members for the House of Representatives, and a delegate to represent the people of Arizona in the House of Representatives of the thirty-eighth Congress of the United States. A number of polling places were in the homes of mining officials and in recorders' offices of various mining districts.

Mining interests were well represented in the first Territorial Legislature. In addition to the most famous miner at that time, Charles D. Poston, who was elected handily as Territorial Delegate, miners composed 44% of the new legislative body:

COUNCIL

Name	Residence	Occupation
Coles Bashford (President)	Tucson	Lawyer
Mark Aldrich	Tucson	Merchant

COUNCIL (cont.)

Henry A. Bigelow	Weaver	**Miner**
Patrick H. Dunne	Tucson	Printer
Robert W. Groom	Groomdale	**Miner**
George W. Leihy	La Paz	**Miner**
Francisco S. Leon	Tucson	Farmer
Jose M. Redondo	Arizona City	Rancher
King S. Woolsey	Agua Fria Ranch	Farmer

HOUSE

W. Claude Jones (Speaker)	Tucson	Lawyer
Nathan B. Appel	Tubac	Merchant
Thomas J. Bidwell	Castle Dome	**Miner**
John M. Boggs	Prescott	**Miner**
Luis G. Bouchet	La Paz	Carpenter
John G. Capron	Tucson	Merchant
Jesus M. Elias	Tucson	Rancher
James Garvin	Prescott	Physician
James S. Giles	Prescott	**Miner**
Gregory P. Harte	Tucson	Surveyor
Norman S. Higgins	Cerro Colorado	**Mining Engr.**
George M. Holaday	La Paz	Hotel Keeper
Gilbert W. Hopkins	Maricopa Mine	**Mining Engr.**
Henry D. Jackson	Tucson	Wheelwright
Jackson McCracken	Lynx Creek	**Miner**
Daniel H. Stickney	Cababi	**Miner**
Edward D. Tuttle	Mohave City	**Miner**
William Walter	Mohave City	**Miner**

The enthusiasm expressed by Gov. Goodwin in his opening address, September 30, 1864, to the newly convened assembly with respect to the mineral potential of Arizona is obvious:

> "The most extensive and important interest of this territory is the mineral wealth. Its development will be greatly promoted by well considered and liberal legislation . . . (Arizona's) mineral wealth is yet unknown, but enough has been discovered to dazzle and perplex the mineralogist with its richness and extent. Whole chains of mountains are seamed with veins of gold and silver. And the gold and copper mines of the Colorado and Hassayampa are only surpassed in richness by the silver mines of southern Arizona. The obstacles which have retarded the development of this wealth will soon be overcome."

The new legislative assembly met only for a brief time, September 26 to November 10. During that period, however, the gentlemen subdivided the territory into the following four counties, also designating the respective county seats: (1) Mohave (Callville), (2) Pima (Tucson), (3) Yavapai (Prescott), and (4) Yuma (La Paz). The first legislature also enacted a code of laws, including mining laws, for the territory.

The separation of later counties and designation of county seats was to a large degree dependent on mining interests. As the focus of mine activity in Mohave county moved, for example, so did the county seat. From Callville the seat was transferred to Mohave City in 1866. During the next seven years, the seat was in Hardyville, Cerbat, and Mineral Park. Eventually, as mineral production dwindled, Kingman was made the county seat in 1887.

Cochise, Gila, Graham, Pinal, and Santa Cruz counties were created from portions of pre-existing counties primarily because of their growing mining communities. The last county created by the Territorial Legislature was named for one of its earliest prospectors, Mason Greenlee.

Gov. Goodwin and several members of his cabinet were, like the miners, struck with gold fever. The Secretary of

State, Richard C. McCormick, and the governor's private secretary, Henry W. Fleury, joined Goodwin in co-signing a number of mining claims. Indeed Secretary McCormick was so impressed by the role of mining and its potential in the new territory that he attempted to design an official seal:

> "The design, that of a stalwart miner, standing by his wheelbarrow, with pick and shovel in hand, the upturned 'paying dirt' at his feet, and the auriferous hills behind him, with motto 'Ditat Deus' (God enriches), forms an appropriate and striking combination."

To this day the importance of mining in Arizona is acknowledged in the great seal of the state. Incorporated into the design is the portal of a mine adit and a miner standing in front, with his pick and shovel, and an ore concentrating facility shown in the background.

Commerce

During territorial days the business of Arizona was closely connected to mining and influenced by mine development. Continuing a pattern begun prior to 1863, the location and construction of roads and Army forts were strongly dependent on the location of mining communities. The need to supply these communities with foodstuffs, clothing goods, medicinal materials, hardware, building materials, and a variety of other products required the efforts of farmers, freighters, blacksmiths, and merchants.

Important early business developers included such names as Barney, Hardy, Ochoa, Tully, Hughes, Goldwater, Hayden, Woolsey, and Zeckendorf. There were many others. As the fabric of society was constructed, other professionals including physicians, lawyers, teachers, ministers, journalists, and engineers established residency. Many of these early Arizonans were diversified in their business enterprises and many invested heavily in mining ventures. An example is Michael Goldwater who reportedly built a mill at Wickenburg in 1865. He operated the mill one month, realizing $3,000 a day, and then sold it.

Grub stakes, wherein normally the investor and the prospector each received 50% of any minerals found, and/or staked, were common. Optimism was high and frequently a prospector would stake 100 claims, requiring $10,000 annual development, when he had only $10 to his name. The lure then, as now, was strong and at times irresistible. The following stanza was found in a mining prospectus of territorial days:

> "Come, little brother and sit on my knee,
> And both of us wealthy will grow, you see,
> If you will invest your dollars with me,
> I will show you where money grows on the tree."

Tucson was the traditional center of mine promotion and, accordingly, it was the home of the American and Mexican Mining Exchange. Established in December, 1880, the Exchange was visited by capitalists and engineers to view ore specimens and trade information.

The "mining bug" infected a variety of people. Around 1900, acting on complaints that quarterly reports had not been received for several years from the Postmaster at Ehrenberg, the Post Office Inspector decided to investigate. He found mail that should have been delivered four years earlier. Apparently Postmaster Daniel had been too busy mining. Daniel had not even opened a letter to him from the Postmaster-General thanking him for the "high class of service . . . rendered . . . at Ehrenberg."

The enthusiasm and high regard held for mining was reflected early in the names chosen for local newspapers. The third newspaper established in the territory was the *Arizona Miner*, published by Secretary McCormick. Its first issue, March 4, 1864, was circulated from Ft. Whipple. It eventually became the *Daily Journal-Miner* of Prescott. Others followed: the *Nugget* and the *Daily Prospector* of Tombstone, *Silver Belt* of Globe, *Our Mineral Wealth* and *Mohave Mines* of Kingman, the *Wickenburg Miner*, the *Pick and Drill* of Prescott, the *Pinal Drill*, the *Copper Era* of Clifton, *Copper Belt* of Jerome, and the *Prospector* of Quijotoa.

Mine Discoveries

With the dangerous Apache, Hualapai, and Yavapai ever lurking, it was difficult for the prospector to evaluate the ground, "with a pick in one hand and a gun in the other." However, the sheer number of increasing miners, banding together, provided more self-protection, and the greater determination exhibited by the Army leaders to subdue the Indians, gradually provided a safer environment in which to develop mines. Railroad construction across Arizona began in 1877 at Yuma, and Geronimo surrendered in 1886. Transport conditions improved and ore could be shipped out and machinery brought in at reasonable prices. Capital investment was attracted from the eastern states and from Europe.

The territorial years witnessed great lode, or hardrock, discoveries of copper, lead, zinc, silver and gold deposits. Some of the finds were truly bonanzas. Among the more important mines that had a major impact on the territory, tabulated by principal metal, are the following:

Copper	**Gold**
Bisbee area	Congress
Clifton-Morenci area	Crown King
Inspiration area	Harquahala
Jerome area	Katherine
Magma	King of Arizona
Miami area	La Fortuna
New Cornelia	Mammoth area
Old Dominion	McCabe-Gladstone
Ray	North Star
Silver Bell area	Oatman area
	Octave

Lead/Zinc	**Silver**
Castle Dome area	Commonwealth
Duquesne	Hermosa
Golconda	Mack Morris
Montana	McCracken
Mowry	Peck
San Xavier	Silver King
Tennessee	Tip Top
	Total Wreck
	Tombstone area
	Vekol

Several of these mines were touted almost as much for their by-product commodities as they were for their principal metal. For example, as important as the United Eastern and Tom Reed mines were as primary gold producers in the Oatman area (more than $27,000,000), the combined precious-metal value of the United Verde and Little Daisy (United Verde Extension) *copper* mines was almost twice as much. The Tombstone area has produced over $30,000,000 in silver, the largest primary silver district in the state, but it has also produced a very significant quantity of gold as well. The production of lead, zinc, silver, gold, and manganese, in addition to copper, from the Bisbee ores, has made this mining camp one of the most stable in the state. It has produced over $1,000,000,000 in metal.

An interesting sidelight to the discovery of the copper deposits of the Clifton-Morenci area is the story of Frederick Remmington. Remmington, a famous western artist, is reported to have lived and placered for about a year in the early 1870's at Gold Gulch, which is located on the southwest side of the present Morenci pit. In three weeks he apparently uncovered $6,000 in placer gold by removing rocks and boulders that covered a depression in which the rich gravel had settled.

Shifting Populations

While the miner may be recognized as the scout of civilization, his somewhat transient nature must also be acknowledged. Because of the rapid development and frequent exhaustion of certain ore deposits, particularly gold and silver, mining communities commonly flourished for a brief time and became ghost towns when the miners searched for more fertile ground.

In 1880, the federal records show that there were 4,678 miners, representing about 21% of the total number of working males. There were, scattered about the territory, seven copper mines, 232 precious-metal lode mines, two placer mines, 24 amalgamating mills. five arrastras, and one operating smelter. Substantial populations were found at the milling and mining villages of Charleston, Contention, McMillanville, Pinal City, and Tombstone.

The peak years of Tombstone were between 1882 and 1884, when the population was probably about 10,000. At this time the city may have been the most cultivated in the West. It was larger than San Francisco and certainly offered most cultural activities. When Cochise county was created in 1881, Tombstone was naturally selected as county seat. When the mines were initially flooded in the late 1880's, the miners and much of the populace left. By 1890, Tombstone was almost dead with a population of 1,875. Its satellite communities of Charleston and Contention were deserted.

McMillanville boomed with a peak population of about 1,500 in 1880 but by 1890, when the mines had played out, there was only one person left. The Silver King mill was located at Pinal which in the early 1880's is reported to have had a population of 2,000 people. This village rapidly disappeared, however, when the Silver King closed in 1888.

By 1890, other mining camps were becoming important population centers. These included Bisbee, Clifton, Arivaca, Harshaw, Reymert, Morenci, Congress, and Jerome. Among the male miners that year, there was one woman who gave her occupation as miner to the census taker.

Mine Contributions

Typically the principal contributions of mining during the years Arizona was a territory, were employment, payrolls, and taxes. Although individual or cumulative company wages are not known, the total income paid to miners must have been large. The total payroll was probably the largest within any one industrial segment of the territory. Employment as a percentage of the workforce varied widely, however, from year to year as changing economic conditions in the nation affected mine production and general employment at home.

According to the 1909 statistics, there were 18,094 miners working in Arizona Territory during that year. This number represented 21% of the total workforce. There were 251 producing mines. A year later, 1910, the United States Geological Survey reported that the territory contained 136 mining districts producing precious metals, copper, lead, mercury, and tungsten; gold was the chief product of 67 districts.

Obviously the relatively large number of mines and the high level of employment, along with substantial total income, had a major impact on the growth of Arizona. It has been reported that in the 50 years since Americans began mining in Arizona, through 1910, the total estimated value of metal production alone was over $600 million.

Taxes represented another major contribution of the mineral industry. This source of revenue collected by the government helped enormously in funding programs to build and operate schools, construct roads, dams, and other public works projects, and support various other territorial requirements.

In 1875, the Eighth Legislative Assembly enacted a law providing for the taxation of the net proceeds of the mines. Generally this amounted to two dollars for every $100 in net proceeds. This net proceeds tax was repealed six years later, leaving property and similar taxes in the hands of the county authorities. In 1884 the Territorial Auditor commented (in referring to the mines) that "the chief industry, the one without which our Territory is nothing" was not paying its fair share in taxes. The Auditor, in 1890, recommended the mineral industry help Arizona erase its more than $88,000-debt by assuming a renewed net proceeds tax of one percent.

By 1900 the net Territorial indebtedness had reached over $1,000,000 and pressure to reinstate additional mine taxes intensified. For years certain voters felt that mine valuations and assessments were too low in comparison to those assessments placed on the cattle and railroad industries. As an incentive to build, however, railroads were often extended tax exemptions for periods of 10 years or more. Eventually the 24th Legislative Assembly, in 1907, passed the Bullion Tax Law which levied a tax based on the value of a mine fixed at 25% of the value of its gross product.

The Fifteenth Legislature voted to move the capitol from Prescott to Phoenix and, in February 1901, the new Territorial Capitol was dedicated and occupied. It was built almost entirely of Arizona products. The foundation was constructed from malapai (andesite or basalt), reportedly mined from Camelback Mountain, between Phoenix and Scottsdale. Gray granite taken from the South Mountains, immediately south of the capitol city, comprised the building stone of the first floor. The upper stories were constructed of tuff quarried from a mine about two miles north of Kirkland, in Yavapai county. Recently, this porous rock has been mined, crushed, and marketed as a kitty litter.

POPULATION OF SELECTED ARIZONA CITIES

1880

As mining communities developed, particularly in the copper camps, a sense of permanence took hold. Families began passing their mining interests and skills on to the next generation. The mining companies played a more active role in the community by providing land and money to build hospitals, churches, libraries, fraternal organizations, YMCA's, YWCA's, and recreational facilities. They actively sponsored participation in the arts and in athletics.

Several examples of this often overlooked generosity should be mentioned. In 1903 the Phelps Dodge Corporation contributed 75% of the construction costs of the beautiful Herring Hall, the first gymnasium on the campus of the University of Arizona. A year later Phelps Dodge (through its subsidiary, the El Paso and Southwestern Railroad) and the Calumet and Arizona Mining Company donated over $37,000 to erect the YMCA building in Douglas.

Under the guidance of its owner, Senator William Andrews Clark, the United Verde Copper Company built a hospital in Jerome and employed a medical staff. The miner received free medical and surgical care; a small fee was charged for his family. A clubhouse was constructed, providing a large men's lounge containing pool and billiard tables, a ladies' lounge, a card room, a soda fountain, and a small ballroom.

In many of the mining towns, the companies attempted to make living conditions comfortable through construction of numerous facilities that were normally present only in or near larger metropolitan communities. The Old Dominion Company provided Globe with a well-appointed library. Youth activities were strongly encouraged and sponsored by the mining companies. The first YWCA in the territory was organized in 1908 in Bisbee.

Arizona's first natural gas line was brought into the copper smelter at Douglas at the turn of the century. This line was financed by a loan of $2,000,000 from Phelps Dodge to the small El Paso Natural Gas Company. Eventually El Paso was able to build a distributing network through the state.

State of Arizona

Population and Politics

On Valentines Day, February 14, 1912, the Territory of Arizona achieved statehood. Two years before, the 13th census of the Nation counted 204,354 persons living within Arizona's territorial boundaries; over 18,000 were miners.

In 1910 the largest cities were Tucson and Phoenix. (Phoenix overtook Tucson during the decade between 1910 and 1920.) The population of some important mining centers was as follows:

Arivaca	2,480	Lochiel	92
Bisbee	9,019	Lowell	4,356
Chloride	275	Mammoth	651
Clifton	4,874	McCabe	139
Congress	471	Metcalf	2,868
Copper Hill	521	Miami	1,390
Courtland	914	Mineral Park	71
Douglas	6,437	Morenci	5,010
Gleeson	600	Mowry	27
Glenwood	101	Oatman	168
Globe	7,083	Oracle	224
Golconda	198	Paradise	267
Goldroad	269	Pearce	517
Greaterville	130	Poland	117
Hackberry	84	Rosemont	68
Hayden	582	Silver Bell	1,721
Helvetia	454	Tombstone	1,582
Humboldt	525	Washington	132
Jerome	2,393	Wickenburg	570
Klondyke	334	Yucca	138

In 1912, the new state of Arizona had 445 active mines, including 51 placer gold operations. There were 72 concentrating facilities (with 4 arrastras) and 11 smelters. A gross value of over $67 million in minerals was produced. During that same year, the legislature created an office of the State Mine Inspector to establish and enforce mine safety standards.

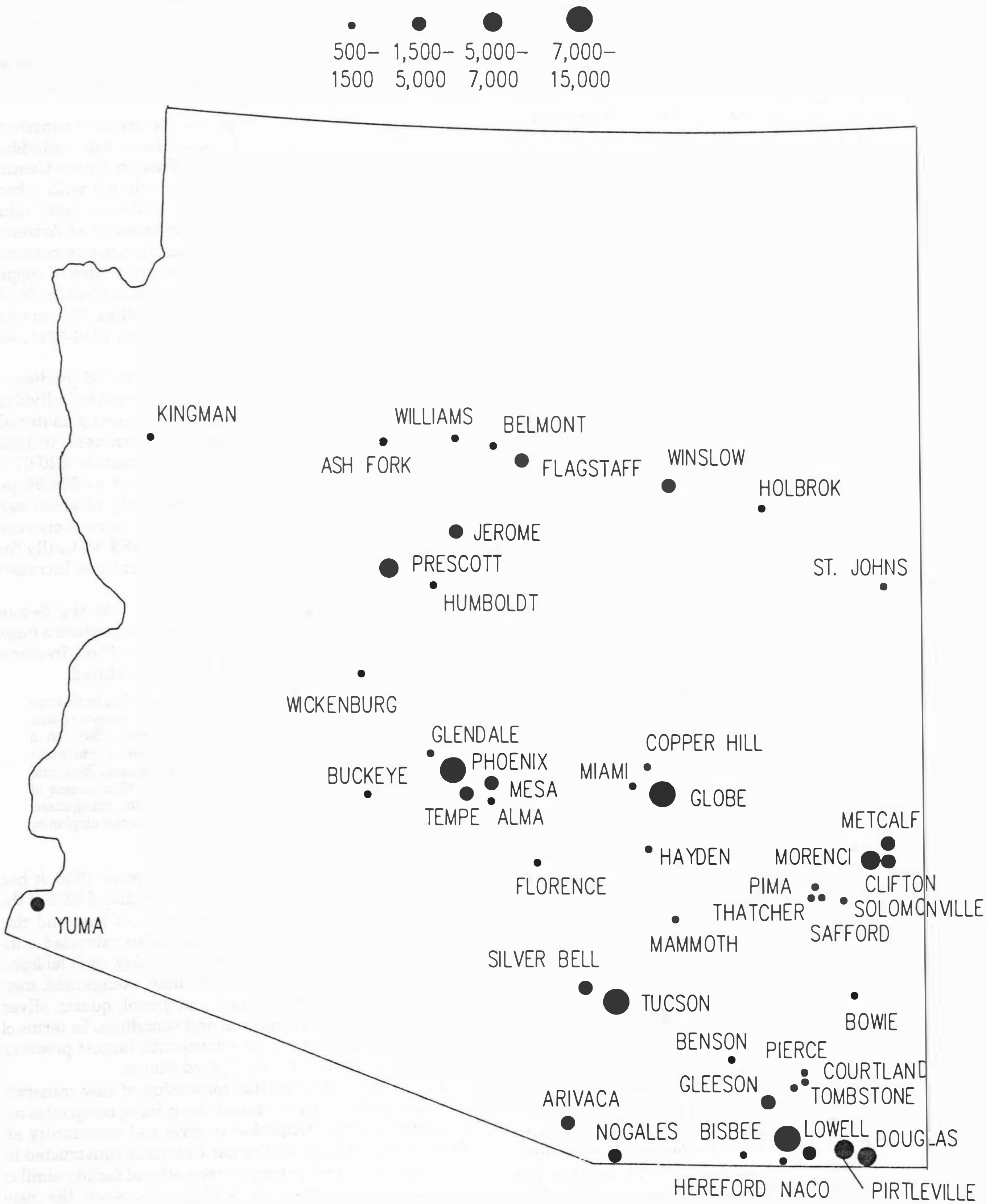
Establishing a new mining code to clarify the rules and regulations governing mine operations and a new mine taxation policy was a priority of the first state legislature. At the first session, the legislature repealed the Bullion Tax and for the next several years the politicians and the mining interests attempted to write an equitable law.

Pressures placed on the mines to produce more during World War I and the strong downturn in production and employment during the depression, created havoc with any set formula of taxation. Property valuations clearly got out of hand, however, when in 1918 the assessed value of all mine property went over $491,000,000, more than 58 percent of the total state valuation. (Meanwhile, the ostrich industry of Maricopa county, comprised of 832 ostriches, received a valuation of $7,335.) The 15th biennial report of the State Tax Commission (December 31, 1940) acknowledged the inherent difficulty in mine taxation when it said that mining property, always the largest and most valuable classification of property "is by far the most difficult on which to place a proper valuation."

A review of population statistics for Arizona's counties shows that, in general and except when a new county was created at the expense of others, from 1864 on, there was relatively steady growth. The most serious setback to this record occurred during the 1930's in the predominantly mining counties of Cochise, Gila, Greenlee, Santa Cruz, and Yavapai. As the price of copper slumped dramatically during the depression, most of Arizona's copper mines closed down or drastically curtailed production. In 1929 over 830 million pounds of copper had been produced, but in 1933 the copper produced had dropped to just over 114 million pounds. The total value of mineral production in the state was the lowest in 38 years.

Because it is generally easier to restart operations at an open-pit mine than it is at an underground mine, the deep, relatively high-grade mines were the only copper producers kept open in 1933. The three that operated were the Copper Queen at Bisbee, the Magma at Superior, and the Little Daisy at Jerome. Unemployment in Arizona was severe and miners looked elsewhere for work. During the 1930's, Cochise county lost over 15% of its population. (Ironically, in 1939, in part because of the tremendous outpouring of copper and other metals, Bisbee became the county seat in place of moribund Tombstone.)

Gila county experienced a 23% decline in population during the depression and Greenlee county suffered the



POPULATION OF SELECTED ARIZONA CITIES

1910

4-15

largest reduction by losing over 43% in the 20-year period between 1920 and 1940. During these two decades, Santa Cruz county lost over 25% of its population; Yavapai county lost nearly 7% of its residents during the thirties. The five counties described lost almost 17,000 inhabitants between 1930 and 1940.

By 1940, the aggregate population of Arizona was just shy of a half million. Continuing an unabated trend, Tucson and Phoenix had grown substantially larger than other towns and the number of significant mining communities had begun to decline. Some of the more important mines were located in the vicinity of the towns listed:

Ajo	3,049	Miami	4,722
Bisbee	5,853	Ray	2,454
Clifton	2,668	Superior	2,526
Globe	6,141	Tombstone	822
Jerome	2,295	Wickenburg	995

During the period, 1912-1940, the state legislature continued to recognize the importance of mining by creating first, the Arizona Bureau of Mines in 1915 and second, the Arizona Department of Mineral Resources in 1939. The Bureau of Mines, housed at the University of Arizona, provided the mineral industry valuable research data in geology, mining, and metallurgy. The Department of Mineral Resources assisted the small miner with his mining and marketing problems and acted as a liason in exploration projects and mine financing programs.

During this same period the Arizona Small Mine Operators Association (ASMOA) was founded to provide a unified organization that could represent the independent miner before the legislature and offer a vehicle for the exchange of technical experience. For a while Charles F. Willis, a mining engineer and former publisher of the *Arizona Mining Journal*, was its executive secretary and editor of its monthly journal, the prestigious *Pay Dirt*.

Mine Contributions

During its initial year (1912), the state ranked first among all states in the production of copper, producing 29% of the nation's total output. Its ranking in silver production was sixth place, seventh in gold. Additional metal and mineral production included lead, zinc, tungsten, semiprecious gem stones (particularly chrysoprase), clay, gypsum, lime, quartz, sand & gravel, and stone.

Important mines operated during the early years of statehood, prior to WW II, included:

Bagdad	Magma	Oatman area
Bisbee area	Mammoth area	Octave
Commonwealth	Miami area	Old Dominion
Iron King	Montana	Ray
Inspiration area	Morenci	Silver Bell
Jerome area	New Cornelia	Tombstone

The two principal mines of the Jerome area, those owned by the United Verde and the United Verde Extension companies, will be remembered for their longevity and their richness. The United Verde deposit was mined almost continuously from 1883 until 1974, and the two copper mines combined have contributed over 10% of the gold and silver produced in Arizona. The total estimated value of production exceeds $600,000,000; truly the United Verde was one of the world's greatest copper mines.

The largest single, primary producer of gold in Arizona was the United Eastern. Its total metal value was more than $14 million. When other properties, including the Tom Reed, Goldroad, Moss, and Telluride, are considered, the Oatman area produced over $35 million in gold and a minor amount of silver.

Tombstone deposits comprised the greatest concentration of primary silver in the state. Important individual mines were the Contention, Good Enough, Grand Central, and Toughnut. These properties, combined with others, have been responsible for over $40 million in metal value.

During the First World War, the capacity of Arizona's mines was relied upon heavily to supply the raw resources for armaments and materiel. A secure source of copper, lead, zinc, and other metals was a vital ingredient in the eventual defeat of Germany and her allies. The production of copper alone during the war years, 1914-1918, was over three billion pounds.

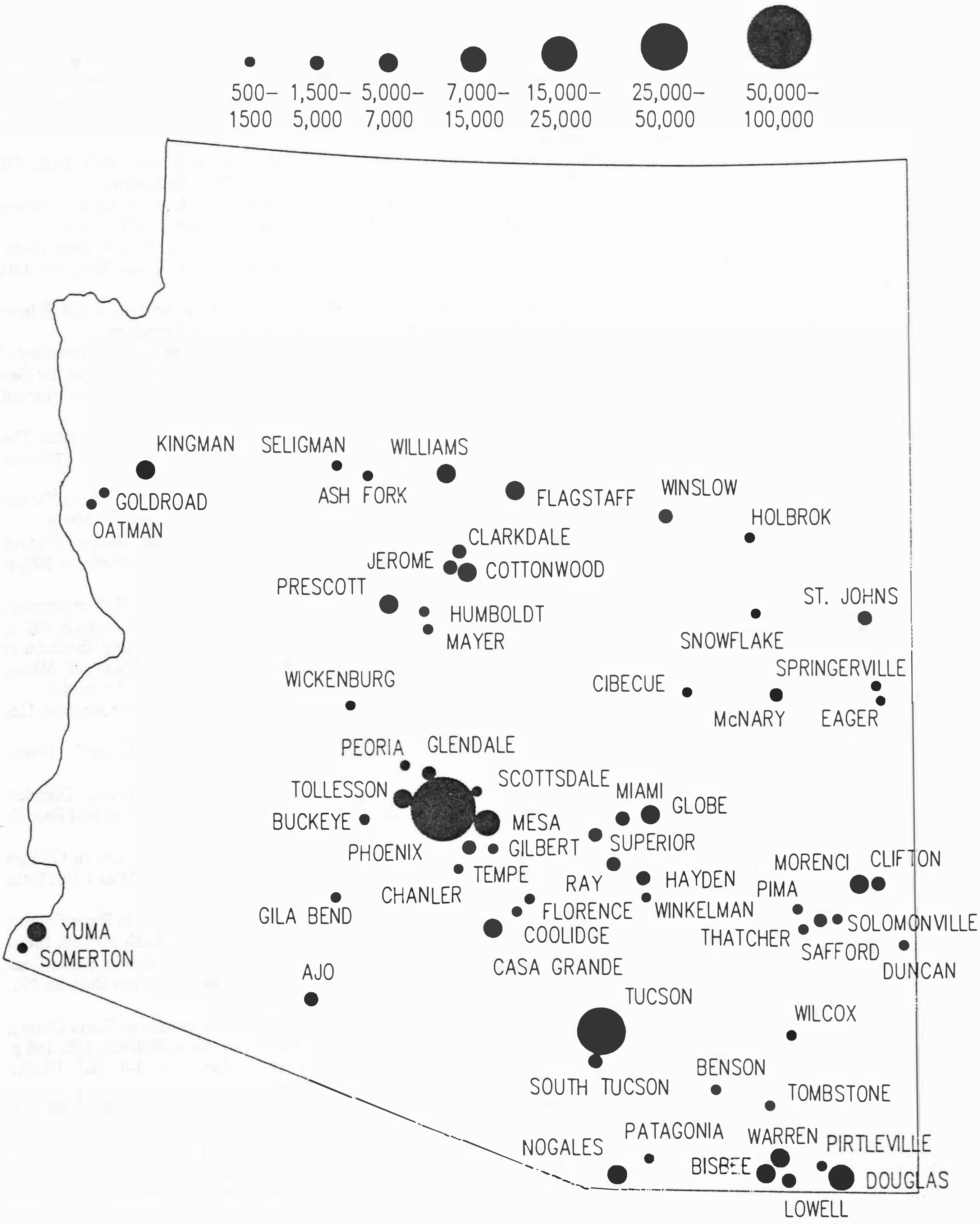
When the major mines closed or curtailed production during the depression, many miners turned to individual operations for their livelihood. Gold-bearing materials were eagerly sought as the federal government, in 1933, raised the price of gold from approximately $20.67 to $25.56. In 1934 the price was increased to $34.95 per ounce. By 1933, the number of mines, many of which were operated by the small miner, producing silicous ores containing gold, and placer gold, reached 489, virtually five times the number in 1929. Placer operations increased from 22 to 179.

As events began to lead the nation into the Second World War, Arizona was again expected to produce a major share of the required mineral materials. The Director of the U.S. Bureau of Mines, R.R. Sayers, stated:

> "Events in 1940 have demonstrated again that in this age of mechanization minerals are indeed the sinews of war. The British have shown that valor can offset, to a remarkable extent, the advantages of superior armament and munitions; but the experience of Finland, Belgium, Greece, and others have revealed the ineffectiveness of heroic men against an avalanche of iron, manganese, aluminum, and petroleum utilized in tanks and airplanes, bullets and bombs."

Arizona was prepared for the challenge. In 1940, it had 1,300 metaliferous mines, alone, and produced 31% of the nation's copper. Its combined production of lead and zinc was the largest on record. The state also extracted antimony, arsenious oxide, asbestos, barite, clay, coal, feldspar, fluorspar, gem minerals, gypsum, lime, manganese, mercury, mica, molybdenum, sand and gravel, quartz, silver, gold, sulphuric acid, tungsten, and vanadium. In terms of gross value, Arizona was the fourteenth largest producer of mineral products in the United States.

Aside from the beneficial conversion of raw minerals to useful products for mankind, the mining companies accelerated their participation in civic and community affairs. The United Verde Copper Company constructed in Clarkdale, the smelter town, a recreational facility similar to the one in Jerome. In addition, however, the new clubhouse contained an auditorium which was often used as an opera house, plus a bowling alley and a theatre. The company provided four swimming pools, several ten-



POPULATION OF SELECTED ARIZONA CITIES

1940

4-17

nis courts and baseball fields, and a golf course.

Recently an engineer, raised and educated in the Northeast, expressed his opinion that his wife, who grew up in the comparatively small town of Bisbee, received a superior education. Her fine education can be attributed primarily to the policy of those early mining companies to provide good schools, excellent teachers, churches and other amenities commonly found in metropolitan areas. This environment attracted employees of high caliber to the isolated mining camps.

Hospitals were built and modernized; libraries and recreational facilities were constructed and equipped; and stores were stocked at reasonable prices. In many cases, affordable, comfortable homes were built by the mining companies. The Miami Copper Company built the local YMCA facility and for years provided the funds to maintain it. Baseball leagues were sponsored and invited to use the company ballpark.

As of 1912, when the El Paso and Southwestern Railroad reached Tucson, the city had subscribed $60,000 towards purchase of a right-of-way and station grounds. The parent company, Phelps Dodge, however, returned the money and urged the city to use it in the construction of a YMCA building. This firm and others donated land for post offices, court houses, schools, men and women's organizations, churches, scouting facilities, fire departments, airports and cemetaries.

Numerous cash contributions, amounting to millions of dollars, have been made to a wide variety of organizations. All the major companies, including ASARCO, Inspiration, Magma, Miami, and Phelps Dodge have supported scholarship programs since before World War II. As an example of its commitment to higher education, Phelps Dodge in the early 1940's, funded 100% of the construction of the impressive College of Mines and Metallurgy Building at the University of Arizona.

Mining has assumed a major role in Arizona history. Initially, the Indians and Spainards caught a glimmer of Arizona's potential mineral wealth. Later, the Americans utilized this natural abundance to build a nation.

The early American prospectors began with simple dreams and enthusiasm, and their efforts prompted the creation and settlement of the territory. The influence of mining in the state became pervasive and it has been recognized in such place names as Poston Butte, Ehrenberg, the Grosvenor Hills, Bronco (Brunchow) Creek, the Weaver Mountains, Peeples Valley, Mowry, and Brady Peak. The individuals for whom these localities are named are to be remembered as pioneers not only in mining, but in a broader sense, as visionary developers of Arizona.

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Appendix 5

Early History of Mining in Arizona
Acquisition of Mineral Rights 1539-1866

by John C. Lacy

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Chapter 1
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Chapter One

Early History of Mining in Arizona
Acquisition of Mineral Rights 1539-1866

Introduction

Arizona provides an unusual historical case study of its mineral development through mineral laws. The first Spanish explorers did not necessarily come to the portion of this country that came to be known as Arizona out of a love of adventure but were driven by a promise made by the mineral laws that one could keep at least a portion of any mineral riches that might be found. As time progressed, however, the legal foundation of laws were frequently unclear or non-existent and laws enacted by ad hoc self-governing groups often premised their enforceability on as little as local consensus.

The activities taken in compliance with the 1536-1550 ordinances of Viceroy Mendoza, the regal codes of 1584 and 1783, gold rush mining district regulations, and the 1864 Arizona territorial mining code are an important source of information about early mining activities because in many instances the only lasting tracks left by the early miners are markings on the ground or public records made in compliance with these laws.

The Spanish Dominion

The Codes of Viceroy Mendoza

The story of mineral exploration in Arizona begins with the odyssey of castaway Alvar Nuñez, known to history as Cabeza de Vaca, who, along with a Moroccan slave known as Estebanico and two others, were marooned when the expedition of Panfilo de Narvaez was destroyed by weather and hostile Indians as the group was attempting to establish a Spanish colonial foothold in Florida in 1528. Cabeza de Vaca and his companions endured an eight-year journey of hardship and captivity during which time they followed the Rio Bravo del Norte (now called the Rio Grande) perhaps into present-day New Mexico, then crossed northern Mexico to the outposts of New Spain near Mocorito, on Mexico's west coast in early 1536.

Nuñez told many stories of strange lands and of several instances where metals and precious gems were being used by the Indians. More significantly, he claimed that Cibola, the legendary seven cities of gold, lay to the north in what is now Arizona. This story was repeated to the Viceroy of New Spain, Don Antonio de Mendoza, in Mexico City on July 23, 1536. Viceroy Mendoza was a practical man and played the story down while attempting to get members of the party to retrace their steps on his behalf. When all refused, Mendoza bought Estebanico and sent Marcos de Niza, a Franciscan friar, to Arizona to investigate the story.

In March of 1539, Niza, Estebanico and a small party of support personnel traveled north through the Santa Cruz Valley to the Gila River and then continued through *Apacheria* to the land of the Hopi in northern Arizona. There, Estebanico was killed by Indians and Niza aborted his mission. For reasons known only to Niza, he reported sighting the seven cities of gold in Hopi land. Thus, based on Niza's report, and a second inconclusive report from Melchior Diaz and Juan de Zaldivar, Viceroy Mendoza authorized an expedition to be undertaken by Francisco Vasquez de Coronado. The expedition left Compostela, the capital of New Galicia, on February 23, 1540.

This authorization by Viceroy Mendoza was critical because inherent within this license was the right to keep the riches that might be found during the expedition subject only to the return of one-fifth of the find to the crown. Coronado was seeking hoarded treasures but the possibility of finding and claiming mineral deposits must have also been on his mind. The Spanish mining law of the day was based on decrees of Alfonso XI in 1385 and Juan I in 1387 proclaiming that all minerals belonged to the crown and could be worked only by a special license which specified that profits would be split two-thirds to the crown and one-third to the miner. In 1504, the right to operate mines was extended to all Spaniards in the New World, provided that their claims were registered and that one-fifth of production was paid to the crown. It was not until 1532, however, before rather vague local implementing regulations were issued by the governing council of New Spain, the *Audencia* of Mexico City. These regulations were superseded by Viceroy Mendoza's own regulations in 1536. Viceroy Mendoza also issued a supplement to these regulations in 1539 related to the registration and exploitation process, and thus, the timing of Coronado's departure may have been influenced by the mining laws.

The existence of a mining law notwithstanding, Cibola turned out to be a pitiful group of mud huts and the only mineral values that Coronado could show on his return after more than two years of travel were some copper ornaments from the chief of the Witchitas and an abundance of turquoise jewelry used by the Zuñi along the upper reaches of the Rio Bravo.

In 1548, Philip II issued the *Ordenanzas del Nuevo Cuaderno* that for the first time clearly applied the laws of Spain to its New World colonies and gave the viceroys authority to issue implementing ordinances as required by local circumstances. Based on this authorization, the first comprehensive mining ordinance for the New World was issued by Viceroy Mendoza on January 14, 1550. This law contained 49 separate provisions and was apparently Viceroy Mendoza's attempt to codify the existing royal pronouncements as he understood them in the framework of a practical mining code for use in New Spain. The essential process was as follows: The discoverer of a mineral deposit was permitted a single claim of 80 varas (a vara is approximately 32 inches) along the strike, or length on the surface, of the vein and 40 varas across the vein. All claims registered after the original discovery were restricted to a smaller claim of 60 varas along the vein and 30 varas across. Each miner was prohibited from having more than two mines within 1,000 varas of the original discovery except by purchase. The original locator had 15 days within which to register his find, the failure of which resulted in the loss of the right to the larger claim. In the case of conflicting claims, the first to register the claim became the owner and where the requests for registration were simultaneous, the claimants were required to draw lots.

After the registration process was complete, the claim holders were required to sink a shaft of three estados (or approximately 18⅔ feet) within three months, and the claim boundaries were required to be marked with stakes of one-half vara in height together with posting of a notice on the claim. The failure to erect these monuments carried a fine of ten pesos (a peso at the time contained approximately three-quarters of an ounce of silver).

Other articles specified the work requirements to maintain the claim and required reports to the viceroy to permit him to monitor the level of mining activity. If a mine was not worked for one year, it was subject to forfeiture under a procedure of "denouncement" of an abandoned mine. Essentially, the petition of denouncement had to be read after mass in the largest church in the vicinity of the mine for four successive Sundays. The petitioner was then required to deepen the discovery shaft an additional three estados within the next three months. The absent owner could however, still appear during the three-month period and reclaim his mine. One suspects that denouncement may have been a risky process. Other provisions of the code included the requirements for working by companies, labor laws, licensing requirements for mining operations and a prohibition against public officials owning any mine or participating as a member of a company owning mines within his jurisdiction.

While the royal prerogatives dealt with general principals recognizing the general rights of the miners and specified the amount of royalty, it was the specifics of Viceroy Mendoza's ordinances that formed the basis of the practical operation of the mining laws of New Spain. However, where conflicts existed, Viceroy Mendoza's code, as late as 1577, was determinative in lawsuits in New Spain in spite of the fact that Doña Juana, as a regent in the name of Philip II in 1559, and Philip II himself in 1563, had issued specific regulations.

It was this state of legal uncertainty that was faced by the next Arizona prospector, Antonio de Espejo. Espejo's rights were further in doubt because all entries into the northern regions of New Spain could only be made with the express permission of the king. Espejo, however, took advantage of a distress call from Friar Agustin Rodriguez, the leader of a franciscan *entrada* into New Mexico in 1581 in search of converts (and silver if they were lucky). Espejo was undoubtedly influenced by reports of soldiers on the Rodriguez expedition of the discovery of mine prospects containing rich silver. In March of 1583, Espejo commenced a rescue mission on doubtful legal authority. Espejo quickly determined that Friar Rodriguez and his companions had been killed, and turned his attention west to the central mountains of Arizona. On May 8, 1583, some writers believe Espejo may have found the rich deposits of Jerome, but most believe he was considerably to the west. In Espejo's own report he stated that "with my own hands I extracted ore from them, said by those who know to contain much silver." Espejo did not attempt to make any official claim to these deposits for himself (probably because of questions raised upon his return regarding the authorization of the trip), but in a petition to the viceroy and the king subsequent to his return, he indicated that some sort of priority was being requested. In spite of the presence or absence of any official claim, however, Espejo's find does not appear to have been worked by the Spaniards, probably the result of the distance to any real civilization, the fact that it was in hostile Indian territory and that substantial mines had been recently discovered in Zacatecas and Durango.

The 1584 Regal Ordinances

When Philip II, on August 22, 1584, promulgated the first comprehensive mining code applicable throughout the Spanish Empire, he wanted to stimulate the Spanish economy and thus wanted a practical law that would be accepted by the miners. Not surprisingly then, it was Viceroy Mendoza's ordinances that formed the basis of the new code. The code contained a remarkably broad grant of rights that granted to the discoverer the right to work mines as their own "possession and property . . . observing, both in regard to what they have to pay us [this is the royal 'we'] by way of duty, and all other respects, the regulations and arrangements, ordered by this edict . . . " This right was characterized as a "direct and beneficial grant of property; and is to be regarded as a qualified gift."

Under these ordinances a miner had 20 days within which to register a mineral find with a local mining justice or in his absence the local *alcalde*. The size of the first (or discovery) claim was 160 varas by 80 varas and could be situated either along or across the vein. The discoverer was not limited in the number of claims he could stake on the same lode, but any claimants after the first discovery were limited to two claims of 120 by 60 varas, each of which had to have three claims between them.

Claims were perfected through the sinking of a shaft or "trial pit" to a depth of three estados which had to be sunk within three months of the original date of registration.

Very clear work obligations were imposed by these ordinances and required the owners of a claim to keep four people working on a mine at all times. If the work was not performed for a four-month continuous period, the mine would be forfeited and in order to maintain rights the owner would be required to file a new registration. After such a default the mine also became subject to "denunciation" by third parties.

The royalty rate, although frequently referred to as the *quinto* or "kings fifth," was, in the case of silver, based on a sliding scale depending on the recovery rate from the ore per *quintal* (101.45 pounds) of ore mined, e.g., 12 ounces or less, 10%; 12 to 32 ounces, 20%; 32 to 48 ounces, 25%; and more than 48 ounces, 50%. Separate provisions required a royalty of $\frac{1}{30}$th for copper, $\frac{1}{10}$th for antimony and one-half for gold. The royalty varied considerably by administrative practice in subsequent years and normally ranged from one-eighth to one-half.

Nowhere in the new ordinances did diligence play such an important part as in the rights of the miner to pursue a vein underground outside of the boundaries of the claim as marked on the surface. Thus, these ordinances constituted the first application in the New World of right to pursue a mineral vein outside the side boundaries of an individual claim, the so-called "extralateral" right. The ordinances stated that if the vein was continuous, the miner could pursue it at depth outside his surface boundaries and was permitted to raise ore from the mine until the owner of the adjacent claim could extend his works to meet the operations. At this point, the first operator was required to withdraw but was not required to return any of the minerals mined. Thus, although the grant of the extralateral pursuit was not a grant of the ownership of the vein itself, it was a defeasible right that could only be stopped by the actual mining activity of the adjoining owner. Not surprisingly, this provision led to disputes.

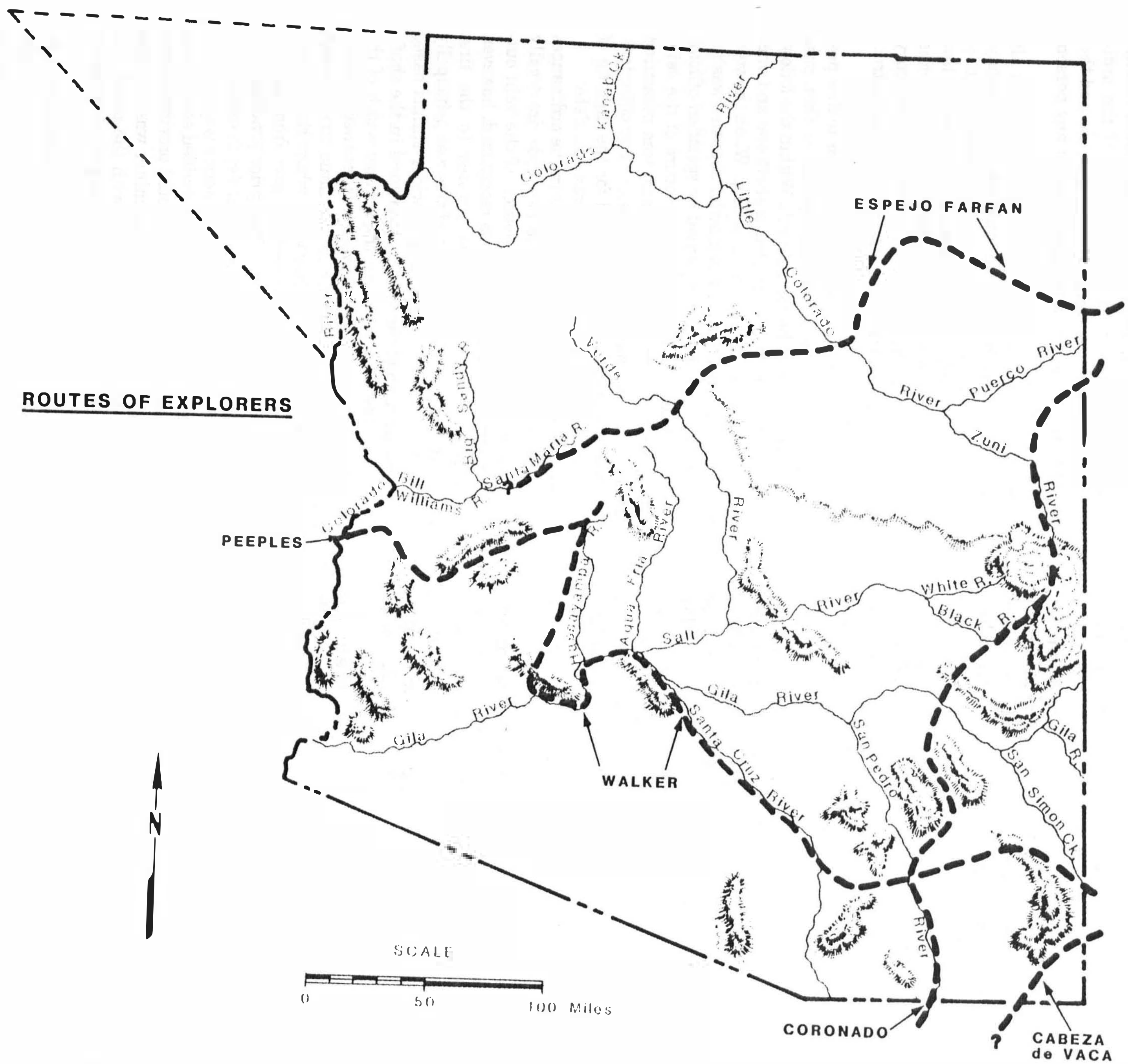
It was under the auspices of these ordinances that the next prospecting expedition came into Arizona. The expedition was ordered by Juan de Oñate, then the new governor of New Mexico. Oñate had been awarded the contract for the conquest and settlement of the pueblo country and established the first seat of government at San Juan, near the present site of Santa Fe, New Mexico on August 18, 1598. Oñate knew mining well as he was the son of a wealthy miner, and in November of that year, made a mineral exploration swing to the west into Arizona in search of Espejo's silver discovery. As a part of this effort Oñate commissioned Capt. Marcos Farfan de los Godos to take eight men and relocate the mines. Farfan traveled from the Hopi land of northern Arizona through the Chino Valley and along the mountain ranges and valleys of west central Arizona. At a site that may have been somewhere along, either the Big Sandy River or the Bill Williams Fork, Farfan's men located from 66 to 72 mining claims and returned to Santa Fe with rich specimens of silver ore. These claims were located in four separate groups one of which was near an old shaft developed by the Indians for paint and seemed to correlate with Espejo's story. There is no evidence that Farfan's mines were ever worked or even that the required acts of location were followed. Since Farfan returned to San Juan in December, it seems improbable that even one or two, much less 60, 18-foot shafts could have been dug.

During the two centuries under the 1584 Ordinances, Arizona was in an administratively territorial status called *Pimeria Alta* and loosely attached to either the State of New Mexico through Santa Fe or Sonora through Parral or Arispe. Whoever had jurisdiction over the area of Arizona, however, the truth of the matter was that mining activity during the period of the 1584 Ordinances was probably minor. This is suggested by the complete lack of documentation evidencing the registration of mines or the registration and shipment of ores from any mines within the area as would have been required under, the 1584 Ordinances. Father Eusebio Kino, Southern Arizona's most prominent explorer and observer from 1687 until his death in 1711, noted in his writings that there were a number of mines along the Santa Cruz Valley and it was thus possible that some Southern Arizona ores were finding their way into the unregistered black market for silver. This seems unlikely, however, as the level of activity that would have been necessary to make such an operation profitable would have most certainly been detected. One mineral discovery, however, would leave a lasting impression.

In 1736, Antonio Siraumea, a Yaqui miner, discovered a deposit of native silver a short distance southwest from the present Nogales, Sonora, at a site variously known as "Arizonac," "Arissona" or "Aruzema." The discovery came to be known as the *planchas de plata* (planks of silver) creating a rush of miners into the area and providing the probable source of the name of the state. The size of the find varied (according to whose report is to be believed) but ranged from 300 to 3,600 pounds. The crown immediately looked into the possibility of declaring this particular find an exceptionally rich mine that should be considered royal property. Capt. Juan Batista de Anza was dispatched to make an official inspection. These efforts to exercise official control over the deposit finally resulted in an order of the viceroy in 1741 closing the area and the eventual legal determination that the deposit was a curiosity and thus not covered by the ordinances. There were, however, no other circumstances where a similar position was taken and a legal treatment of the *planchas de plata* taken by the viceroy was specifically overruled in the 1783 code. This "change" of the law was probably a recognition of the impossibility of enforcement, as in case of the *planchas de plata*, even after the authorities seized the deposit and with no official working, the deposit nonetheless disappeared within a very short time with the ores undoubtedly fed into a thriving black market for contraband silver bypassing the royalty collectors.

The 1783 Regal Ordinances

During the latter part of the 18th century, it became obvious that changes were required in the mining laws of New Spain.The most difficult problem that faced Mexican jurists concerned the identification of the applicable legal authority to work the mines. The 1584 Ordinances provided the basic source but this law had application throughout the Spanish Empire and the law of the Indies had directed that the 1584 Ordinances would be observed



Routes of the Mineral Explorers. Routes of the mineral exploration *entradas* beginning with Alvar Nuñez and ending with the Peeples Party.
Illustration by Rick R. DuPont.

5-5

only in those countries where it was not at variance with the municipal laws of each province. The laws applied in the Spanish colonies were issued in the form of *cedulas, decretos, resoluciones, ordenamientos, reglamentos, autos acordados,* and *pragmatics* each of which had different weight under different circumstances. It was thus not surprising that authorities had considerable difficulty determining what law to follow. In 1680, the famous *Recopilacion de Leyes de los Reinos de las Indias* was published in an attempt to provide a digest for the laws in force in the Indies. However, in the case of the mining law, neither the 1584 Ordinances nor the local ordinances were included in the digest. Francisco Xavier de Gamboa, a Mexican jurist finally charted the path of the various mining laws in his *Commentarios a las Ordinanzas de Minas* published in 1761. Charles III agreed with Gamboa's views and specifically permitted the publication of the work. Principally as a result of Gamboa's commentaries, Charles III promulgated a new code of mining ordinances applicable only to New Spain on May 26, 1783.

The location procedures established by the 1783 Ordinances were not dramatically different from the 1584 Ordinances although the provisions were refined significantly. This law survived the Mexican Revolution that began in 1810, and would remain the mining law of Mexico until repealed with the passage of a mining code by the Mexican Republic in 1884. It was thus the law of the land at the time the Mexican States of California, New Mexico, Texas, Northern Sonora and the northern territorial claims were carved out of Mexico and added to the United States by the Treaty of Guadalupe Hidalgo in 1848 and the Gadsden Purchase in 1853.

The new code provided an elaborate system of organization in a tribunal of miners who were elected at a convention with each mining town being represented by delegations of locally elected deputies. The allocation of representatives was based on the size of mining operations within the various districts. It was the duty of the tribunal, through the Royal Tribunal General, to provide the communication between the miners and the king by way of an annual report to the viceroy. In addition to the annual report, the tribunal could also bring matters to the attention of the viceroy at any other time when it was deemed necessary.

The officials within this organizational structure, beginning with the various territorial deputations, were vested with the power to decide all matters concerning the management of the mines, including matters arising out of discovery, denunciation, rights of property drainage, desertion or destruction of pillars. The law specifically directed that all disputes would be handled summarily "without any of the usual delays and written declarations, or petitions of lawyers . . . " This clear expression of aversions to lawyers went back to 1520 when Hernando Cortez, with royal permission had prohibited "attorneys and men learned in the law" from setting foot in New Spain on the ground that experience had shown that they would be sure by their evil practices to disturb the peace of the community.

The basic grant to the miners was stated as follows:

> Without separating them from my royal patrimony, I grant them to my subjects in property and possession, in such manner that they may sell, exchange, or in any other manner, dispose of all their property in them upon the terms of which they themselves possess it . . .

The grant was subject to two conditions; first, that royalty be paid and second, that the operations would be conducted in accordance with the provisions of the ordinances. Any default was considered a forfeiture and the mine was then subject to a further grant to any person who denounced it.

In addition to gold and silver, the law applied to all precious stones, copper, lead, tin, quicksilver, antimony, zinc, bismuth, rock salt and other fossils. The application to mercury was a substantial extension from earlier law as mercury had been very tightly controlled as a means of controlling black market activities because mercury was essential in the amalgamation process for the extraction of gold and silver.

The registration process required the locator to first present a statement to the territorial deputation, then post a notice on the door of the local church. Within the following 90 days the locator had to sink a shaft one and one-half varas in diameter and ten varas deep. When the vein was thus ascertained, one of the district deputies was required to visit the site accompanied by specified official witnesses to determine the physical nature of the vein. At the time of the inspection, the claim was measured and its boundaries marked by the locator. If no objections were raised during the 90-day period for the digging of the shaft, the locator's registration was complete.

One of the more interesting changes in the ordinances related to extralateral rights. The new code drastically limited the earlier rights of possession of the vein outside the surface boundaries. It was recognized, however, that certain rewards should be granted to the first discoverer of an "inclined" vein, and this was principally done by permitting the granting of wider claims based on the declination of the vein as measured in the shaft. If the vein was perpendicular, the surface width of the claim was 100 varas but if the vein was inclined, the surface was measured according to a formula that allowed the locator a width of up to 200 varas where the declination of the vein was 45 degrees or more from perpendicular. Further, as a hold-over from prior practices, the miner was permitted to work a vein at depth outside the boundaries of the claim only if prior notice was given to the adjoining owner and profits were divided equally until such time as the adjoining owner could provide his own access, at which time the adjoining miner was required to withdraw. The failure to comply with the notice and sharing provisions would result in trespass damages of twice the value of the ores taken.

The law went on to provide elaborate mechanisms for working of the mines including safety, flooding and mine drainage, provisions regarding joint operations of mines and the disposition of disputes, labor laws (including, for example, prohibitions against paying miners in merchandise, a requirement to pay extra wages for working in hard ground, protection from excessive garnishment of wages, and even protection from some forms of imprisonment), environmental protection, infrastructure, processing and marketing of ore, financing of mining operations, accreditation of mining officials and mining education.

The mining activities in Arizona under the 1783 Code were sporadic to say the least. There were several reasons for this. The priesthood, the only permanent residents of the area other than Indians, was prohibited from registering and working mines and Arizona was still a long way from supply lines of Mexico where other richer silver deposits continued to be much more accessible. There was a period, however, between 1790 until approximately 1820, when a relative calm in the never-ending guerrilla war between would-be colonists and the Apache permitted a foot-hold in southern Arizona by Mexican settlers. It is doubtful, however, that mining activities during this period included anything beyond the narrow region adjacent to the Santa Cruz Valley.

There were, however, some specific references to mining during this time. The mineral deposits at Ajo were supposedly discovered in 1750 by prospectors from the missions. When the site was visited by trapper Tom Childs in 1836, he reported the existence of a 60-foot shaft, suggesting that the initial 10-vara location requirement had been satisfied, and the shaft deepened as a result of a subsequent denouncement. Prospectors from the missions supposedly also conducted mining activities at Quijotoa and Aribac or Arivaca in the 1770s, and one account refers to workings at Quijotoa, Cababi and Calabasas where a few individuals eked out an existence mining gold as late as 1828. Possible independent confirmation of mining at Arivaca exists with a listing of 20 mines in a deed by which the ranch at Arivaca was conveyed to American entrepreneurs in 1856.

The Dominion of the United States of America

The "Spanish" Laws

During the war between the United States and Mexico the territory of Arizona fell under United States dominion with the capture of Santa Fe by the United States Army of the West led by Gen. Steven Watts Kearny. On September 22, 1846, a code of laws was issued by General Kearny's military government that adopted the common law of England but with the proviso that all prior laws "not repugnant to or inconsistent with the constitution of the United States and the laws thereof or the statute laws in force for the time being, shall be the rule of action and decision of this territory."

Such a provision proved scant guidance for the miners because without an express provision adopting the mining laws of Mexico, there was no real assurance that the Mexican mining laws were not repugnant to the laws of the United States. In an effort to clarify the situation, the legislative assembly of New Mexico Territory, during its first session, memorialized the Congress of the United States on July 7, 1851, to pass laws "that the laws of Mexico on the subject of mines and mining be declared and perpetuated." No such action was forthcoming from the United States Congress and the miners, therefore, did pretty much as they pleased.

In the western part of New Mexico Territory, even then called Arizona, the search for the *planchas de plata* continued. Tom Childs, after his initial trip to Ajo, introduced his copper discovery to Peter R. Brady who in turn obtained the interest of George Bartlett, the first boundary commissioner, who perpetuated the story in his 1854 boundary survey report. Brady, it should be noted, returned to Ajo in 1854 and organized the Arizona Mining and Trading Company, the first American enterprise in Arizona engaged in mining. Brady reported that 17 mining locations were made in 1855 after it was determined on what side of the border the mine was situated.

Finally, in 1854-55, Charles D. Poston, who would eventually become known as the "father of Arizona" because of his efforts to sever Arizona from New Mexico Territory and admit the area as a separate state, along with Herman Ehrenberg, a German mining engineer, came upon the scene in search of the *planchas de plata*. While Poston may have been pursuing a rather nebulous mineral occurrence, the public records clearly show that he was concerned about the legalities of what he might find and believed that absent any clear legislative action by the United States the laws of Mexico were applicable. Thus, since no public official, or anything even close to an *alcalde* existed in southern Arizona he arranged to have himself appointed as the assistant clerk of Doña Ana County. This appointment was good enough for him to consider himself as such an officer and he acted accordingly as a combination recorder and justice of the peace for Southern Arizona.

Poston and his party never did find the *planchas de plata* but did find silver in the Santa Rita and Cerro Colorado Mountains. The first mining claims located by Poston and his associates (recited as Frederick Brunckow, Charles Schuchard, Herman Ehrenberg, Theodore Moohrmann, George W. Fuller, Samuel N. Heintzelman, Edgar Conkling and William Wrightson) were the Salero, Heintzelman and Arenia mines on February 1, 1857. The shafts on the claims were recited in their notices to have been dug to 30 feet (adopting the 10 vara requirement with the exception of the Salero mine which recited a shaft of 80 feet) and recorded in books maintained by Poston in his "official" capacity as being located "under the laws of Mexico or of the United States" to cover all bases. Poston apparently never considered the proscription under the Spanish laws of ownership by public officials.

In addition to the claims staked by Poston and his associates, eight other claims are shown in the public records of New Mexico Territory as being located in Southern Arizona from the time of the Gadsden Purchase until 1862. Two of these claims were 18 miles south of Fort Buchanan (possibly the mine eventually acquired by Sylvester Mowry), one near Dragoon, one 30 to 40 miles east of Sacaton Station (possibly near Ray) and four "10 leagues (the Spanish *legua* was 1/25th of a degree of latitude or about 2.6 miles, but a days journey on horseback was considered to be seven leagues) from Avivaca toward Papago country."

The lack of clear opinion as to the applicability of either the laws of Mexico or the United States in the location of mining claims was also evident from the public records of Doña Ana County, which included that portion of the lands acquired from Mexico under the Treaty of Mesilla (which we know as the Gadsden Treaty), where the miners attempted to cover all bases. The typical mining claim recorded during 1852 through 1863 recited that it was being staked:

> . . . according to the Mexican mining law which we believe to be in full force in this territory but should it at any time appear that said laws are not in force, then in that case we would wish to hold the same under the preemption laws of the United States.

The "Mining District" Regulations

While Poston and his associates looked to the organization of a new government to act as a transition from the pre-existing laws of Spain and Mexico to those of the United States, an entirely different form of law was put into place in those areas where "civilization" had not yet touched. These laws were the "mining district regulations" that were adopted by groups of individual miners beginning in California and Nevada who, in the absence of any legal authority in the frenzy of the early gold rushes, enacted self-governing regulations within geographic "mining districts." These regulations or bylaws were memorialized in the form of mining district regulations and represented a compilation of traditions, customs and practices of the miners that flooded the western goldfields from the United States and the world over, including principally England, Germany, Mexico and Chile. As such, they represented the accumulated customs and practices of the miners of Derbyshire and the High Peak district in England, Saxony in Germany and the ordinances of New Spain and Peru. Each separate mining district usually constituted the extent of a single mineralized area and each had its own set of regulations. Considering the number of such districts, the regulations were remarkably uniform.

In general terms, the mining districts were organized and managed as follows: After a public notice to miners within the area, a meeting was held to establish the name of the district, to fix its boundaries and to elect a president and recorder. The regulations would initially decree that each miner was allowed only a single claim, but the discoverer was allowed a double claim in recognition of his find. The regulations frequently addressed the issue of capacity of individuals to hold claims within the district and frequently restricted ownership to citizens of the United States (or those who intended to be citizens) but also frequently attempted to exclude those of Mexican and Chinese ancestry. The regulations then described the mechanics for acquiring title specifying the dimensions of the claim, requirements to post notice, mark boundaries, and record a notice of the location with the district's recorder. The regulations also required that the land be developed through the performance of some sort of work or the maintenance of tools on the property. Finally, provisions were usually made for the settlement of disputes which almost universally required the submission of disputes to a meeting of miners within the district who would collectively act as a jury with the president of the district presiding as the judge. This procedure must have been both awkward and created a circus-like atmosphere. For example, in the Walker Mining District of Yavapai County, on March 6, 1864, a jury, after hearing 11 witnesses, returned a verdict of 18 to 11 in favor of the defendants.

The first areas within Arizona that were made subject to the mining district rules were the La Paz and Castle Dome placer deposits of Yuma County. Work in the area began under Col. Jacob Snively, the former secretary to Sam Houston, in 1858. Most of the miners in the area were returning from disappointments with the playing out of the goldfields in California's mother lode and brought with them the practices of the area. The first written regulations, however, were not adopted until October 6, and December 8, 1862, when the La Paz and Castle Dome Mining Districts were officially organized. This delay can probably be attributed to the fact that the early activities were related to attempts at placer mining, where only the place of working was protected, and the later attempts concerned the development of lode or "hard rock" mineral deposits that required both more ground and more security because of the higher development costs.

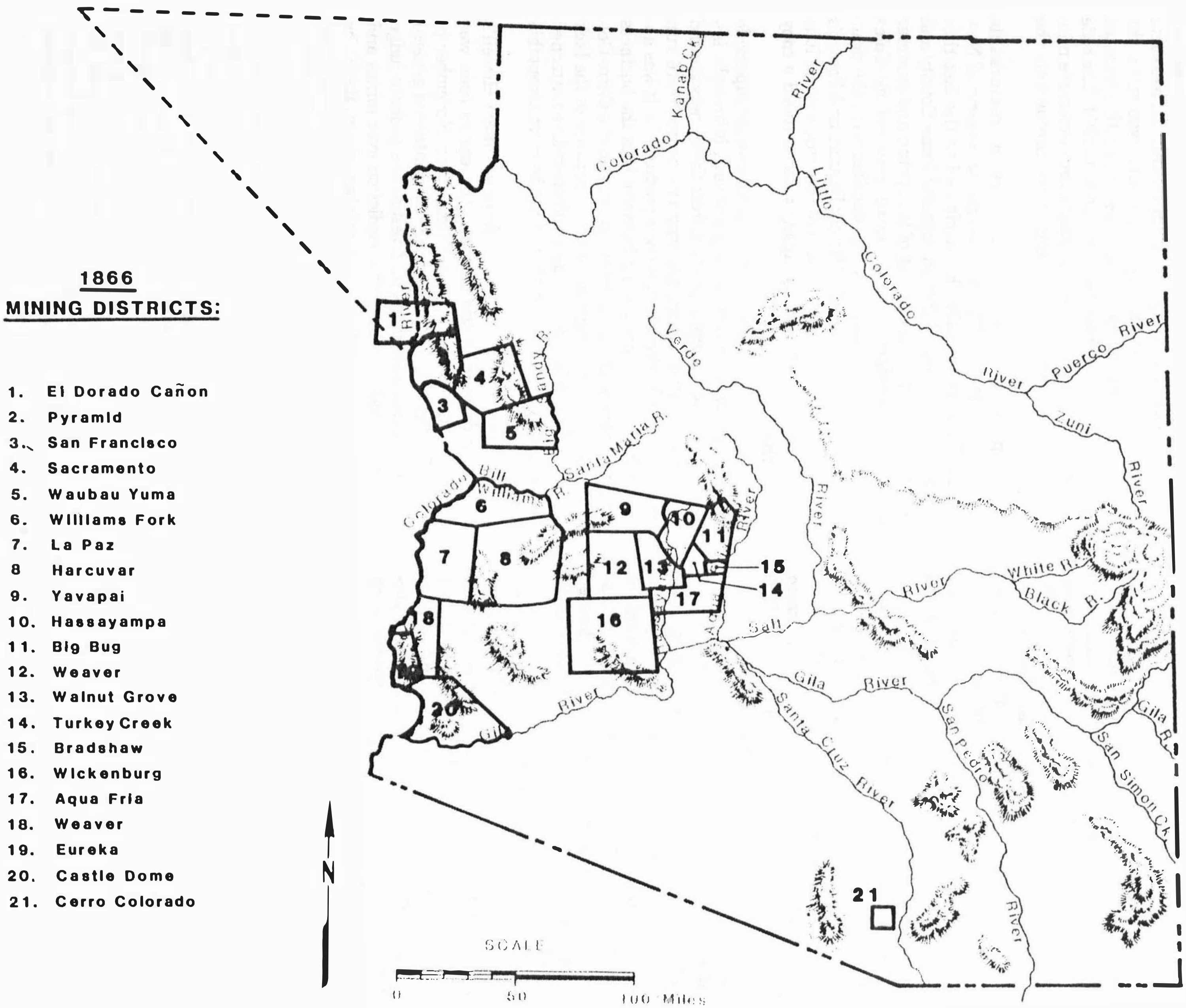
It is possible that this organization was also premised on the fact that the New Mexico Territorial Legislature in 1862, legitimized past practices by a statute specifying that:

> The location and transfer of mining claims heretofore made, shall be established and provided, in contest, before the courts, by local rules, regulation, or customs of the miners in the several mining districts of the territory in which such locations the transfers were made.

The public records suggest that it was Herman Ehrenberg who was responsible for the organization of the La Paz and Castle Dome Mining Districts and, given his long association with Charles Poston and Poston's concern with legalities, this statute may have provided the required legal basis.

With regard to the content of the regulations, according to the La Paz District regulations, mining claims were limited to 200 feet in length along the vein per individual (most claims were made by groups who aggregated their rights to create claim of approximately 1,600 feet) and if a claim was not worked or recorded for 20 days, it was subject to forfeiture. No width was specified, thus no question could exist as to the right to follow the lateral extent of the vein because apparently only a single claim width could be placed along any vein.

The tightest legal control within any Arizona mining district was found in the rules of the Walker prospecting expedition of 1862-63. This paramilitary organization, commanded by mountain man and trapper Joseph Reddeford Walker, Jr., started in Colorado and provisioned itself in New Mexico before coming into Arizona by way of the Santa Rita copper mines in southwestern New Mexico and through Apache Pass where they single-handedly set back peaceful Indian relations for years by the capture, torture and eventual murder of Mangas Coloradas, the chief of the Mimbrenos Apaches. The party eventually proceeded westerly along the Gila River to near Gila Bend, where they turned north across the desert to the Hassayampa River near Wickenberg, then continued north along the Hassayampa into the Prescott area. It was there that the Pioneer District was established on May 10, 1863, and several other districts followed. The district laws of the Pioneer and associated districts followed the tradi-



Mining Districts in 1866. The Mining Districts were self-governing units of miners that predated the Territorial government. The boundaries of the organized districts are shown as they existed in 1866. *Illustration by Rick R. DuPont.*

tional format but with additional provisions designed to perpetuate the ownership of the "initial pioneers" by excluding others until the "first comers" had selected the best ground. Further, anyone of Mexican descent was also excluded. This exclusion caused trouble, however, and within six months after the decree was passed a second decree appointed a committee to decide "who are and who are not Mexicans."

The Cerro Colorado District in southern Pima County, by contrast, while also generally based on the traditional format, and probably influenced by Poston's views, placed significant powers in the hands of the recorder. The district regulations published on April 23, 1864, required the recorder to have office hours only between 12 noon and 1 p.m., five days a week and allowed him to charge $1.00 for the recording of any instrument. One Dollar was also charged for anyone who wished to examine the records.

Pauline Weaver, one of the old trappers turned prospector, was also a very active organizer of a number of new mining districts in his position of scout and guide for the exploration party organized by A. H. Peeples who began on the Colorado River in 1863 then traveled upstream on the Bill William's Fork and the Santa Maria River into the Prescott area. Henry Wickenburg was chasing this party at the time of his discovery of the Vulture Mine and he thereafter organized the Wickenburg District.

The original "official" records of the mining districts were contained in a book held by the recorder which, in many cases, have been unfortunately lost. As a result of this, for example, little is known about the original location documents for the Moss mine near Hardyville located in 1862-3 and the Planet mine on the Bill Williams Fork located in 1864.

The mining district regulations for the approximately 25 organized districts that existed in 1864 typically limited claims to from 200 to 400 feet along the vein (300 feet was used most frequently and in one district placer claims were limited to a length of 150 feet) and usually 150 feet on each side (although the Cerro Colorado permitted 300 feet). Only two districts imposed specific work requirements as a part of the location process with Cerro Colorado following the Spanish tradition requiring a shaft of 30 feet while Turkey Creek required only 10 feet. The performance of work on the claim was also a universal requirement to maintain possessory right and the regulations typically required three days work during each 90-day period. The Bradshaw District had the most involved set of claims with the possibility of different claims for lodes, placers, surface or washing, and millsites. Each miner was normally limited to one claim except that the original discoverer was frequently recognized by permitting a larger or additional claim.

The laws frequently also recognized extralateral rights except that such a grant was noticeably absent from the regulations of the Cerro Colorado District and the Turkey Creek District near Prescott, which mentioned the right of the locator to follow all of the "dips, angles and variations" of the vein but only within the lateral extent of the claim.

Arizona Territory's "Ordinanzas de Mineria"

The initial "rule" of the individual mining districts was short lived as the Territory of Arizona was officially established with the arrival of the appointed territorial officials in December, 1863. One of the first orders of official business was to convene a state legislature and enact a legal code. Judge William Howell, an associate justice of the territorial Supreme Court, was given the task of preparing the code which was eventually presented to the legislature for action on October 4, 1864. The code proposed by Judge Howell included a very extensive mining code that would apply uniformly throughout the territory.

The proposed mining code bore a remarkable resemblance to the 1783 *ordenanzas de mineria* of New Spain. This can probably be attributed to the fact that Judge Howell's judicial district included Pima County and Judge Howell had spent most of the spring and summer in Tucson working in office space provided by Coles Bashford, who was undoubtedly familiar with the practices in the Cerro Colorado Mining District and Poston's historical usage of the practices of the *ordenanzas*. It is also known that Poston's company files included a copy of *Gamboa's Commentarios*.

Inasmuch as the proposed mining code would supersede most of the power of the mining districts, it brought immediate and vehement opposition from the miners around the Prescott area. Given the way the camps were run around Prescott, this attitude was predictable. It was apparently Judge Howell's view, however, that the business climate in the southern part of the state in the Cerro Colorado District was much more stable because of the lack of Indian hostilities in the area and therefore patterned his proposals after the laws that would be most acceptable in that area.

In the end the arguments in favor of Judge Howell's mining code carried the day, and the entire code was passed by the first legislative assembly on November 3, 1864. The first part of the mining code contained general administrative provisions and vested the probate judge of each judicial district with jurisdiction over mines and set up a record system. The mining claim itself, or *pertenencia*, using the Mexican terminology, was defined as being 200 yards square including the vein. The notice had to be posted at the opening of the vein and filed with the recorder within three months. The discoverer was also required to take up an additional adjoining claim which was to be the property of the territory of Arizona and to be held for the benefit of the common schools. The failure to make such a claim would result in the forfeiture of the claim and the discovery. Mining claims were perfected by the claimant's sinking at least one shaft to a depth of 30 feet or to running a tunnel of 50 feet in length into the main body of the vein during the first year after location. After the work was completed the recorder was required to visit the site to examine the work and make a record and certificate of the result of the examination. Upon completion of the certification process, the mining code permitted the claimant to petition the probate court for a confirmation title which was given after public notice of the application. Two years were then allowed for the claimant to develop a mine and procure machinery to work the claim. After expiration of this term, the claimants were obligated to hold actual possession of the mine which was defined as meaning 30 days work per year.

Where a claimant did not work his mine in compliance with the provisions of the mining code, it was subject to relocation by third parties. This act of relocation required the relocator, after the initial registration, to give the former owner notice and permit three months within which the former owner could remove anything of value from the claim. After this period, any improvements remaining on the property became the undisputed property of the new claimant without compensation to the former owner.

The tradition of the individual miner was not ignored by the mining code, as it contemplated the continuation of the mining districts and appointed the clerks of the probate court as recorders for the respective districts. Mechanics were also established for the creation of new districts as well as a procedure for litigation (which included the right of the probate judge to appoint a commission of experts to make reports to the judge where such was determined to be necessary).

Despite the objections of the miners around Prescott, the mining community generally applauded Judge Howell's effort. The Mining and Scientific Press published in San Francisco was enthusiastic and noted that the square claims would "keep down the luxurious crop of litigation which the mode of location usually adopted in [California and Nevada] has engendered." The article concluded that a uniform law was preferable to the "multifarious and generally ill-digested local laws in California and Nevada."

Judge Howell's mining code never really had an opportunity to benefit from years of trial and legislative amendment because of a basic legal flaw. This flaw was that the territory of Arizona and the miners by their district regulations could not legally determine the ultimate right of ownership of minerals in the public lands of the United States. This was within the sole purview of the United States Congress. As a result of preoccupation with a political philosophy of manifest destiny and the conflicts leading to the civil war, the Congress had chosen not to interfere with the self-governing efforts of the western miners by the enactment of any legislation. This void was filled, however, with the enactment of the first federal mining law on July 14, 1866. When news of this new federal law was published in the Arizona Miner in Prescott on September 26, 1866, the call immediately went out, undoubtedly fueled by miners around Prescott, for a repeal of Arizona's *ordenanzas de mineria*. In a quick answer, the Arizona legislature approved a new mining law on November 5, 1866. The new law had only seven articles and brought back the general authority of the old mining districts to enact their own rules so long as they were not inconsistent with the very general provisions of the new federal law.

The new solid basis provided by the federal mining law allowed Arizona's mines to come to full flower, and Arizona provided another example of T. A. Rickard's axiom that "civilization follows the flag, but the flag follows the pick."

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Appendix 6

Jurassic Ash-Flow Sheets, Calderas, and Related Intrusions of the Cordilleran Volcanic Arc in Southeastern Arizona: Implications for Regional Tectonics and Ore Deposits

by Peter W. Lipman and Jonathan T. Hagstrum

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Jurassic ash-flow sheets, calderas, and related intrusions of the Cordilleran volcanic arc in southeastern Arizona: Implications for regional tectonics and ore deposits

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ABSTRACT

Volcanologic, petrologic, and paleomagnetic studies of widespread Jurassic ash-flow sheets in the Huachuca–southern Dragoon Mountains area have led to identification of four large source calderas and associated comagmatic intracaldera intrusions. Stratigraphic, facies, and contact features of the caldera-related tuffs also provide constraints on the locations, lateral displacements, and very existence for some major northwest-trending faults and inferred regional thrusts in southeastern Arizona. For example, the intricate Cochise thrust system, as mapped by others in the southern Dragoon Mountains, consists instead of primary depositional contacts within caldera-fill megabreccia, and the inferred regional thrusts do not exist, at least as previously interpreted. Silicic alkalic compositions of the Jurassic caldera-related, ash-flow tuffs; bimodal associated mafic magmatism; and interstratified coarse sedimentary deposits provide evidence for synvolcanic extension and rifting within the Cordilleran magmatic arc. Gold-copper mineralization is associated with subvolcanic intrusions at several of the Jurassic calderas.

INTRODUCTION

Continental-margin arc volcanism was virtually continuous along the North American Cordillera from Alaska to Mexico during Mesozoic time, although much of the record is obscured by batholith emplacement, regional metamorphism, and tectonic dismemberment. Jurassic and Cretaceous continental-arc volcanic suites, including large-volume ash-flow tuffs and associated calderas, are exceptionally preserved and only weakly metamorphosed in southeastern Arizona (Fig. 1), where the arc rocks are cratonward (east) of the main Cretaceous Cordilleran batholiths. Regional associations between Cretaceous ash-flow sheets, newly identified caldera sources, and porphyry copper-ore deposits were reviewed by Lipman and Sawyer (1985), and several of the calderas were subsequently studied in more detail (Sawyer, 1989; Lipman and Fridrich, 1990; Lipman, in press). Lipman and Sawyer (1985) also briefly noted evidence for Jurassic calderas in the region.

Previous detailed geologic mapping and stratigraphic studies of the Jurassic volcanic rocks of southeast Arizona, compiled and summarized by Drewes (1981), have provided invaluable guides for subsequent petrologic, isotopic, paleomagnetic, and geochronologic studies (Kluth and others, 1982; Kluth, 1983; Riggs, 1987; Krebs and Ruiz, 1987; May and Butler, 1987; Asmeron and others, 1990; Riggs and Busby-Spera, 1990). Recently, some Jurassic rocks, mainly exposed farther west than those discussed here, have been interpreted in terms of active volcanic processes within an arc tectonic setting (Busby-Spera, 1988; Riggs and Busby-Spera, 1990; Riggs and Haxel, 1990; Schermer and Busby-Spera, 1990).

Here we summarize preliminary reconnaissance volcanologic and petrologic studies that (1) define four Jurassic ash-flow calderas and identify four associated outflow tuff sheets in southeastern Arizona (Fig. 1), (2) place limits on the locations and displacements along inferred later Mesozoic regional faults, and (3) define relations between caldera-related intrusions and associated mineralization. Identification of calderas and correlations with outflow tuff sheets are based on comparisons with younger caldera systems, reinterpretation of existing geologic maps, and new field and lab studies. Intracaldera ash-flow accumulations typically are thick relative to related outflow tuff sheets, reflecting caldera subsidence concurrently with eruption, and large blocks of older rocks are commonly enclosed in intracaldera tuff, representing landslide debris from oversteepened caldera walls (Lipman, 1984).

HUACHUCA MOUNTAINS–CANELO HILLS

Three petrologically distinctive ash-flow sheets, associated calderas, and related intrusions are discontinuously exposed in stratigraphic sequence over an area of about 2,500 km^2 in the southern Huachuca Mountains and adjacent eastern Canelo Hills (Figs. 1, 2). Erosional remnants of the outflow tuff sheets from these calderas are preserved in the Mustang Mountains to the north, where excellent stratigraphic sections are preserved (Fig. 3). Stratigraphic and petrologic correlations with the near-source and intracaldera tuffs are supported by paleomagnetic data (Fig. 4). Together, these three tuff sheets and associated calderas constitute a regionally notable ash-flow sequence. In contrast, many Mesozoic ash-flow tuffs in southeastern Arizona, including the Cretaceous rocks, are mainly preserved within a single mountain range as structurally subsided intracaldera deposits, and the regional outflow tuff sheets have been largely removed during subsequent tectonism and erosion.

Montezuma Caldera and Crystal-Rich Dacite Tuff

The oldest exposed Jurassic ash-flow sheet is a uniform, phenocryst-rich dacite (30% crystals of plagioclase, biotite, and quartz; 68% SiO_2). As outflow tuff filling broad paleovalleys cut in Paleozoic strata in the northern Mustang Mountains (Fig. 3), this unit consists of two compositionally similar cooling units a few tens of meters thick (Table 1, nos. 1–2). The densely welded devitrified red-brown tuffs are separated by a few meters of sandstone and conglomerate containing andesite clasts.

Similar dacitic welded tuff of intracaldera character ("siliceous volcanic rocks" of Hayes, 1970) is as much as 1,400 m thick (with no base exposed) in Montezuma Canyon and adjacent

Geological Society of America Bulletin, v. 104, p. 32–39, 5 figs., 1 table, January 1992.

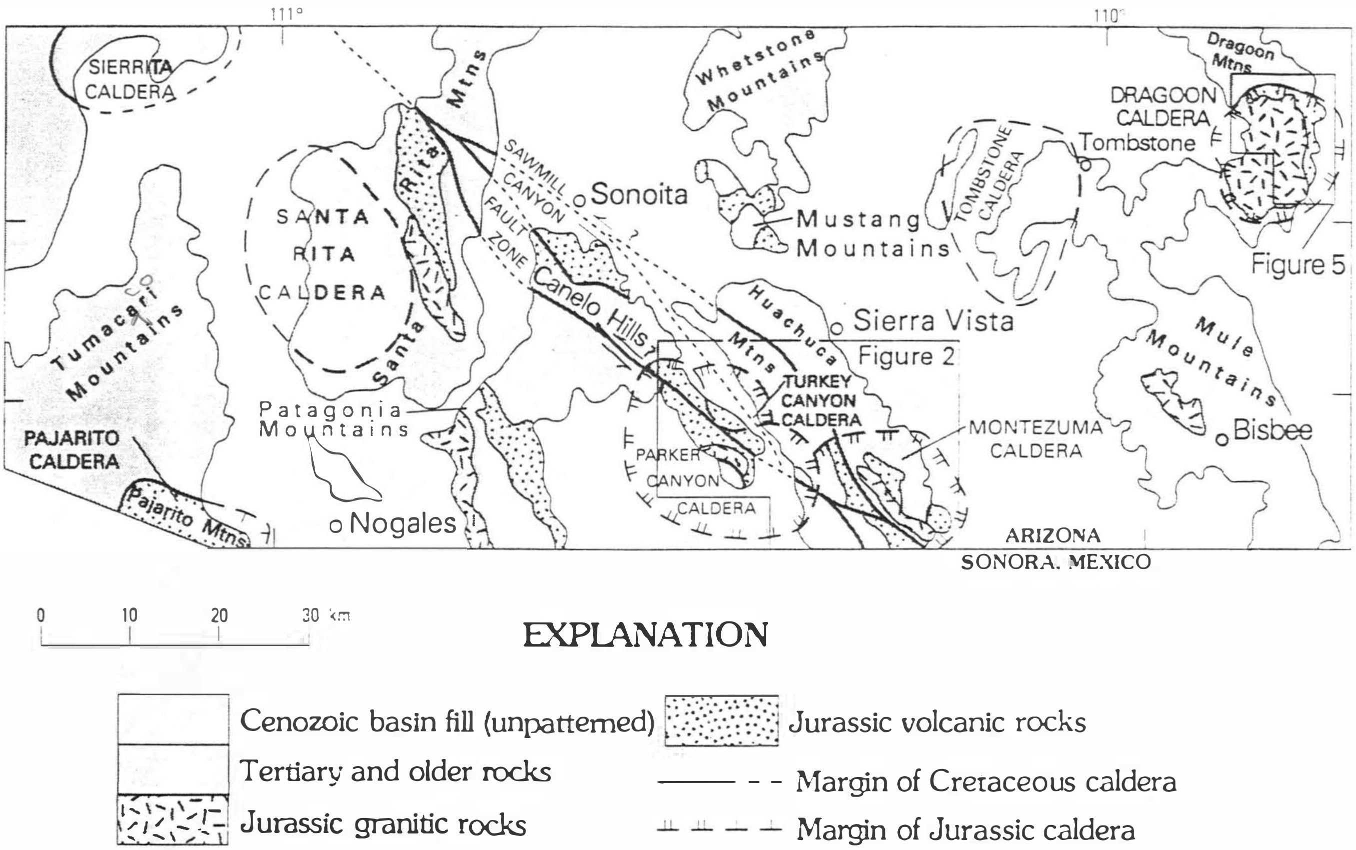

Figure 1. Index map of southeastern Arizona, showing locations of Jurassic volcanic rocks, ash-flow calderas, and associated intrusions. Locations of Cretaceous calderas are from Lipman and Sawyer (1985).

parts of the southern Huachuca Mountains (Fig. 2), where it constitutes matrix surrounding huge slide blocks of Paleozoic carbonate (Hayes and Raup, 1968). Mappable carbonate masses are as long as 2 km (some of these are composite aggregates of multiple blocks), and many more sedimentary clasts are too small to map. Upper parts of the intracaldera tuff are red-brown, as in the Mustang Mountains, but deeper tuffs are green-gray, due to propylitic metamorphism. Interpretation of the thick tuff unit in the Montezuma Canyon area as the intracaldera correlative outflow tuff in the Mustang Mountains is supported by similar phenocryst types and abundances, position at the base of the same tripartite regional Jurassic ash-flow sequence as exposed in the Mustang Mountains, and similar paleomagnetic inclinations (Fig. 4).

The intracaldera dacite tuff is exposed over an elliptical area of 8 × 16 km, elongate northwest and dipping outward from an axial pluton (Huachuca Quartz Monzonite, dated by K-Ar at 168 Ma; Drewes, 1980). The geometry suggests a deeply eroded caldera resurgent dome, complexly modified by later regional folding and thrusting (Fig. 2). A mapped thrust fault between the intrusion and tuff to the northeast (Hayes and Raup, 1968) cannot be a major regional structure, because the same intracaldera tuff is present on both sides of the fault, and the tuff in the mapped hanging-wall block is hornfelsed by the pluton in the footwall. Irregular skarn mineralization is localized along contacts between the Huachuca pluton and carbonate megablocks within the intracaldera tuff.

Interpretation of caldera features in this area is complicated by regional faults juxtaposing post-caldera Cretaceous sedimentary units with the Jurassic and older rocks. Detailed distinction between caldera-related volcanic structures and regional tectonic features will require careful restudy of a large part of the southern Huachuca Mountains.

Turkey Canyon Caldera and Crystal-Poor Rhyolite Tuff

A distinctive crystal-poor rheomorphic rhyolite tuff ("rhyolite lava" member of the Canelo Volcanics; Hayes, 1970) is present as an outflow sheet in the Mustang and Huachuca Mountains and as intracaldera tuff in the Turkey Creek Canyon area of the southern Canelo Hills. In the Mustang Mountains (Fig. 3), this light tan, densely welded unit, containing 3%–5% small phenocrysts of quartz and feldspar, forms the middle tuff of the tripartite outflow ash-flow sequence.

Lithologically similar densely welded rhyolite tuff, which becomes slightly more phenocryst rich upward 3%–10%), directly overlies the intracaldera dacite tuff within the Montezuma caldera in the southern Huachuca Mountains. This distinctive phenocryst-poor, outflow tuff is about 35 m thick on the south side of Montezuma Canyon and closely resembles the middle tuff unit in the outflow sequence in the Mustang Mountains (Fig. 3). In addition to similar color and phenocrysts, the middle tuff in both areas is characterized by extreme flattening and lineate flowage of pumice fragments, which is transitional to extensive rheomorphism and development of ramp structures upward in sections (especially in the Mustang Mountains). The middle rhyolitic tuff also contains striking spherulitic and lithophysal crystallization textures absent in the other tuff units. The tabular overall geometry of the outflow tuff sheet in

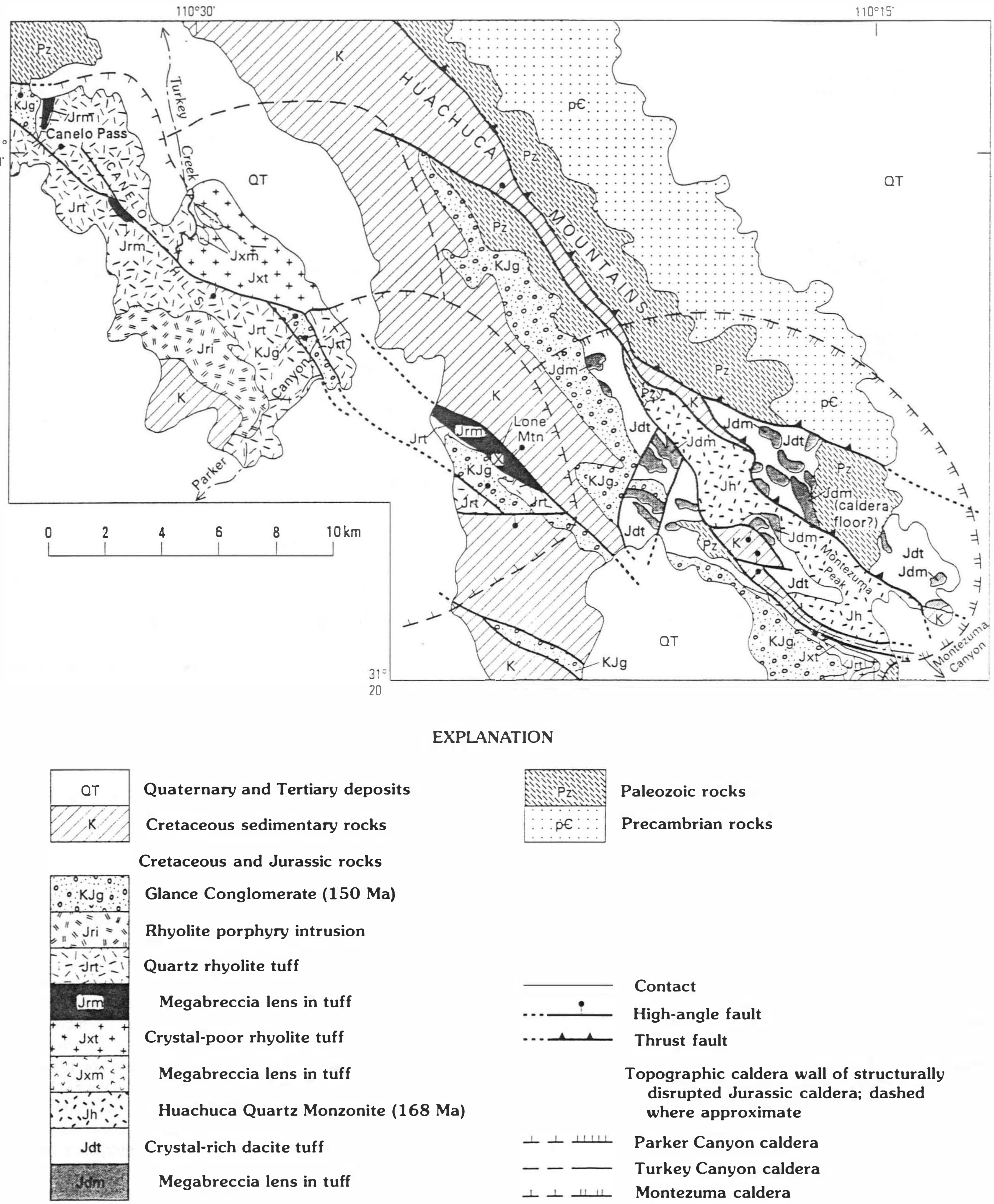

Figure 2. Generalized map of Jurassic volcanic rocks and approximate inferred caldera boundaries in the southern Huachuca Mountains and southeastern Canelo Hills. Generalized and modified from Hayes and Raup (1968).

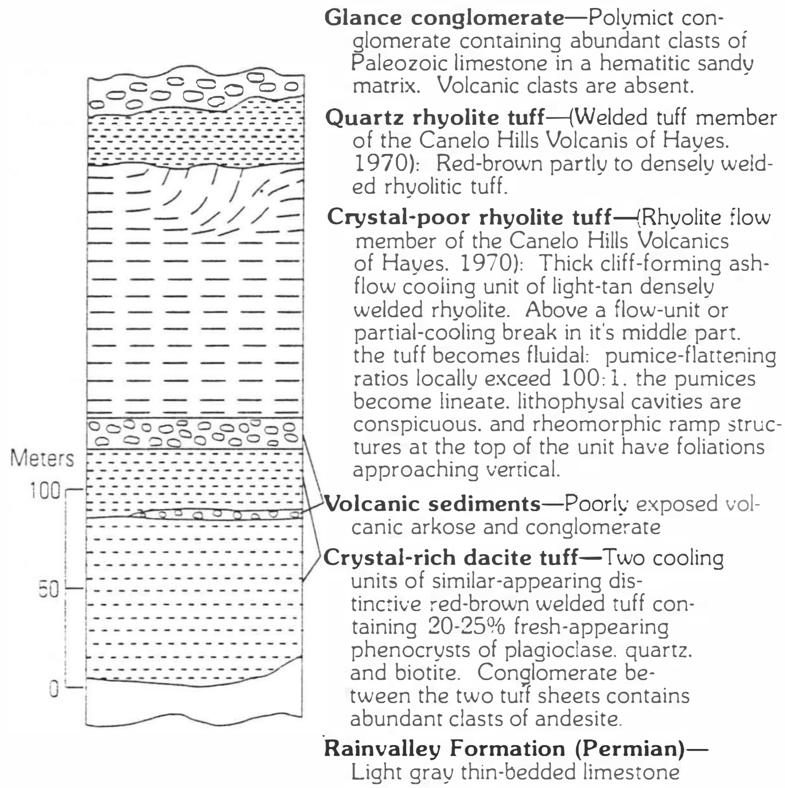

Figure 3. Composite section through Jurassic ash-flow sheets in the northern Mustang Mountains (based on exposures in section 9, R. 18 E., T. 20 S.; and in sections 17 and 20, T. 20 S., R. 19 E.).

Montezuma Canyon and in the Mustang Mountains and the lack of large or abundant lithic clasts indicate that it is outflow rather than an intracaldera accumulation.

In contrast, lithologically similar crystal-poor rhyolitic tuff, characterized by included blocks of Paleozoic carbonate sediments as much as 1 km long, is several hundred meters thick with no base exposed in the thickest sections and occupies an elliptical area about 6 km long in the Turkey Creek Canyon area of the southeastern Canelo Hills (Fig. 2). This unit is widely characterized by extreme rheomorphism to a flow-laminated, lava-like appearance. The degree of rheomorphism locally decreases within a few meters of the enclosed megablocks, in places providing the only clear preservation of flattened pumices and other original pyroclastic textures. The top of this unit in Turkey Creek Canyon has widely developed carapace breccias and ramp structures, comparable to those found in rhyolitic lava flows.

Interpretation of the rheomorphic tuff in Turkey Creek as the intracaldera correlative of the outflow tuffs exposed in Montezuma Canyon and in the Mustang Mountains is supported by similar stratigraphic position, rock compositions (Table 1, nos. 4–6), and paleomagnetic polarities, as well as paleomagnetic data for overlying and underlying units (Fig. 4). The large angular dispersion of paleomagnetic directions for the crystal-poor rhyolite (as much as 75° is likely caused by changes in the ambient field direction during magnetization, perhaps related to a polarity reversal during cooling of this tuff unit). In contrast to the underlying crystal-rich dacite tuff in the Mustang Mountains, the crystal-poor rhyolite has undergone strong alkali exchange (potassium metasomatism). The rheomorphism and alkali exchange may be additional partial causes for the scatter in magnetic polarities for the crystal-poor rhyolite. No post-caldera intrusions related to the Turkey Canyon caldera are exposed, nor is there evidence of caldera resurgence or associated metallic mineralization.

Parker Canyon Caldera and Quartz Rhyolite Tuff

The uppermost major ash-flow sheet in the Mustang and Huachuca Mountains is a phenocryst-rich, red-brown rhyolite characterized by abundant quartz and feldspars (welded tuff member of the Canelo Hills Volcanics; Hayes, 1970). This unit is the highest identified Jurassic unit in the Mustang Mountains (Fig. 3); it also forms a continuous outflow sheet on the south side of Montezuma Canyon, ponded within the Montezuma caldera and overlying the rheomorphic rhyolite tuff and intervening bedded tuffaceous sedimentary rocks (Fig. 2).

Lithologically similar, massive, quartz-rich tuff, as much as several kilometers thick with no

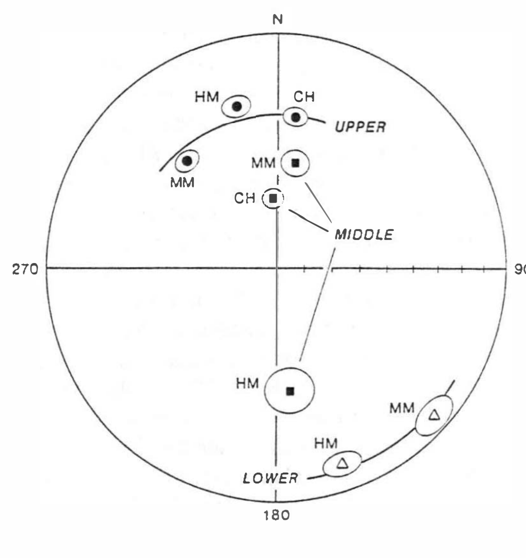

Figure 4. Mean paleomagnetic directions for the three regional Jurassic ash-flow sheets, within 95% confidence limits. *UPPER*, upper quartz rhyolite tuff; *MIDDLE*, rheomorphic crystal-poor rhyolite tuff; *LOWER*, crystal-rich dacite tuff. CH, southern Canelo Hills; HM, Huachuca Mountains; MM, Mustang Mountains. Directions for upper and lower units are dispersed along arcs of equal inclination due to subsequent vertical-axis rotations in the region (Hagstrum and Lipman, 1991). More scattered directions for the middle unit are probably due to a polarity reversal of the geomagnetic field during cooling and magnetization of this unit, and perhaps additionally to the rheomorphic flow and/or K metasomatism that have affected this unit. Diagram is an equal-area plot where filled symbols indicate projection from the lower hemisphere and unfilled symbols from the upper hemisphere.

TABLE 1. CHEMICAL ANALYSES OF JURASSIC ASH-FLOW TUFFS AND ASSOCIATED INTRUSIONS, SOUTHEAST ARIZONA

Number:	1	2	3	4	5	6	7	8	9
Source:	Montezuma caldera			Turkey Creek caldera			Parker Canyon caldera		
Unit:	Dacite tuff		Intrusion	Rheomorphic rhyolite tuff			Quartz rhyolite tuff		Intrusion
Location*	MM	MM	HM	MM	MM	CH	CH	HM	CH
Setting	Outflow	Outflow	Resurgent?	Outflow	Outflow	Intracaldera	Intracaldera		Resurgent?
Data†	USGS	USGS	KR	USGS	USGS	KR	KR	KR	KR
Sample	86L-1A	86L-1B	HM30L	86L-2A	86L-2B	CH28L	CH31L	HM11L	CH53L
SiO_2	68.2	68.1	69.35	79.6	78.9	75.17	76.28	75.37	75.46
Al_2O_3	15.7	15.9	15.10	10.6	10.9	13.44	12.83	12.84	13.47
Fe_2O_{3tot}§	3.86	3.95	2.93	0.71	1.21	1.16	1.15	0.96	1.16
MgO	1.27	1.29	1.51	0.21	0.10	0.19	0.53	0.25	0.19
CaO	1.88	1.95	2.11	0.47	0.10	0.03	0.05	0.08	0.05
Na_2O	4.22	4.49	4.02	<0.15	<0.15	2.53	0.65	0.77	1.10
K_2O	3.73	3.51	4.28	7.86	8.39	7.20	8.20	9.41	8.28
TiO_2	0.62	0.60	0.51	0.15	0.18	0.24	0.24	0.25	0.26
P_2O_5	0.20	0.19	0.11	<0.05	<0.05	0.02	0.03	0.04	0.02
MnO	0.11	0.08	0.08	0.03	0.05	0.02	0.04	0.03	0.01
LOI	1.64	1.73	1.77	1.29	0.95	0.93	1.47	1.16	1.31
Rb	126	111	270	· ·	345	330	350	550	410
Sr	799	752	420	· ·	47	10	80	70	40
Zr	211	223	130	· ·	179	220	200	190	220
Nb	12	12	20	· ·	15	20	20	20	30
Y	23	23	10	· ·	32	50	50	60	40

*CH, southeastern Canelo Hills; HM, Huachuca Mountains; MM, northern Mustang Mountains.
†USGS, new analyses; KR, from Krebs and Ruiz (1987).
§Total iron reported as Fe_2O_3.
· ·, not determined.
Note: all major-oxide analyses recalculated to 100%, volatile free. USGS analyses: major oxides, in weight percent, determined by X-ray fluorescence methods by J. Taggart; minor elements, in parts per million, determined by energy dispersive X-ray fluorescence methods (KEVEX) by D. Yager.

base visible, is superbly exposed along Parker Canyon at the southeast end of the Canelo Hills (Fig. 2), where this tuff is inferred to fill its caldera source. The northeast topographic margin of the Parker Canyon caldera is preserved locally as a steeply dipping, depositional contact of the quartz rhyolite unconformably against the crystal-poor rhyolite within the Turkey Canyon caldera (Fig. 2).

Abundant megablocks are enclosed within upper parts of the intracaldera crystal-rich rhyolite near Canelo Pass, where the alternation of blocks and tuff was previously misinterpreted as multiple discrete volcanic units separated by sedimentary debris (Kluth and others, 1982; Kluth, 1983). At Lone Mountain (Fig. 2), a massive lens of shattered, crystal-poor rhyolite interleaves with the quartz rhyolite tuff and was probably derived from the rheomorphic tuff fill of the Turkey Canyon caldera. Previous mapping of this body as in-place, crystal-poor rhyolite requires complex fault boundaries to account for its location (Hayes and Raup, 1968). Obscurely exposed, quartz-bearing, weakly welded tuff forms local veins and films within the shattered rhyolite, which is readily interpreted as a massive caldera slide breccia lens. Smaller masses of Paleozoic carbonates and sandstones also occur as breccia blocks lower within the quartz rhyolite tuff in the Lone Mountain area.

At both intracaldera and outflow sites, the quartz rhyolite tuff is characterized by a low-inclination, normal magnetic polarity that is distinct from both underlying tuff units (Fig. 4). Dispersion of declination directions for this unit, as well as for the lower dacite tuff, is interpreted as resulting from Cenozoic vertical-axis rotations between mountain ranges (Hagstrum and Lipman, 1991).

In lower Parker Canyon, the intracaldera, quartz-rich rhyolite (Hays and Raup, 1968) is intruded by compositionally similar rhyolite porphyry (Table 1, nos. 7–9) and is interpreted as a cogenetic post-caldera intrusion. Both the tuff and associated intrusions have been affected by extreme alkali exchange, similar to that in the underlying, crystal-poor, tuff unit. No significant mineralization is known to be associated with the rhyolite porphyry intrusions. The fill of the Parker Canyon caldera appears to dip homoclinally to the southwest, and no resurgent doming is evident from available structural data.

SOUTHERN DRAGOON MOUNTAINS

A fourth caldera remnant of probable Jurassic age contains spectacular megablocks of intracaldera type enclosed in tuff matrix; it is associated with large granitic intrusions in the southern Dragoon Mountains, near the old mining camps of Courtland and Gleeson (Fig. 5). Although the area is of restricted interest for Jurassic igneous problems because of the limited areal extent, generally poor exposures, and widespread alteration of the volcanic rocks, these rocks host copper-gold mineralization seemingly associated with caldera-related intrusions. The area is also tectonically important because the caldera-related megabreccias were previously interpreted as key evidence for regional thrusting involving Upper Cretaceous rocks (Gilluly, 1956; Drewes, 1980, 1981).

Dragoon Caldera and Tuff of Courtland

In the Courtland-Gleeson area, gray to reddish-brown, rhyolitic tuff, containing 15%–25% small phenocryst fragments (mostly <0.5 mm) of quartz, sanidine, minor altered plagioclase, and sparse biotite, constitutes the matrix for spectacular blocks of Paleozoic and less common Mesozoic sedimentary rocks (Fig. 5A). Most of this tuff, here designated the tuff of Courtland, is weakly welded, probably reflecting rapid cooling due to the large volume of enclosed megablocks. All the tuff is variably altered to clays and impregnated with calcium carbonate, precluding reliable determination of original magmatic composition. In the least altered samples, phenocryst mineralogy and the abundances of elements such as Ti and Al, which are typically relatively immobile during alteration, suggest that the original composition was a low-silica rhyolite.

Megablocks enclosed by the tuff of Courtland include most Paleozoic sedimentary units of the region, as well as a few small masses of Precambrian Pinal Schist (Gilluly, 1956). Some lithologically coherent masses are as much as a kilometer across, although such bodies are permeated by healed fractures, and the tendency of the soft tuff matrix to be preferentially concealed by surficial deposits hinders precise determination of the sizes of individual large blocks. The stratigraphically chaotic distribution and sequence of the blocks, which led Gilluly to interpret them as a complex thrust breccia zone, are beautifully illustrated by his detailed mapping at several scales up to 1:12,000 (Gilluly, 1956, Pls. 11–12, Figs. 7–9). Northwest of Courtland toward South Pass, Paleozoic blocks are similarly enclosed by tuff. Several blocks were mapped as thrust slices (Drewes, 1981, Pl. 4), and large fragments of andesite and dacite lava flows in a tuffaceous matrix are in steep contact with Mesozoic arkosic conglomerate of uncertain affinity that may mark a remnant of the topographic caldera wall.

Even the detailed maps by Gilluly and Drewes are too generalized to show many veins and films of rhyolite tuff between and penetrating the blocks. In gully exposures, blocks of Paleozoic limestone up to several meters across are seen to be completely enclosed in the tuff. Tuff is molded around irregular margins of shattered sedimentary blocks, and compacted-pumice foliation in the tuff locally dips steeply, reflecting the draping and squeezing between blocks. Sheared contacts and shearing internally within the tuff are rare; little evidence exists for significant tectonic disruption.

The preserved remnants of the rhyolite tuff of Courtland and associated megabreccia fringe the

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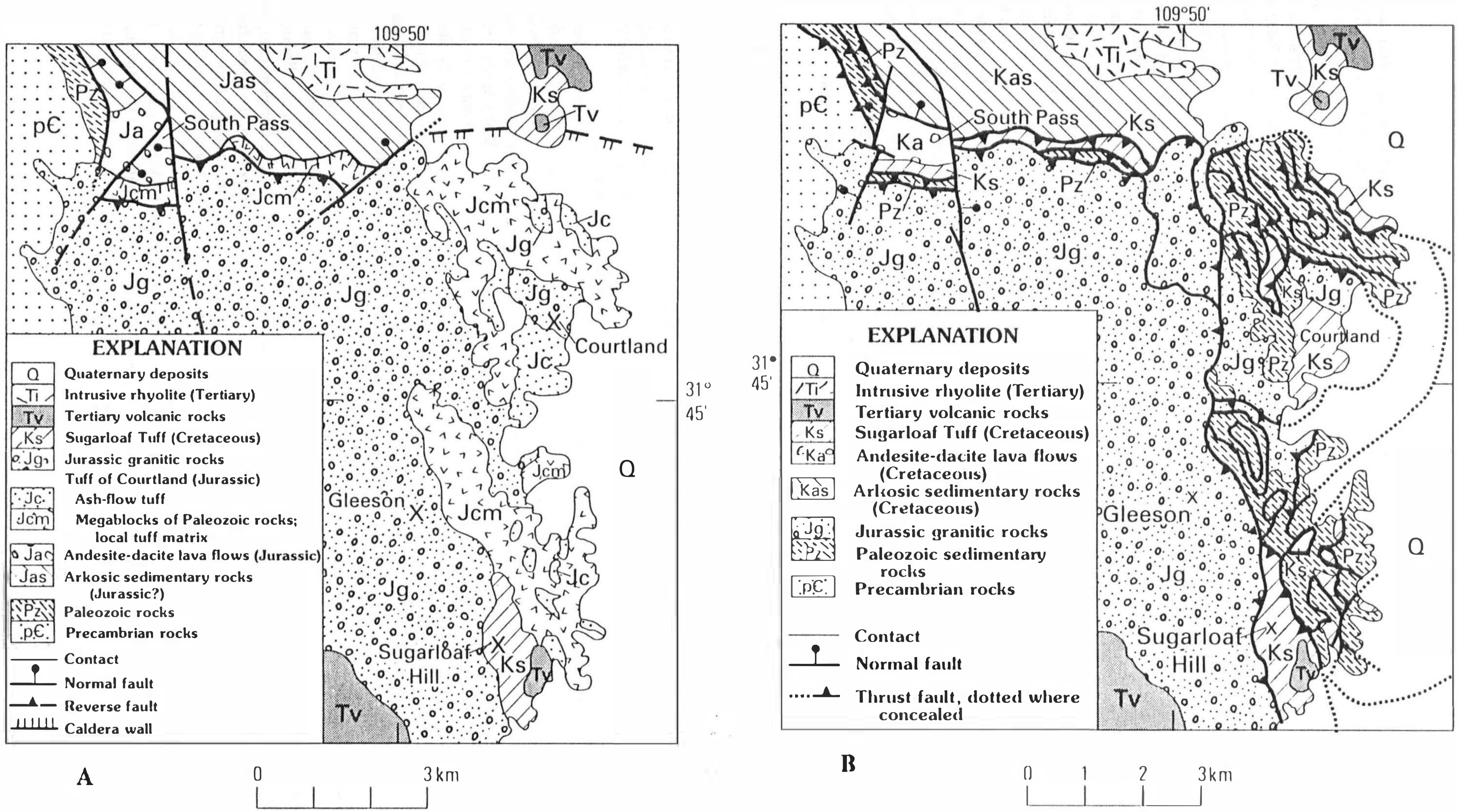

Figure 5. Generalized maps showing alternative geologic interpretations for the Courtland-Gleeson area, southern Dragoon Mountains. Modified from Gilluly (1956) and Drewes (1981). A. Jurassic caldera interpretation (this report), showing remnants of north wall of inferred Dragoon caldera and voluminous collapse-megablocks of Paleozoic rocks in ash-flow matrix (tuff of Courtland). Reverse fault near South Pass may have accommodated resurgent uplift of caldera core during solidification of Jurassic granitic intrusions. Many small, high-angle faults not shown. B. Regional imbricate thrust-fault interpretation of Gilluly and Drewes. Inferred imbrication would be far more complex than can be shown at this scale (Gilluly, 1956, Pls. 11–12, Figs. 7–9).

large Gleeson Quartz Monzonite of Jurassic age (181 Ma by K-Ar; Drewes, 1981) and are intruded by the Copper Belle Monzonite Porphyry and Turquoise Granite (Gilluly, 1956). Although the best exposed contacts between the tuff of Courtland and the Gleeson Quartz Monzonite are faults along the north side of the intrusion near South Pass, poorly exposed contacts to the east suggest that this pluton intrudes the intracaldera tuff-megabreccia assemblage. If the undated Copper Belle and Turquoise intrusions are associated with the Gleeson Quartz Monzonite, then the tuff of Courtland, which these plutons intrude and alter, is likely also Jurassic.

The mineralized reverse fault along the north side of the Gleeson intrusion, although interpreted by Drewes as a strand of his regional Cochise thrust of Cretaceous age, alternatively could represent a reactivated caldera ring fault near the north boundary of the Dragoon caldera, accommodating post-collapse resurgent uplift. Analogous resurgent uplift accommodated along caldera ring faults is well documented for younger ash-flow calderas elsewhere (Lipman, 1984).

Relations among the inferred Jurassic units along the north side of the Gleeson intrusion near South Pass are complicated by uncertain stratigraphic identification of arkosic sedimentary rocks and andesite-dacite lavas (mapped as Cretaceous by Gilluly and Drewes), a complex gridwork of small-scale, high-angle faults (not portrayable at the scale of Fig. 5), and the small area of surviving exposures. Some intermediate-composition lava flows, as mapped by Drewes, are megablocks in ash-flow matrix, but the northernmost lava exposures near South Pass appear more coherent and may rest depositionally on sedimentary rocks previously interpreted as Cretaceous in age (Js? in Fig. 5A; Kas in Fig. 5B). Andesitic clasts in the sedimentary rocks indicate that volcanism was already active in the area at the time of sedimentation. Further detailed mapping and geochronologic study of the intermediate-composition volcanic rocks could be informative.

Sugarloaf Tuff and Regional Structure

Near Gleeson, the tuff of Courtland, enclosed megablocks, and erosionally exposed Gleeson Quartz Monzonite are all overlain unconformably by a less altered, younger ash-flow unit of Cretaceous age (73 Ma; Drewes, 1980; referred to as the "lower tuff member of the Sugarloaf Quartz Latite" by Gilluly, 1956). Because the dacitic lavas that constitute the upper member of the Sugarloaf Quartz Latite as defined by Gilluly are now known to be middle Tertiary (Tv in Fig. 5; 33 Ma according to Drewes, 1980) and are absent at the type locality (Sugarloaf Hill; Fig. 5), the dated ash-flow sheet that comprises the only volcanic unit at the type locality is here redefined as the Sugarloaf Tuff. The Sugarloaf Tuff is part of the Upper Cretaceous (Laramide) ash-flow field of the region (Lipman and Sawyer, 1985); the overlying Tertiary dacite lavas are too poorly understood to warrant assignment of a formal stratigraphic name at this time.

In comparison with the rhyolitic tuff of Courtland, the Sugarloaf Tuff is a more phenocryst-rich brown dacite containing abundant biotite and plagioclase, and only sparse quartz and sanidine. The Sugarloaf Tuff, which was previously not mapped separately from the unconformably underlying intracaldera tuff of Courtland by Gilluly and Drewes, also differs in the absence of large lithic fragments of Paleozoic strata; the Sugarloaf has the typical character of an outflow-tuff sheet. The unconformable depositional contact at the base of the Sugarloaf Tuff, overlying the intracaldera tuff of Courtland and Jurassic granite, further supports the interpreted Jurassic age for the tuff of Courtland. In composition and age, the Sugarloaf Tuff closely resembles the 72-Ma ash-flow tuff (Uncle Sam Porphyry of Gilluly, 1956) associated with the Tombstone caldera to the west (Lipman and Sawyer, 1985), but differences in paleomagnetic directions (J. T. Hagstrum, unpub. data) suggest that these two tuffs may constitute separate (perhaps closely related) ash-flow sheets.

The unconformity along the base of the Sugarloaf Tuff was previously mapped by Gilluly (1956) as a west-dipping thrust fault, juxtaposing the Gleeson intrusion over the volcanic and breccia assemblage, and interpreted by Drewes (1980, 1981) as an exposure of his inferred regional Cochise thrust. Along the west base of Sugarloaf Hill where this contact is best exposed, however, it dips gently eastward, and partly welded basal Sugarloaf Tuff is molded against an irregular erosional surface cut into the intrusion. Fossil soil lenses of decomposed granitic rock are preserved locally along the unconformity. No fault is present.

OTHER JURASSIC CALDERA FRAGMENTS

In addition to the Jurassic caldera systems discussed here, outflow Jurassic ash-flow sheets are locally preserved in several other mountain ranges farther west in south-central Arizona, including Santa Rita (Drewes, 1971; Riggs and Busby-Spera, 1990) and Tucson Mountains (Drewes, 1981, Pl. 9; Lipman, in press). Thick ash-flow accumulations of intracaldera type, enclosing apparent slide blocks and associated with petrologically similar intrusions, are present in the Pajarito and Patagonia Mountains.

In the Pajarito Mountains (Fig. 1), thick massive dacitic welded tuff, containing exotic megablocks and associated with intrusive dacite porphyry, was tentatively interpreted as caldera related by Drewes (1980, 1981). These rocks have since been demonstrated to be Jurassic in age, and the caldera interpretation developed further by Riggs and Haxel (1990).

In the Patagonia Mountains (especially American Mine, Thunder Mine, and UX structural blocks), Simons (1972) described sections of Jurassic welded tuff as much as several kilometers thick intruded by granite and containing intermixed megablocks of diverse Paleozoic sedimentary units. Although hydrothermal alteration is severe and widespread in these rocks, the presence of several Jurassic caldera fragments seems assured.

DISCUSSION

Recognition of widespread Jurassic ash-flow sheets and calderas in southeastern Arizona has consequences for regional patterns of sedimentation, lateral displacements on major northwest-trending faults and inferred regional thrusts, and implications for mineralization potential. Much remains to be learned about these regional problems by more detailed study of the Jurassic volcanic rocks.

The existence of Jurassic ash-flow calderas supports recent proposals that regional extension occurred within the Jurassic magmatic arc and influenced subsequent sedimentation (Bilodeau, 1982; Busby-Spera, 1988). The Jurassic ash-flow sheets constitute part of a bimodal volcanic suite dominated by silicic rhyolite with much smaller volumes of mafic rocks that are mainly basaltic andesite and basalt. The mafic rocks are weakly alkalic and have other chemical features that are globally associated with extensional tectonism (Krebs and Ruiz, 1987).

The Jurassic volcanic rocks are widely overlain by distinctive limestone-clast conglomerates (Glance Conglomerate), which represent initial deposits of the Upper Jurassic and Lower Cretaceous Bisbee Group and have been interpreted as deposited in growing fault-block basins in an extensional back-arc setting (Bilodeau, 1982; Dickinson and others, 1987, 1989). Although relations in the Huachuca area are broadly in agreement with such interpretations, some thick sections of the Glance were deposited within the Jurassic calderas and may reflect local volcanogenic depositional controls as well as regional tectonics. For example, sedimentary rocks mapped as Glance Conglomerate in the Montezuma Canyon and Canelo Pass areas overlie the ash-flow sequence within the Montezuma and Parker Canyon calderas, respectively. In Montezuma Canyon, the basal sediments are monolithologic fanglomerate of welded tuff, perhaps derived from a growing resurgent dome within the caldera. Horizons of chaotic breccia higher in the sedimentary section probably represent landslide deposits reflecting continuing instability of the caldera walls. In the Canelo Pass area, analogous breccia lenses interleaved with Glance Conglomerate also may represent caldera-wall landslides. Detailed sedimentological and provenance studies of the Glance Conglomerate in proximity to the Jurassic calderas could be a rich field for future research.

Stratigraphic and structural features of the Jurassic calderas also provide constraints on regional fault structures. Several strands of the major northwest-trending Sawmill Canyon fault zone pass through the Huachuca Mountains. This fault zone, like others of similar trend in southern Arizona, has been postulated to accommodate major left-lateral offsets (Drewes, 1981). Yet exposures of outflow quartz rhyolite tuff in the northern Mustang Mountains and in the southeast Huachuca Mountains presently lie about 25 km in divergent directions from the source Parker Canyon caldera, across most strands of the Sawmill Canyon zone (Fig. 1). Such a distribution of the tuff would be unlikely if this fault zone involves more than a few tens of kilometers of displacement. In addition, vertical-axis rotations indicated by the paleomagnetic data, both for the Jurassic and Cretaceous volcanic rocks in the region, are clockwise, suggesting right-lateral shear and thus right-lateral movement on the major northwest-trending faults in the region (Hagstrum and Lipman, 1991).

A key area of surface control for the inferred regional Cochise thrust, interpreted as representing a regional décollement for more than 100 km east-west in southeastern Arizona (Drewes, 1980, 1981), is in the Courtland-Gleeson area. There, the main inferred western thrust strand is the unconformity at the base of the Sugarloaf Tuff, and the previously mapped complex of easterly strands are landslide-related megablocks within tuff filling the Dragoon caldera. Thus, no evidence exists for a regional Cochise thrust in the southern Dragoon Mountains.

Relations between mineralization and the Jurassic caldera structures are less clear than for the Cretaceous calderas, where several major porphyry copper systems developed in subvolcanic intrusions emplaced along ring faults late in the caldera cycle (Lipman and Sawyer, 1985). Significant gold-copper mineralization within the large hydrothermally altered area at Courtland-Gleeson appears associated with caldera-related intrusions (Copper Belle Monzonite Porphyry, Turquoise Granite). Modest skarn and other mineralization is associated with the apparently resurgent Huachuca Quartz Monzonite in the Montezuma caldera, and also with the probable caldera fragments in the Patagonia Mountains. The important porphyry copper mineralization that is associated with a Jurassic pluton at Bisbee suggests additional potential in other Jurassic intrusions, as well as the desirability of evaluating Bisbee as a possible deeply eroded Jurassic caldera system.

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Appendix 7

Geology and Silicate-Alteration Zoning at the Red Mountain Porphyry Copper Deposit, Santa Cruz County, Arizona

by James L. Quinlan

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GEOLOGY AND SILICATE-ALTERATION ZONING AT THE RED MOUNTAIN PORPHYRY COPPER DEPOSIT, SANTA CRUZ COUNTY, ARIZONA

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ABSTRACT

The Red Mountain porphyry copper deposit located in southwestern Arizona (fig. 1) occurs within an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Silicate alteration, sulfide distribution, and assay data have been used to define the deposit.

As presently outlined, the deposit is divided into three parts: (1) a small, near-surface chalcocite blanket, (2) a near-classic, porphyry copper bulk sulfide deposit, 5,000 feet below the summit of the mountain and 3,500 feet below the chalcocite blanket, and (3) a deep-level breccia pipe in the core zone of the bulk sulfide deposit.

At least three major and distinct alteration and mineralization pulses are recognized at Red Mountain. Much of the alteration at the surface is the result of the supergene modification of a zoned and essentially copper-barren hypogene alteration system. Superimposed on the early hypogene system and recognized at depth is a smaller, more intense near-classic porphyry copper alteration zone with a partially defined copper-sulfide shell. The breccia pipe occurs within the core area of the shell and represents a later, even more restricted hydrothermal event. Silicate and sulfide zoning within the breccia pipe indicates that the pipe itself is a miniature zoned porphyry copper deposit.

The most obvious clue to the deep-level orebody at Red Mountain is the near-surface chalcocite blanket. The blanket deposit formed by secondary enrichment of copper in a low-grade halo or plume which extended upward from the deep-level deposit to the present surface, or at least 5,000 feet. Pyrite, largely from the phyllic zone of the early and essentially copper-barren alteration system, not only provided a favorable host environment in which the blanket could form, but also on oxidation provided much of the acid needed for the secondary enrichment process.

INTRODUCTION

Geologic Setting

Red Mountain is underlain by an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Figures 2 and 3 are generalized maps illustrating surface geology and alteration features. Figures 4 and 5 are diagrammatic cross sections showing geologic and alteration features.

Three layered volcanic units are recognized at Red Mountain. The upper, or tuff unit, consists mainly of tuffs, flow, and breccias of rhyolitic and dacitic composition. It crops out over much of the mountain and is up to 2,400 feet thick (figs. 2 and 4). It is essentially the same as the "Volcanics of Red Mountain" described by Drewes (1971a), which he correlates with the Gringo Gulch volcanics of Paleocene(?) age.

Underlying the tuff unit are approximately 3,000 feet of andesite and trachyandesite flows, breccias, sills, and dikes locally referred to as the andesite unit. Hornfels bands occur near the base of the unit. The andesite unit crops out on the flanks of Red Mountain and is cut in drill holes (figs. 2 and 4). It is part of the Upper Cretaceous trachyandesite or doreite (Ka) unit, mapped and described by Simons (1974). Simons reported a potassium-argon date of 72.1 ± 3 m.y. B.P. for a sample from the unit.

The lowest layered rock unit is the felsite-latite unit. It underlies the andesite unit and includes interlayered andesites near the top. It consists mainly of volcanic conglomerates and breccias, silicified tuffs, flow(?), interlayered and cut by latite sills and dikes. The unit crops out in Alum Gulch on the south side of Red Mountain and is recognized in deep drill holes on the south and west flanks of the mountain (figs. 2 and 4). It correlates with the Upper Cretaceous silicic volcanics (Kv and Kla Units) mapped by Simons (1974).

The layered rocks at Red Mountain are cut by several textural varieties of porphyritic rocks, which range in composition from granodiorite to quartz monzonite. The porphyries are recognized as dikes and irregular bodies in outcrop and drill holes (fig. 2 and 4).

The layered rocks generally strike north and dip 14° E. The dominant trend of local shears and fractures is N. 20° E. with steep dips toward the northwest and southeast. Less numerous are shears and fractures that strike N. 70° E. and dip steeply northwest or southeast. No large faults are recognized on the mountain, but several occur on its flanks (fig. 2).

Silicate Alteration

Silicate alteration at Red Mountain is easy to recognize but difficult to interpret. Near the center of the deposit, changes in the alteration assemblage

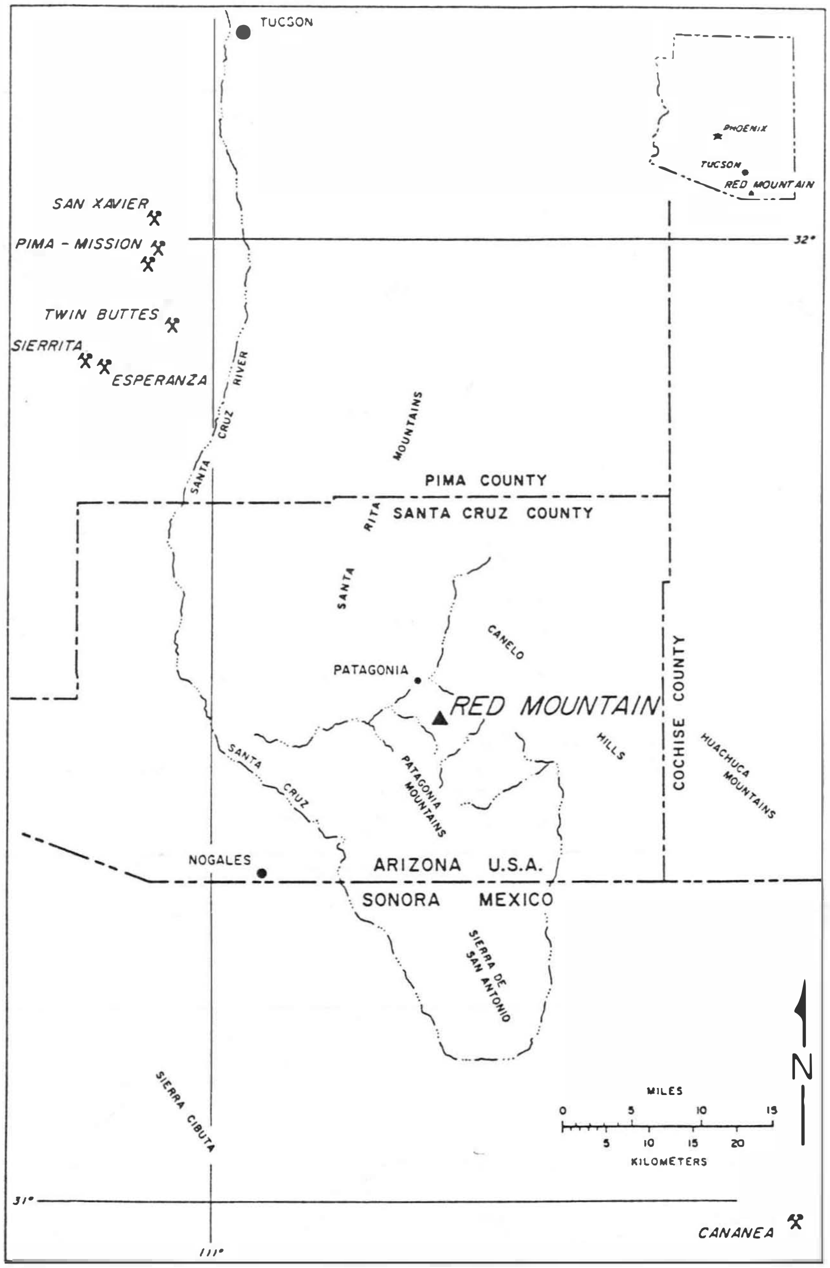

Fig. 1. Index map showing the location of the Red Mountain porphyry copper deposit. After R.M. Corn, Economic Geology, Vol. 70, No. 8, Dec. 75

with depth are most obvious (fig. 5). Lateral zoning at depth, which is a critical guide to ore, is much more subtle and to date has been best quantified by thin-section studies (fig. 6).

The strong vertical alteration zoning recognized at Red Mountain is partly controlled by differences in rock types with depth. Near the center of the system, the tuff unit is intensely altered to an assemblage of quartz-sericite-pyrite-kaolinite-alunite. The sericite content increases with depth, whereas the content of kaolinite and alunite decreases. At the tuff-andesite contact, the assemblage abruptly changes to quartz-sericite-chlorite-pyrite with minor hematite and kaolinite. With the exception of outlying Hole 158, the pyrite content rapidly decreases in depth through the upper part of the andesite unit (fig. 7). The alteration assemblage further changes with depth within the andesite through a biotite-magnetite-pyrite assemblage to a biotite-orthoclase-anhydrite-magnetite-chalcopyrite assemblage. Within the felsite-latite unit, the assemblage is orthoclase-quartz-anhydrite-chalcopyrite-biotite. The alteration within the porphyritic rocks is generally reflective of the adjacent intruded rock and depth. It is expressed by a quartz-sericite-pyrite-kaolinite assemblage at shallow depths and an orthoclase-anhydrite-biotite-chalcopyrite assemblage at greater depths.

The lateral changes in alteration are much more subtle. At the surface, hypogene alteration is strongly masked by supergene effects but is discernible. Within the tuff unit, the lateral zoning is expressed as a central core area of more abundant sericite, quartz veining, and limonitic stain (fig. 3). Outward from the core area, a more argillic zone is characterized by abundant clays and alunite with less sericite, silica, and iron. The transition from

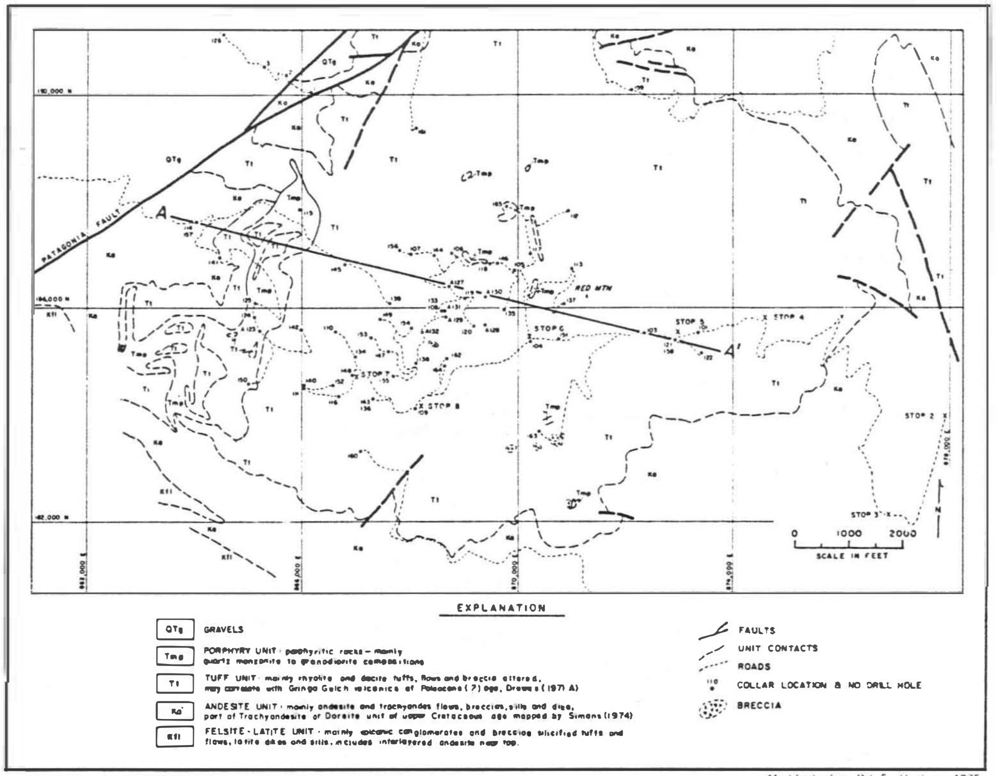

Fig. 2. Generalized surface geologic map of Red Mountain, Arizona. Modified after D.L.E. Huckins, 1975

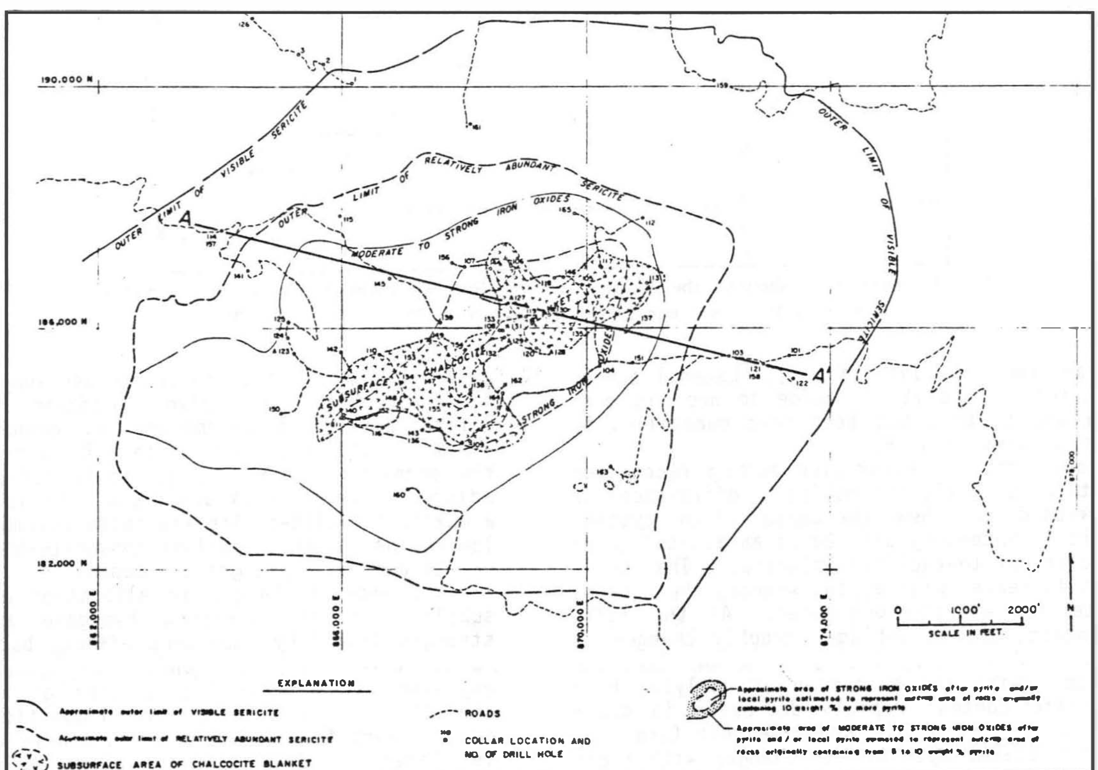

Fig. 3. Generalized surface alteration map of Red Mountain, Arizona. Modified after D.L.E. Huckins, 1975.

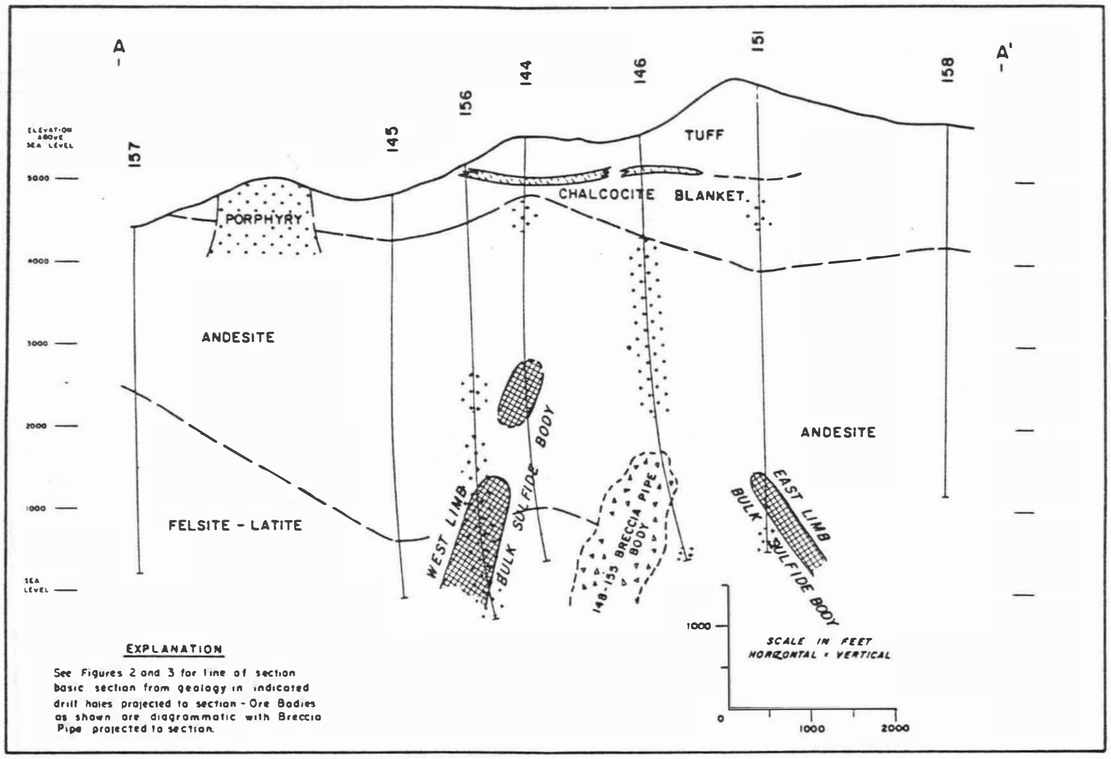

Fig. 4. cross–section A–A'. looking northeasterly, diagrammatically showing geology at Red Mountain, Arizona .

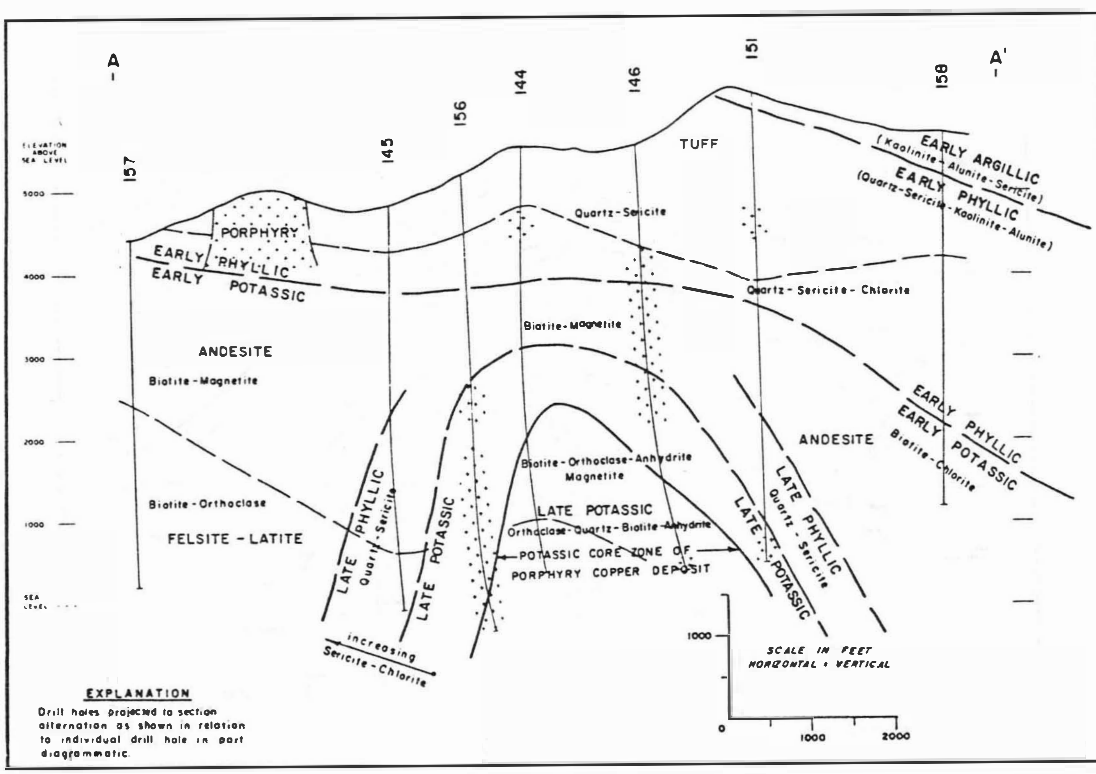

Fig. 5 Cross section A–A', looking northeasterly, diagrammatically showing silicate alteration at Red Mountain, Arizona.

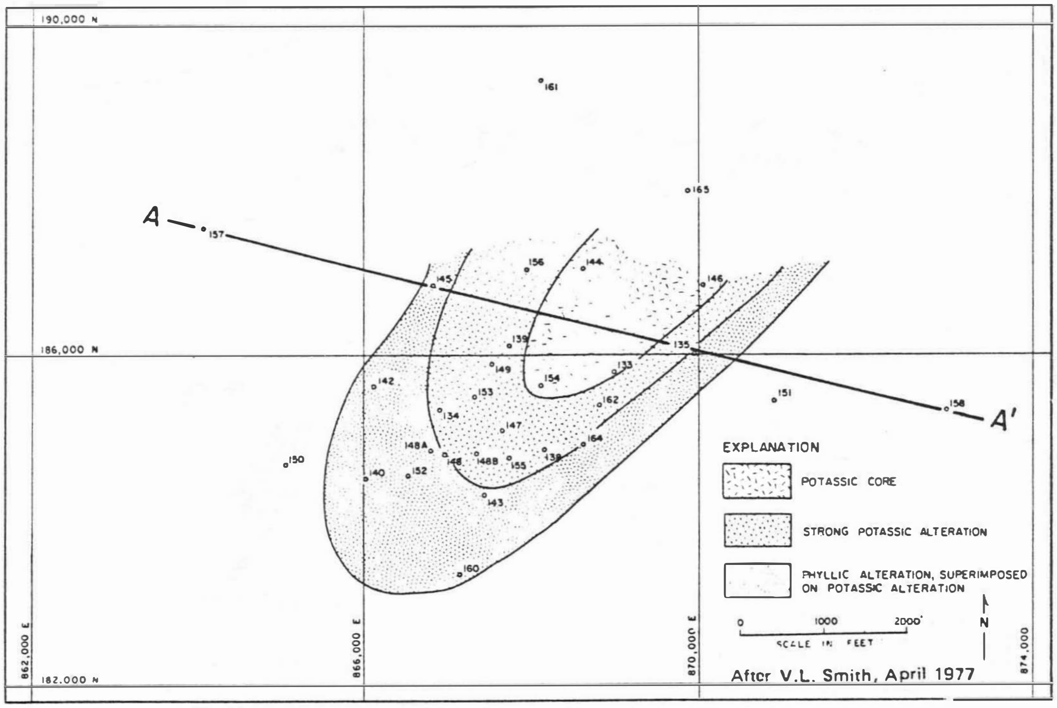

Fig. 6 Map showing silicate alteration between elevations 2,000' and 2,500' at Red Mountain, Arizona. Developed from petrographic study of thin sections from selected holes.

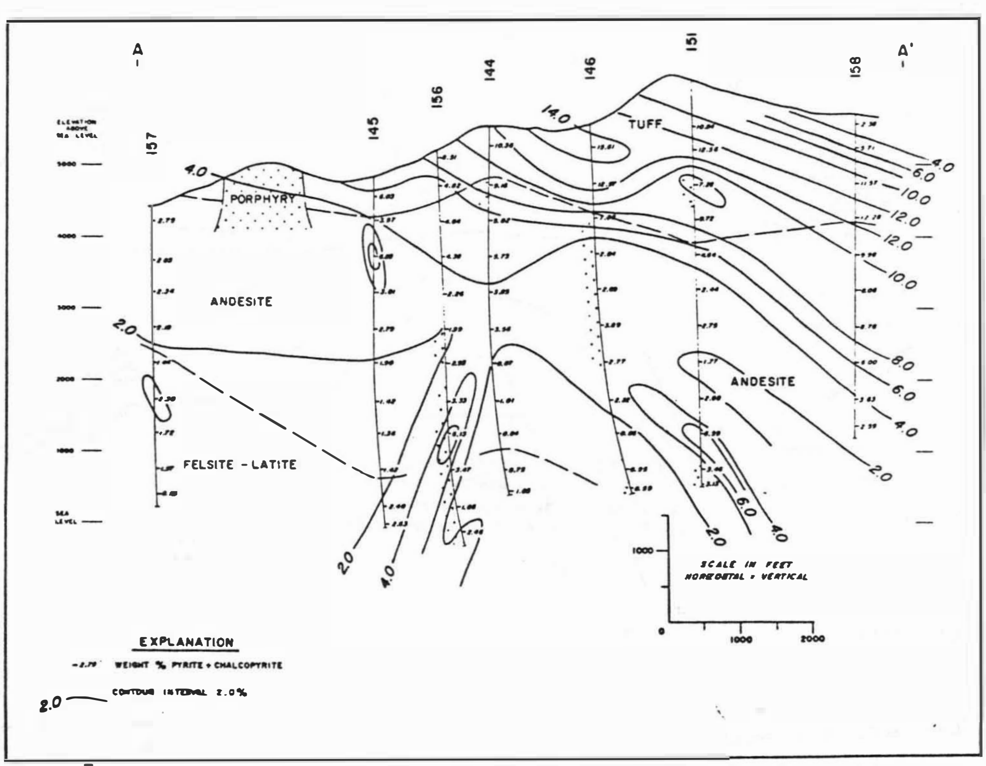

Fig. 7. Cross section A–A', looking northeasterly, showing total sulfide distribution at Red Mountain, Arizona.

sericitic-argillic alteration within the tuff unit to propylitic alteration in the surrounding andesite unit to the northeast, east, south, and southwest appears to be partly due to change in rock type. The suggestion is that the alteration mushroomed or extended farther laterally from a mineralization center in the tuff unit than in the underlying andesite unit. Within the andesite unit on the west and northwest flanks of the mountain an intense supergene argillic alteration is superimposed directly upon hypogene biotite-magnetite alteration. Within this area of relatively low original pyrite, chalk turquoise was formed as the more common supergene copper mineral within the argillized andesite.

At depth, the central core area is marked by an orthoclase-quartz-biotite-anhydrite alteration mineral assemblage. There is a general decrease in the amount of these minerals outward from the core area with increasing amounts of sericite and chlorite. This is illustrated on figure 6, which was developed from a study of thin sections obtained from selected holes between elevations of 2,000 and 2,500 feet.

Father out, as seen in Holes 157 and 161, a biotite-magnetite assemblage is recognized in the andesite unit. In Hole 157, this assemblage changes to biotite-orthoclase in the felsite-latite unit. Although the assemblage is potassic, the intensity of the potassic alteration appears much less than that recognized in the core area of the deposit. Locally, late quartz-pyrite veinlets enclosed in sericitic envelopes cut the previously described alteration features.

Figure 5 illustrates in cross section, my concept of the major silicate alteration features at Red Mountain; that is, a large early zone alteration system that accounts for most of the alteration recognized at the surface. The primary porphyry copper deposit lies in the potassic zone of this large early system. The alteration associated with the primary deposit has been superimposed on the early alteration system and zoning is similar to that described by Lowell and Guilbert (1970) and Rose (1970). It is suspected that the two silicate alteration systems are closely related in origin and time with the porphyry copper phase representing a late but more restricted event in the development of the complex Red Mountain hydrothermal system. The sulfide distribution data also clearly point to two distinct alteration phases as does the fluid inclusion data of Bodnar and Beane (1980).

Sulfide Distribution

The principal sulfide minerals at Red Mountain are pyrite and chalcopyrite. Secondary chalcocite is present, particularly in the blanket deposit. Bornite has been identified in deep holes near the center of the system and enargite in the upper part of holes overlying the deep orebody. Small amounts of molybdenite, tennantite, galena, and sphalerite have been identified locally.

The sulfide content of the rocks at Red Mountain has been estimated during core logging and in the deep holes has been determined on the basis of sulfur and sulfide sulfur assays.

For the purposes of the sulfide distribution studies, it has been assumed that pyrite and chalcopyrite are the only significant primary sulfide minerals in the Red Mountain system. The amounts of each below the zone of secondary enrichment are calculated from copper and sulfide sulfur data by assigning the amount of sulfide sulfur needed to convert the copper present in an interval to chalcopyrite and assigning the remaining sulfide sulfur to pyrite. Sulfate data have been converted to anhydrite equivalents where anhydrite is recognized in the deep drill holes.

The sulfide data have been assembled and posted in several different manners on plans and cross sections; that is, by rock type and as various elevation intervals. Most revealing are the bulk data when assembled and posted at elevation intervals of 500 feet or more. In general, plans and sections have been prepared showing pyrite, chalcopyrite, and total sulfide (combined pyrite and chalcopyrite) distribution, and pyrite to chalcopyrite ratios. Pyrite and total sulfide maps and sections are reflective of each other, and maps and sections showing pyrite distribution are not included in this report.

Plan illustrations accompanying this report show relative bulk chalcopyrite (fig. 8), total sulfide distribution (fig 9), and relative pyrite to chalcopyrite ratios (fig. 10) between elevations of 500 and 1,500 feet. All three maps show the same basic pattern and closely match the silicate alteration pattern shown in figure 6. Although drilling has yet to outline the entire system, available data indicate an elongate but nearly classic copper-sulfide shell. Thus all three plans, and in particular the ratio map (fig. 10), are useful in indicating where a drill hole lies within the system.

Cross sections prepared from the sulfide data, that is, data assembled at 500-foot elevation intervals, not only confirm the picture developed in plan but add to it. Total sulfide and chalcopyrite data have been assembled on Section A-A', which passes through the core area of the lower sulfide system as well as outlying Holes 157 and 158 (figs. 7 and 11). The section showing total sulfide distribution (fig. 7) clearly demonstrates a two-part system. A large primary sulfide high, mostly pyrite, is recognized near the surface in the upper parts of the central drill area and in Hole 158. This pyrite is within and generally an integral part of the intense quartz-sericite alteration assemblage recognized at the surface. The section also suggests that Hole 157 lies in the core area of the large primary sulfide system and would account for the potassic alteration recognized in the hole. It is also apparent that the strong iron oxides recognized on the upper western slope of Red Mountain (fig. 3) are related to the upper sulfide system.

The copper system recognized at depth in the central drill area and shown on the sulfide distribution and ratio maps (figs. 8, 9, and 10) is also apparent in the cross sections showing total sulfide and chalcopyrite distribution (figs. 7 and 11). Although the amount of total sulfides in the lower system (fig. 7) is less than that in the upper system, it is clear on figure 11 that the copper is associated with the lower system. Further, it is apparent in sections that the lower sulfide system closely follows the central area silicate system, and like the silicate system, is superimposed on the earlier and larger system.

THE ORE SYSTEM

For discussion purposes, the Red Mountain deposit is divided into three separate and distinct parts: (1) an upper-level chalcocite blanket deposit, (2) a deep-level bulk sulfide deposit, and (3) a breccia pipe deposit within the core area of the deep porphyry copper system.

Chalcocite Blanket

Chalcocite is recognized along fractures and as coatings on pyrite grains from the surface to a depth of 2,500 feet or more. Much of the chalcocite appears to be concentrated in a flat blanketlike deposit near an elevation of 5,000 feet and within the high pyrite

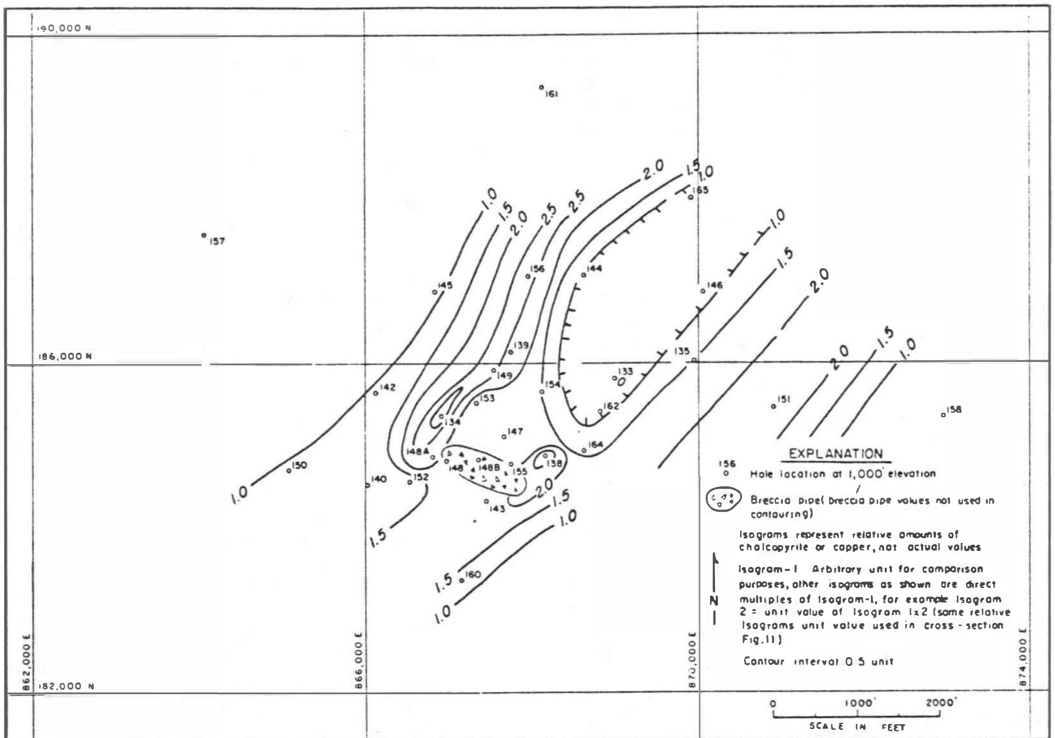

Fig. 8. Map showing relative chalcopyrite distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

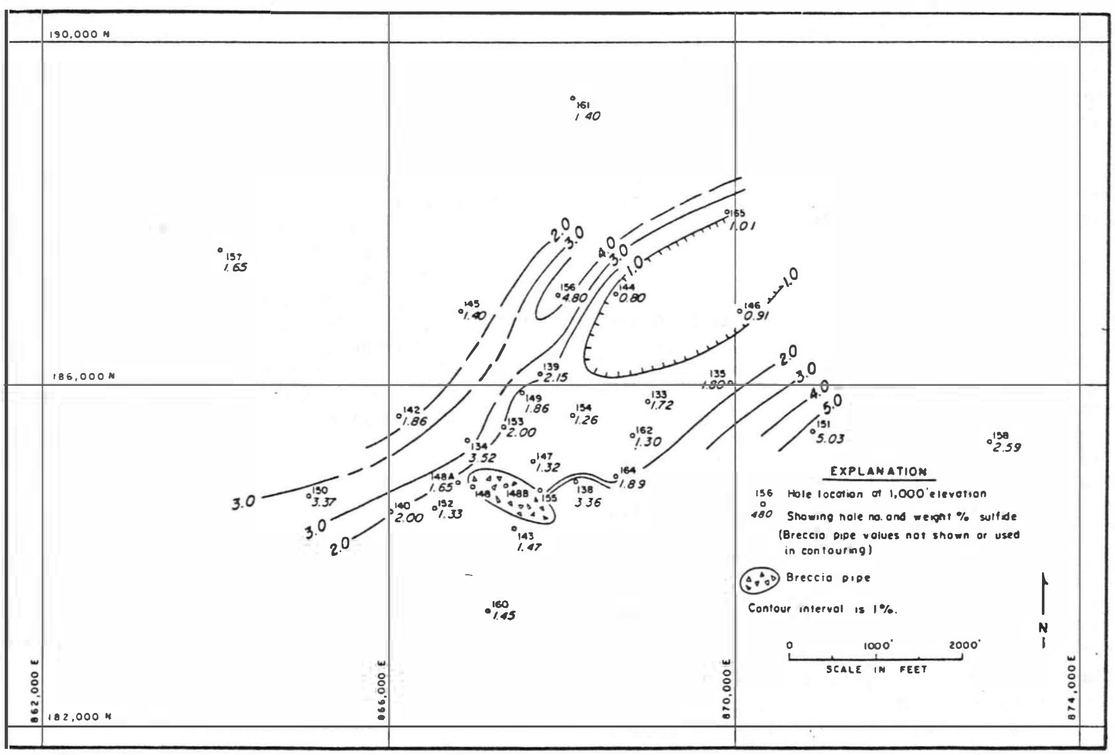

Fig. 9. Map showing total sulfide distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

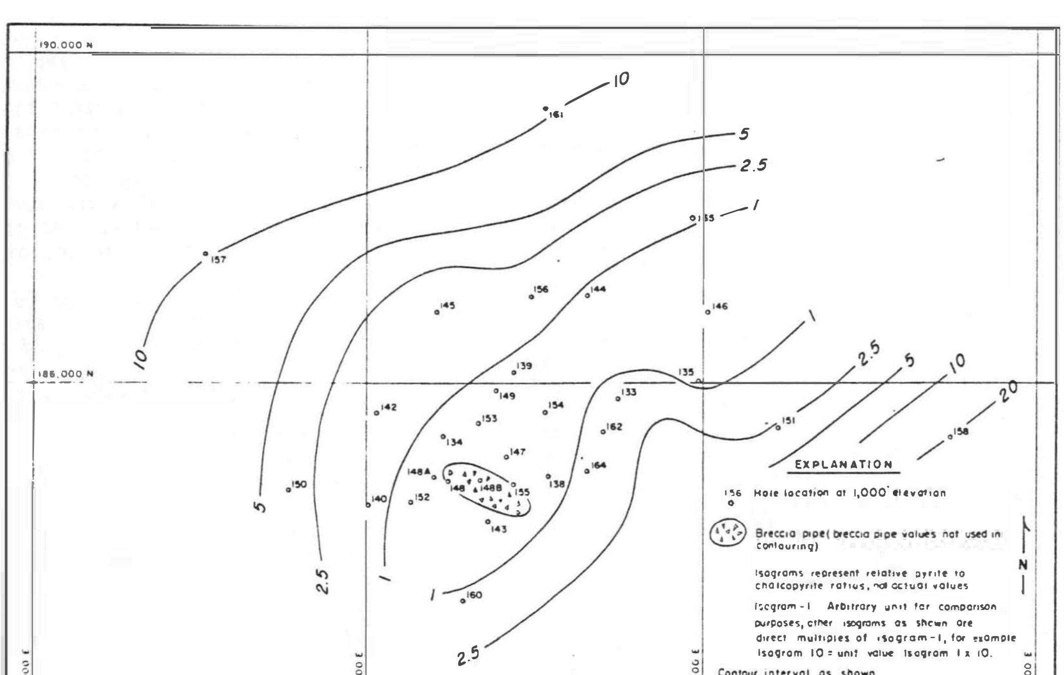

Fig. 10 Map showing relative pyrite / chalcopyrite ratios between elevations 500' and 1,500' at Red Mountain, Arizona.

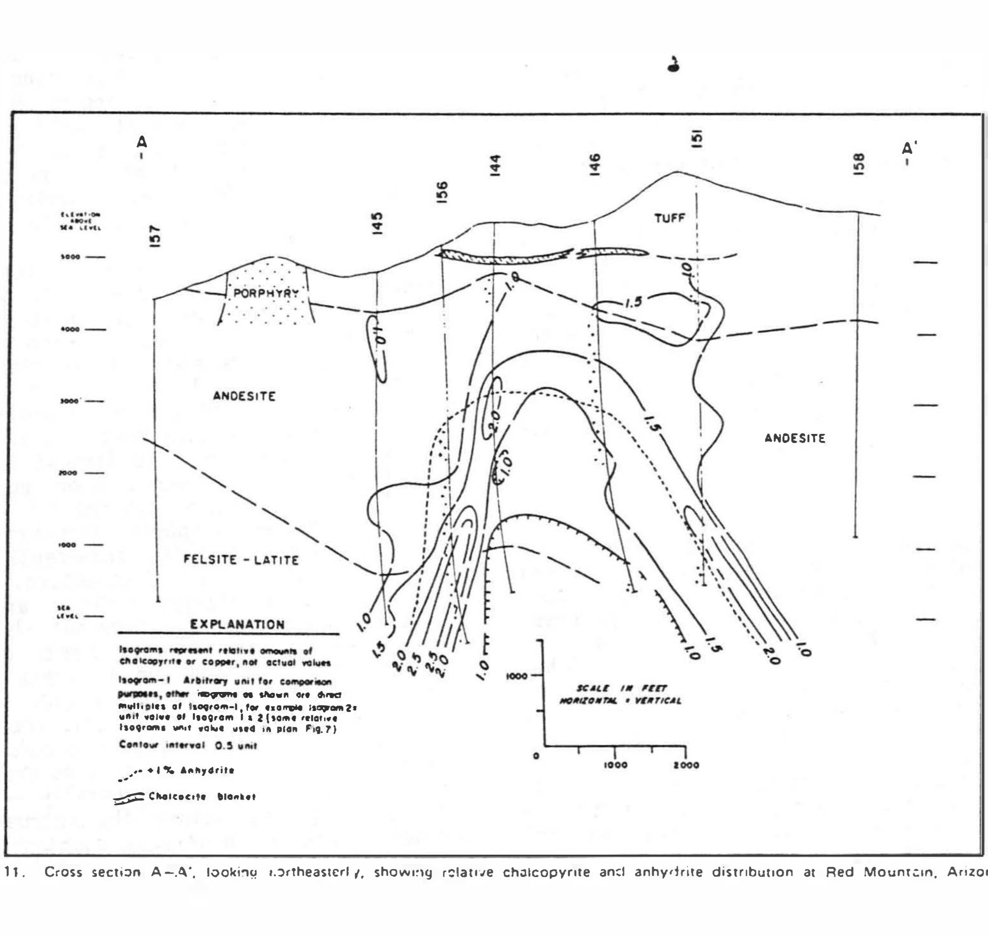

Fig. 11. Cross section A–A', looking northeasterly, showing relative chalcopyrite and anhydrite distribution at Red Mountain, Arizona.

zone of the early alteration system (figs. 10 and 11). As currently defined, the blanket ranges in thickness from 15 to 150 feet. It appears to be in the process of being destroyed by weathering and erosion. The deeper scattered chalcocite showings, which are usually controlled by fissures or shears probably represent recent copper migration.

The chalcocite blanket almost directly overlies the deep porphyry copper orebody (figs. 3 and 11). The distribution of copper above the deep porphyry copper system, as reflected by the relative copper or chalcopyrite values shown in figure 11, suggests that the blanket was formed by enrichment of a protore halo or plume extending at least to the present surface, or 5,000 feet above the main ore system. Pyrite from the early phyllic zone undoubtedly played an important part in the formation of the blanket. Not only did it provide a favorable host environment for deposition of chalcocite but also is the primary source of acid for the secondary enrichment process. Also, Bodnar and Beane's (1980) description of late-stage mineralization in a quartz-pyrite veinlet containing minor chalcopyrite and galena in a surface sample, RM 11, is evidence that the ore-stage primary mineralization extends far above the main deposit.

Deep-level Bulk Sulfide Deposit

The zone of deep-level porphyry copper mineralization at Red Mountain is an integral part of the copper shell as recognized in the alteration and sulfide study. Holes 146, 165, and the deeper parts of Hole 144 describe the low-sulfide, low-copper core of the system. A low-sulfide, low-copper tail extends from the core and is recognized in seven holes, 133, 135, 154, 147, 143, and 152. A breccia pipe is defined in Holes 148, 148B, 148C, and 155 and lies within the elongate tail area.

Nine drill holes are immediately peripheral to the core area and the elongate tail, and it is in the area of these nine holes that most of the deep-level copper outside the breccia pipe occurs. Seven of the nine holes contain thick and/or higher grade ore intervals. Ore is recognized on both the west and east limbs of the copper shell (fig. 4).

Much, if not most, of the deep-level copper occurs as chalcopyrite along veinlets and fractures, and only a small amount occurs as disseminated grains. From work to date, it is obvious that the area of the copper shell is not uniform in grade and not every where of interest. Local controls and structure apparently played an important part in copper mineralization within the shell area. For example, chalcopyrite enrichment is noted along both sides of andesite-porphyry contacts in several holes.

148-155 Breccia Pipe

The 148-155 breccia pipe recognized at Red Mountain has many features common to mineralized breccia pipes at other porphyry copper deposits. It is perhaps the deepest copper-molybdenum breccia pipe presently known anywhere in the world. Not only is it of potential economic interest because of the higher grade ore associated with it, but it is also of considerable scientific interest because of its depth, position within the system, and the mineralization and alteration associated with it.

The Dyna-drill has been used to control the direction of drill holes for a better evaluation of the pipe. In all, four holes (148-148B, 148C, and 155) have intersected the pipe (fig. 12).

The 148-155 breccia pipe, as envisioned from drill-hole data, is shown in plan and diagrammatic section in figure 12. Although in part diagrammatic, the plan and section represents a reasonable interpretation based on drill-hole intercepts within the pipe and the confining restrictions of adjacent holes. In plan, the intercepts in Holes 148 and 155 are about 800 feet apart and define the minimum dimension of the long axis of the pipe. The pipe has been assigned a long axis of 1,100 feet. The section better illustrates the available information. As shown, the top of the pipe is at an elevation of 1,750 feet or approximately 4,000 feet below the surface, and ore has been exposed over a vertical range of 1,300 feet. Hole 148 bottoms in ore within the pipe near sea-level elevation.

As mentioned before, the 148-155 pipe lies within the high-potassic, low-sulfide, and low-copper tail extending southward from the core of the deep porphyry copper system (fig. 10). The alteration within the pipe is separate and generally distinct from that of the surrounding rock. This is well exemplified in Holes 148B, 148C, and 155. These holes enter the pipe near its top from an area of low-sulfide, low-copper, and strong potassic alteration. At or within a few feet of the pipe contact, alteration abruptly changes to phyllic with abundant sericite and up to 30 percent by weight of pyrite. Strong phyllic alteration persists near the top of the pipe but gives way to potassic alteration with depth. Only in Hole 155 is a significant amount of possible mineralization leakage recognized above the pipe. Although the pipe contact is this hole is sharp and distinct, bands of pipe-type mineralization are evident for 40 feet above the pipe. Shears with chlorite, sericite, and quartz-sulfide veinlets similar to pipe mineralization are recognized up to 775 feet above the pipe.

Unlike many breccia pipes described in the literature, the mixing and movement of fragments great distances up or down the pipe has not been recognized in the 148-155 breccia pipe. Although fragments are broken and rotated, the composition of fragments, with but a few exceptions, appears to be similar to that of fragments in the immediate wall of the pipe. More detail is needed to substantiate this observation. It may also be noted that neither the contact between and andesite and felsite-latite units nor the thickest hornfels horizon appears disturbed or distorted near the breccia pipe.

The ore breccia generally consists of angular fragments of felsite and andesite in a matrix of orthoclase, quartz, anhydrite, chalcopyrite, and pyrite. Sericite is abundant near the top and is also recognized close to the sides of the pipe in deeper intercepts. Calcite, molybdenite, and a dark-gray sulfosalt, tentatively identified as tennantite, are accessory minerals. Breccia fragments are commonly an inch or less in diameter. The largest fragment recognized was 18 inches in diameter. Open vugs are common.

A distinctive unbrecciated but altered and mineralized quartz-eye porphyry intrusion occurs within the breccia pipe. Drilling intercepts, up to 65 feet long, suggest a dikelike structure. Brecciated fragments of the quartz-eye porphyry are recognized outside the main intrusive body but always near its margin. Sericite is the most common alteration product in the intrusion and and in areas of the pipe near where the intrusion is recognized. Within the intrusive body, the sericite is relic after plagioclase and biotite phenocrysts and also occurs as a major constituent in the altered fine-grained groundmass. Pyrite and chalcopyrite generally occur as fine disseminated grains within the intrusive body. These minerals are not nearly as abundant in the intrusion as in the brecciated areas of the pipe and generally constitute from about 1.5 to 3 weight percent of the rock. Though variable, the amount of pyrite generally exceeds the amount of chalcopyrite.

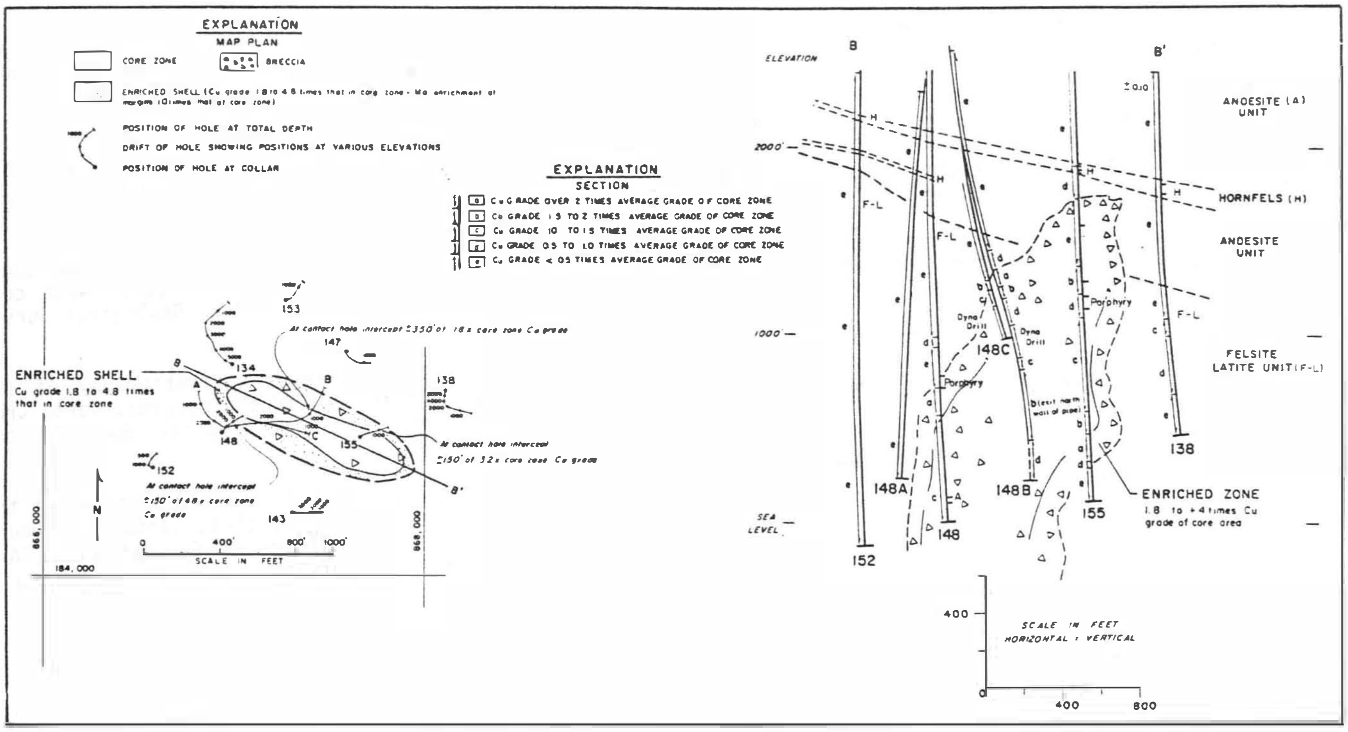

Fig. 12. Plan map and diagramatic cross section, looking northeasterly 148–155 breccia pipe at Red Mountain, Arizona.

A definite enrichment of copper, molybdenum, and silver is recognized at the pipe margin, particularly in the deeper intercepts. The enrichment is related to the concentration of chalcopyrite- and molybdenite-rich sulfide lenses at the margins. The grade of copper at the margins of the pipe is from 1.8 to 4.8 times that in the core area of the pipe. Molybdenum enrichment at the margins is ten times, and silver from two to four times that of the pipe core.

The silicate alteration and sulfide distribution pattern recognized in the pipe, though different in scale, is much the same as that recognized in many large porphyry copper systems, that is, a core area of strong potassic alteration with lower sulfide content. This is followed upward and to a lesser extent outward toward the pipe margins by a phyllic zone with increased sulfides. The suggestion is that the pipe itself may represent a more intense but miniature zoned porphyry copper system superimposed over the main or bulk phase of porphyry copper alteration and mineralization.

DISCUSSION

Silicate and sulfide alteration patterns have proved a useful guide to ore at Red Mountain. In particular, the use of copper and sulfide-sulfur assay data to estimate and study the approximate distribution of pyrite and chalcopyrite within the complex alteration zone has proved a valuable tool to define the deposit and as a guide for exploration.

The recognition of three separate, major, and distinct hydrothermal events at Red Mountain is believed significant. All three pulses appear to be closely related in time and origin to each other and to porphyry intrusions. The indicated sequence of hydrothermal events starts with the development and formation of a large, zoned, and essentially copper-barren silicate-sulfide alteration system, followed by at least two distinct alteration and copper-mineralization pulses. Each of these later pulses is more restricted and intense and formed a higher-grade deposit than its predecessor. This suggests that differentiation in the magma chamber may have played an important role in the segregation and enrichment of copper for the late-phase hydrothermal fluids.

More work is needed to confirm and expand on some of the implications and observed relationships in the 145-155 breccia pipe. Whereas the pipe contains open vugs, most evidence indicates that it formed with its top many thousands of feet below the surface. The presence of both brecciated and unbrecciated, altered, and mineralized quartz-eye porphyry within the pipe attests to the interplay between intrusion, brecciation, alteration, and mineralization. One suggestion is that volatiles or fluids from the magma may have played an important part in brecciation as well as alteration and mineralization in the pipe. A better understanding of the processes that formed the pipe would undoubtedly lead to a better understanding of porphyry copper deposits.

In conclusion, it should be stressed that the deep-level porphyry copper deposit at Red Mountain is a plum within a large and complex altered zone. The most obvious clue to the deep-level deposit is the chalcocite blanket that was formed by the secondary enrichment of copper in a low-grade plume that extended at least to the present surface, or 5,000 feet above the deep-level deposit.

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ROAD LOG

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Fleetwood R. Koutz
ASARCO, Tucson, Arizona

Mileage Cum.	Inc.	
0.0	0.0	START. Patagonia, Arizona, Post Office at the junction of State Highway 82 and county road leading to the San Rafael Valley, Harshaw, and Lochiel. Good view of Red Mountain on the right.
1.6	1.6	The Patagonia fault is exposed in outcrop across wash. Fault zone consists of several strands, with consolidated Tertiary gravels on northwest and Meadow Valley Andesite (72.1 ± 3 m.y.) on southeast side of fault zone. Bold outcrops on southeast side of outcrop area are silicified breccias along fault strand in Meadow Valley andesite.
2.7	1.1	STOP 1. Road-cut exposures of Meadow Valley Andesite. These exposures are typical of many Meadow Valley exposures outside of main Red Mountain alteration zone. Would call attention to purple color and propylitic alteration. In core of Red Mountain alteration zone, andesite is typically altered to a black, biotite—magnetite-rich rock. Clay and limonite are common along many fractures in the exposures and quartz veinlets and manganese oxides may be seen along some of the fractures.
4.7	2.0	STOP 2. Locations of Stops 2 through 8 shown on Figure 2. Turn off from San Rafael Valley-Harshaw-Lochiel county road onto road leading to Red Mountain. Will transfer from bus to four-wheel drive vehicles at this point. Outcrops in wash ahead are generally propylitically altered Meadow Valley Andesite. Local bleach zones are mainly controlled by linear structures. Clay, gypsum, and limonite are the most common minerals in these zones.
5.2	0.5	STOP 3. View of southeast side of Red Mountain. Would call attention to route of road leading up mountain, talus-covered landslide blocks and cliffs in upper layered tuff unit. This upper layered, altered tuff unit is much more resistant to erosion than the underlying andesite, and this accounts for the present topographic high at Red Mountain.
7.1	1.9	STOP 4. At outcrop in altered tuff unit 5,000 feet east of alteration center at

Red Mountain (see figs. 2 and 3). Rock is principally clay altered; also note alunite veinlets. Stop is at about outer limit of visible sericite in Red Mountain alteration zone.

7.5 0.4 STOP 5. At collar of Hole No. 158. Road cuts and outcrops of altered tuff unit ±2,000 feet closer to Red Mountain alteration center than at Stop 4. Note increase in sericite and pyrite (2 to 2.5 wt. %) content over that at Stop 4.

See map figures 2 and 3 and cross-section figures 4, 6, 10, and 11 illustrating geology, alteration, and sulfide changes at and between Stops 5 and 6.

8.4 0.9 STOP 6. Crest of Red Mountain ridge and near collar of Hole No. 151. Road cuts and outcrops of the tuff unit are inside the area of relative abundant sericite and iron oxides after pyrite. Adjacent drill-hole data show original pyrite content of up to 18 weight percent and an average content of from 10 to 12 percent (fig. 6).

8.8 0.4 STOP 7. At collar of Hole No. 148. Road, drill-pad cuts, and outcrops are in altered tuff unit, within zone of relatively abundant sericite and iron oxide. Note quartz and alunite veinlets in drill-pad cut. Will discuss and point out feature of deposit from viewpoint at this stop.

9.0 0.2 STOP 8. End of Red Mountain tour. View overlooking Hardshell or afternoon tour area. Return down Red Mountain to STOP 2 south on Harshaw Creek Road to Harshw Town Site (Lunch Stop). This is Stop A of the Hardshell half of the field trip guide as published in Arizona Geological Society Society Volume XV (1984), "The Hardshell Silver, Base-metal, Manganese Oxide Deposit, Patagonia Mountains, Santa Cruz County, Arizona: a Field Trip Guide," p. 199-217.

Appendix 8

exerpts from

Mineral Deposits of the Santa Rita and Patagonia Mountains, Arizona

by Frank C. Schrader

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HISTORY OF MINING AND PRESENT CONDITIONS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[3] Idem, p. 52.

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

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

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

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

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

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

[1] Raymond, R. W., Mineral resources of the United States for 1875, pp. 389–390, 1876.
[2] Blake, W. P., Mining: Report of the Governor of Arizona for 1903, pp. 112–115; Geology of Arizona: Idem, pp. 126–135.
[3] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1905, pp. 138, 153, 155–156, 1906.

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

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

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

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

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

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

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

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

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

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

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

PRODUCTION.

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

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

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

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

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

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

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

[1] Raymond, R. W., Production of precious metals west of the Rocky Mountains for 1875.
[2] Burchard, H. C., Report of the Director of the Mint on the production of precious metals for 1880, p. 112.
[3] Idem for 1881, p. 300.
[4] Idem for 1884, p. 80.

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

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

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

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

District.	Year.	Ore treated (tons).	Gold.		Silver.		Copper.		Lead.		Zinc.		Total value.
			Fine ounces.	Value.	Fine ounces.	Value.	Pounds.	Value.	Pounds.	Value.	Pounds.	Value.	
Helvetia and Empire	1903	100			936	$500							$500
	1904	40			200	100			20,000	$600			700
	1905	600					75,000	$11,700					11,700
	1906	11,852	46.42	$960	4,444	2,977	706,625	141,325					145,262
	1907	5,711	7.35	152	6,903	4,556	478,970	95,796	28,989	1,537			102,041
	1908	944	3.68	76	2,085	1,105	93,602	12,355	16,573	696			14,232
	1909	12,250	28.88	597	20,166	10,486	1,168,878	150,711	113,670	4,888			166,682
	1910	148	3.15	65	1,372	741	10,013	1,272	10,881	479			2,557
	1911	40			838	444	13,043	1,630	5,378	242			2,316
	1912	586	2.37	49	16,873	10,377	39,792	6,565	3,759	169			17,160
		32,271	91.85	1,899	53,817	31,286	2,585,923	421,354	199,250	8,611			463,150
Harshaw and Patagonia	1903	266	4.83	100	3,996	2,099	1,562	216	66,884	1,842			4,257
	1904	461			5,265	2,865	27,000	2,510	37,855	1,513			6,888
	1905	1,500	31.93	661	73,590	44,448	9,000	1,404	338,840	15,925			62,438
	1906	122,025	17.00	352	61,895	41,470	7,934	1,507	1,454,972	82,931			126,260
	1907	14,705	37.83	782	41,493	27,386	482,006	96,402	533,358	28,268	57,038	$3,365	156,203
	1908	330	28.88	597	9,034	4,788	47,748	6,302	5,882	247			11,934
	1909	117	5.22	108	1,146	597	21,222	2,758	2,276	98			3,561
	1910	673	41.84	865	81,209	43,853	40,085	5,091	86,666	3,814	10,853	586	54,209
	1911	52	7.02	145	595	315	18,915	2,364	1,483	67			2,891
	1912	2,029	46.73	966	18,933	11,644	273,260	45,089	39,145	1,762			59,461
		142,158	221.28	4,576	297,156	179,465	928,732	163,643	2,567,361	136,467	67,891	3,951	488,102
Tyndall and Wrightson	1903	10	2.42	50	70	37	2,600	359					446
	1904												
	1905												
	1906	24	1.68	35	564	378	2,448	475	13,584	777			1,665
	1907	423	58.34	1,206	7,891	5,208	21,615	4,323	92,503	4,903			15,640
	1908	621	47.11	974	6,614	3,506	35,529	4,690	79,133	3,324			12,494
	1909	1,667	12.58	260	6,194	3,220	126,979	16,508					19,988
	1910	38	.63	13	1,706	922	2,068	252	1,913	84			1,271
	1911	594	4.98	103	11,565	6,129	54,285	6,786	183,029	8,236	16,844	960	22,214
	1912	302	75.17	1,554	4,397	2,704	30,130	4,971	48,673	2,190	25,539	1,762	13,181
		3,679	202.91	4,195	39,001	22,104	275,654	38,364	418,835	19,514	42,383	2,722	86,899
Greaterville placers	1903		92.91	$1,920									$1,920
	1904		120.93	2,500									2,500
	1905		241.88	5,000	62	$37							5,037
	1906		136.64	2,824	28	19							2,843
	1907		241.87	5,000	48	32							5,032
	1908		150.01	3,101	16	8							3,109
	1909		106.42	2,200	17	9							2,209
	1910		103.43	2,138	15	8							2,146
	1911		99.99	2,067	20	11							2,078
	1912		171.20	3,539	29	18							3,557
			1,465.28	30,269	235	142							30,431
Grand total		178,108	1,981.32	40,959	390,209	232,997	3,790,309	$623,361	3,185,446	$164,592	110,274	$6,673	1,008,582

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EMPIRE DISTRICT.

GENERAL FEATURES.

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

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

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

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

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

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TOTAL WRECK MINE.

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

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

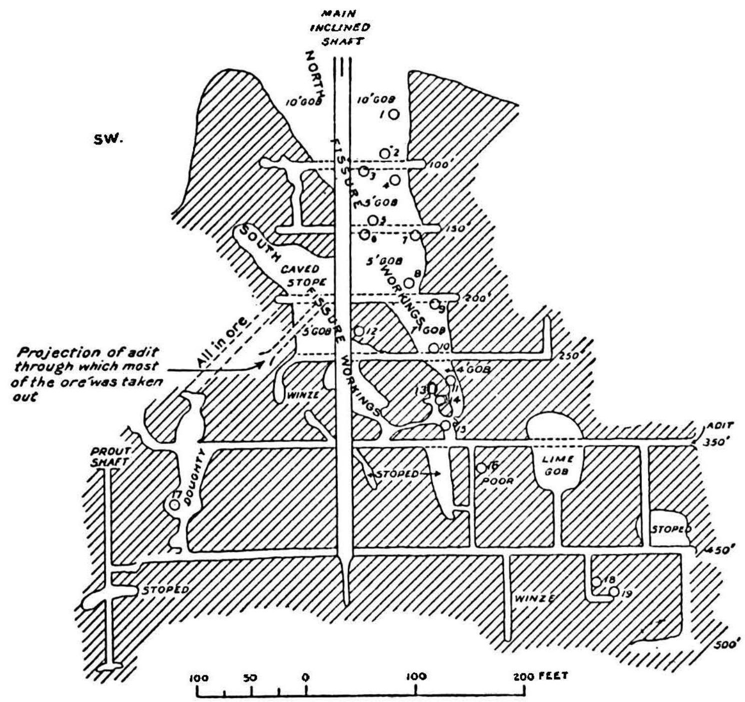

FIGURE 15.—Diagrammatic longitudinal section of Total Wreck mine on dip of main vein.

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

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

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

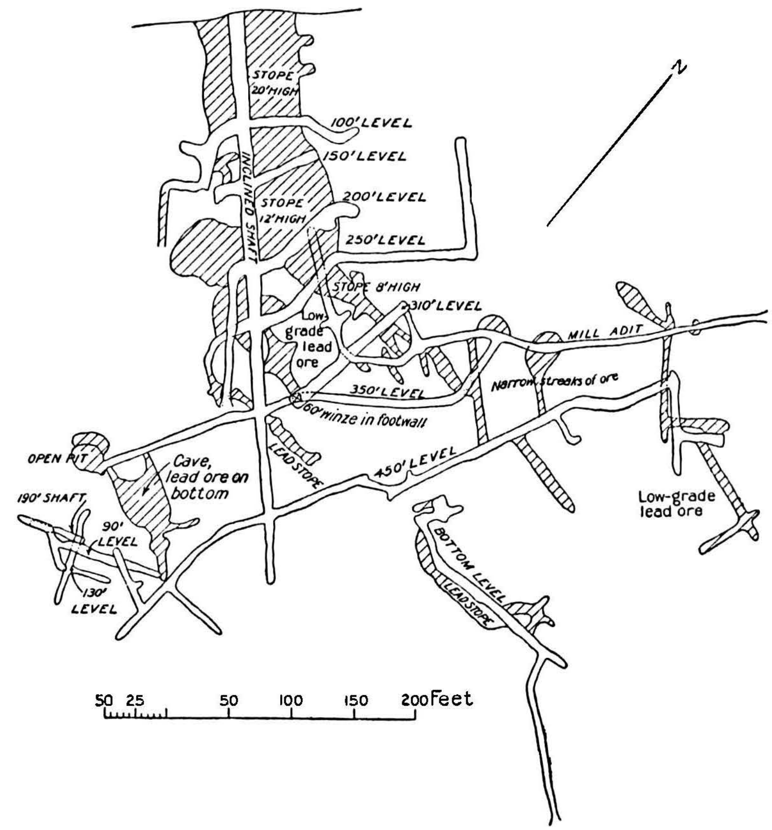

FIGURE 16.—Plan of underground workings, Total Wreck mine.

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

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

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

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

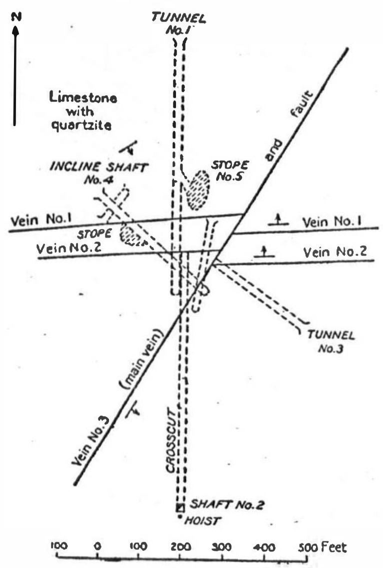

FIGURE 17.—Diagrammatic plan of veins of Total Wreck mine.

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

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

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

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

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

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

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

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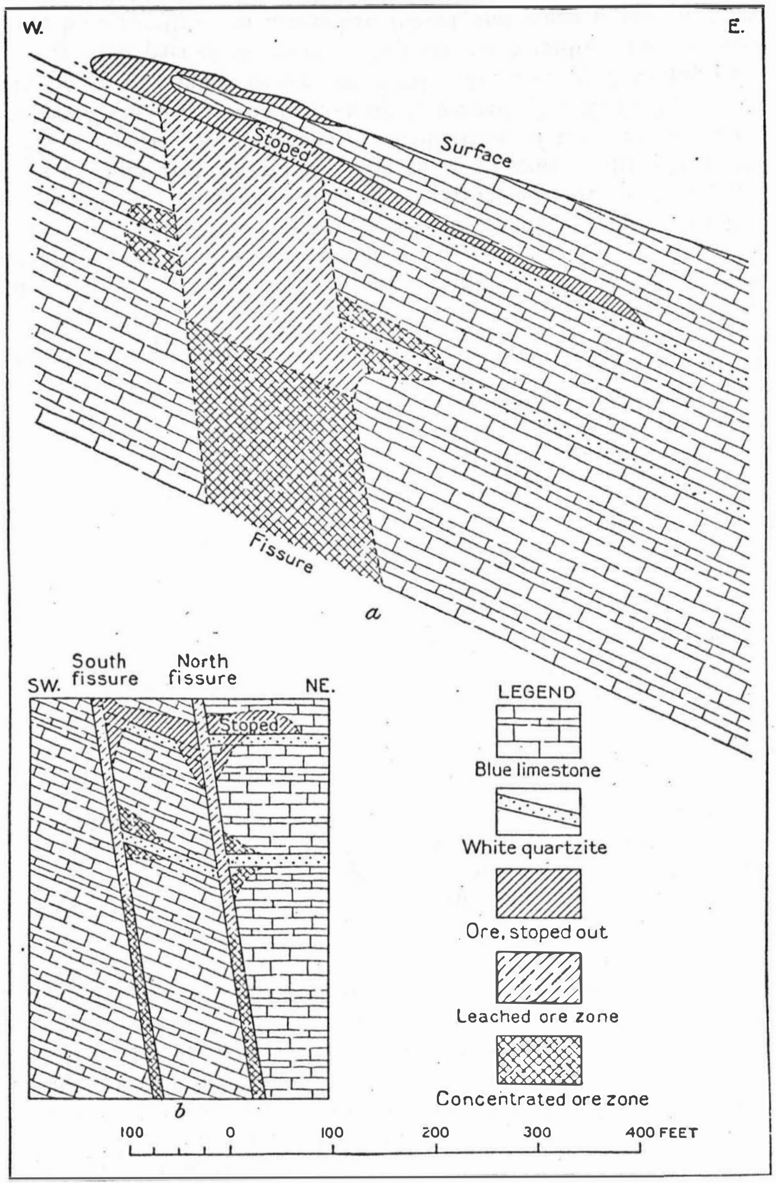

FIGURE 18.—Sections of fissures and ore bodies in Total Wreck mine. *a*, Oblique section near surface; *b*, cross section on 350-foot level.

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

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

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

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

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

COPPER CAMP.

GENERAL FEATURES.

The Copper camp is located 3 miles southwest of the Total Wreck mine near the center of the Empire Mountains, in a north-south belt about a mile wide and 3 miles long, mostly in the west side of an irregular open valley or embayment that extends northward into the heart of the range and is known as the Basin. The principal settlement is near the Hilton ranch, in the northern part of the belt at an elevation of about 5,000 feet. It is reached by a wagon road of easy grade leaving the Pantano road about a mile north of the Total Wreck mine. The deposits are in the same limestone belt as those of the Total Wreck mine and extend from the granite contact on the north through the foothills and into the lowland on the south. The rocks are principally the dark limestone with interbedded quartzites, about the same as at the Total Wreck mine. They dip in general about 45° SSE. or S. They are faulted, folded, and

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intruded by the granite batholith on the northwest, the characteristic zone of contact metamorphism being well developed and the two rocks welded together in places. They are cut by dikes of the same granite and by aplite, rhyolite, and greenish lamprophyric rocks. The clearest examples of the intrusive character of the granite found in the area occur in this camp, at the Copper Point mine and elsewhere.

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

VEINS AND ORES.

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

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

VERDE QUEEN MINE.

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

At the principal opening, the Verde Queen, the vein or lode has a width of about 25 feet and dips 80° SE. It is in the gray limestone, and a bed of quartzite forms the footwall. It is opened principally by a 280-foot shaft and three levels, located 50, 150, and 280 feet below the surface and containing respectively 75, 125, and 50 feet of drifts. The ore contains chiefly copper, silver, and lead in the form of the usual copper carbonates, silver chloride, and lead molybdate, in a yellowish-brown gangue composed of utahite, hydrous sulphate of iron, and a little quartz. Much of it carries from $4 to $7 in gold

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to the ton. The mine, which was not enterable at the time of visit, is said to contain considerable good ore in sight.

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

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

HILTON GROUP.

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

JEROME NO. 2 MINE.

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

FORTY-NINE CLAIM.

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

RED CLOUD MINE.

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

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

HILTON RANCH VEIN.

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

COPPER POINT PROSPECT.

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

DAVIDSON CANYON AND VICINITY.

CALIFORNIA MINE.

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

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

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

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

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

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

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

MONTANA MINE.

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

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

LAVERY MINE.

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

GREATERVILLE DISTRICT.

GENERAL FEATURES.

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

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

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

a mile in diameter. It rises 500 feet above the surrounding surface and is associated with the mineral deposits. Quaternary gravels overlie the granite on the northwest and the Mesozoic and other formations on the east.

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

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

LODE DEPOSITS.

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

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

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

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

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ANDERSON PROSPECT.

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

ENZENBERG MINE.

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

FRIEZ PROSPECT.

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

HANCOCK MINE.

The Hancock mine is 2 miles west of Greaterville and a mile east of the Mountain King mine. It is on a 3-foot quartz vein in granite. The vein dips to the west and is opened mainly by a 100-foot shaft

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which shows galena and pyrite. The mine was worked by W. M. Robinson in 1885 and is reported to have shipped some rich ore carrying lead carbonate and horn silver.

HUGHES MINE.

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

QUEBEC MINE.

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

ROYAL MOUNTAIN MINE.

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

ST. LOUIS MINE.

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

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

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

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

SUMMIT MINE.

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

YUBA MINE.

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

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

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

WISCONSIN MINE.

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

OTHER PROSPECTS.

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

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

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

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

PLACER DEPOSITS.

LOCATION.

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

HISTORY AND PRODUCTION.

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

The gravels were worked in those days by rocker and long tom, as water was very scarce. A number of Mexicans made their living by packing water in canvas or goatskin bags on burros from Gardner Canyon, 4 miles to the south. The current price of water was about 3 cents a gallon. Notwithstanding the difficulties of work, the output for each man was $10 or more a day. By 1881[1] the richer stream gravels had been worked over, wages were reduced, and the work became more difficult, and these conditions led a number of men to leave the camp. Many were also discouraged by the Indians, who usually attacked small parties away from the town and rendered the life of the prospector unsafe until late in the eighties.

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

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

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

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

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

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

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

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

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

[2] Report of the Governor of Arizona for 1903, p. 229.

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

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

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

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

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

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

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TOPOGRAPHY.

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

CHARACTER AND DISTRIBUTION OF GRAVEL.

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

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

GOLD.

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

PRODUCTIVE GULCHES.

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

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

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

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

Kentucky Gulch.—In Kentucky Gulch, which heads south-southeast of Granite Mountain and joins Boston Gulch at Kentucky camp, the gold occurs throughout its length on bedrock in a channel 6 to 10 feet in width. At the upper end of the gulch the pay streak lay at the surface, but the covering gradually thickened to 6 feet at the mouth of the gulch.

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

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

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

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

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

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

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

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

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

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

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

SOURCE OF THE PLACER GOLD.

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

It accordingly seems probable that the placers may have been formed by the concentration of the gold freed by long-continued weathering and erosion from the vast amount of rock that was removed from the area extending westward to and beyond the present crest of the Santa Rita Mountains. The talus and wash, at first relatively lean in gold, were originally spread out upon the side of the mountain in a vast, more or less continuous constructional sheet sloping eastward toward Cienega Creek. As the top or surface gravels were removed their gold content was mostly left behind, gradually

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enriching the portion of the sheet which remained. Finally, owing to climatic changes or uplift of the range, the present drainage lines were laid out and developed, whereupon gold extraction and concentration became more intense in the rapid downcutting of the stream courses and the consequent removal of the gulch gravels, and this process is still going on. In the process of concentration, where the drainage is normal, certain ledges contribute more to the gulches by which they or their resultant gravels are drained than to others.

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

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

FUTURE OF THE CAMP.

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

[1] Oral communication.

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

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LOCATION AND GENERAL FEATURES.

The Harshaw district adjoins the Wrightson and Redrock districts on the south. It is about 5 miles wide and extends from Sonoita Creek at Patagonia 9 miles southeastward to a point 3 miles beyond Harshaw. Harshaw Creek marks the northeast boundary; Meadow Valley Flat the east boundary; an east-west line passing just south of the American mine the south boundary, separating it from the Patagonia district; and the main ridge of the Patagonia Mountains to the west of Alum and Flux gulches the west boundary, separating it from the Palmetto district (Pl. I, in pocket).

The principal settlement is Patagonia, which is on the railroad and is a flourishing mining center with about 200 residents. It is the chief distributing and supply point for the district as well as for a much larger surrounding region. Two daily passenger and mail trains stop here.

Harshaw, in the south-central part of the district, was also once a prosperous village and camp and has mostly stone buildings, but in 1909 only a few families were living there. The other principal camps, as shown on the map, are the Hardshell, World's Fair, Wieland, Elevation, Standard, and Thunder. A daily stage and mail service is maintained between Patagonia, Harshaw, Mowry, Washington, and Duquesne. The roads and trails in the district are good and the mines and prospects as a rule are easy of access.

The topography is rough and much of it in the western part, which lies in the Patagonia Mountains and rises to elevations of more than 6,000 feet, is rugged, of the type produced by erosion of volcanic rocks in an arid climate. Red Mountain, a castle-shaped mass in the north-central part of the district just south of Patagonia (Pl. XVI, *B*), reaches an elevation of 6,350 feet, whence the surface declines to 4,500 feet in a radius of 2½ miles. South of Red Mountain and east of the Patagonia Mountains the elevations rise to about 5,000 feet. The drainage is principally northwestward into Sonoita Creek by way of Harshaw Creek on the east and Alum Gulch on the west. Both streams flow through canyons in the middle parts of their courses.

The bedrock of the district comprises five or more formations, which, named in ascending order, are the Paleozoic limestones, quartz diorite, granite porphyry, rhyolite, and andesite (Pl. II, in pocket). They are described under "Geology" (p. 44), and their general relations are indicated in section *E–F* on Plate III (in pocket). The most important of the formations with reference to the mineral deposits are the diorite, granite porphyry, and rhyolite.

The Paleozoic limestones occupy only a small east-west belt along the middle part of the southern border of the district, but this belt is a part of the limestone area around Mowry on the south, described on page 294.

The quartz diorite and granite porphyry belong with the group of Mesozoic intrusive rocks and the rhyolite and andesite with the Tertiary volcanic rocks.

The quartz diorite occupies an irregular belt about three-fourths of a mile wide and nearly 3 miles long, extending from a point about a mile southeast of Harshaw northwestward to the World's Fair mine and Alum Canyon.

The granite porphyry occupies a belt about half a mile wide along the western border of the district, where it seems to underlie the rhyolite. This belt is but the eastern part of the much larger area in the Palmetto district, on the west.

The most extensive formation is the rhyolite, which, besides occurring in a north-south belt near the west border of the district, occupies a belt 2 miles wide extending across the north-central part and includes practically the whole of Red Mountain. It is a coarsely porphyritic, tridymite-bearing rock profusely impregnated with pyrite, chalcopyrite, and chalcocite disseminated in crystals and grains and at a number of places contains promising copper prospects. The oxidation of the iron content of these minerals colors the entire mountain a brilliant red. In Alum Canyon, on the southwest, the weathered surface of the rock and the alluvial gravels derived from it are coated with efflorescences and incrustations of alum, some of whose constituents seem to be derived from the pyritic contents of the rock by oxidation.

The next most abundant rock is the andesite, which occurs in flows and tuffs filling chiefly the valleys and low places. It overlies the rhyolite and other older rocks. Besides occupying an irregular circular area about 2½ miles in diameter in the south-central part of the district, north of Harshaw, it also occurs in a belt about a mile wide extending thence northward along the Patagonia road for about 3 miles.

In the western part of Alum Canyon occur also locally some syenitic rocks, described on page 68.

Occupying two belts, each about 1½ miles in width, across the northeast and southwest ends of the district, the Quaternary gravels shown in Plate II more or less deeply cover the bedrock formations above described.

LODE DEPOSITS.

DISCOVERY AND MODE OF OCCURRENCE.

The Patagonia Mountains are well mineralized and contain many attractive prospects, chiefly in copper ore of concentrating grade. Mineral deposits were discovered here in the early days. Among the first producing properties in the Harshaw district are the Old Trench, January or Pádrez, Hermosa, Hardshell, Alta, Flux, World's Fair, and other mines, most of which are opened to depths of 300 to 500 feet and have produced large quantities of high-grade lead-silver ore.

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The deposits occur principally in veins in the diorite, granite porphyry, and rhyolite, generally in association with younger intrusive rocks. They consist chiefly of lead-silver ores carrying some gold and are in general very similar to the ores of this class occurring in the Tyndall and Wrightson districts, on the northwest. Some of the mines, however, contain principally copper minerals. The veins are mostly large and the ores are in general easily reduced.

The district contains about 40 mines and prospects, most of which are given in the subjoined list. Some of them, as the Hardshell, Hermosa, Alta, World's Fair, and Flux, are opened to depths of several hundred feet and have produced many thousand dollars' worth of rich ore. They occur mostly in the canyons or deep drainage ways, where the veins and deposits have been exposed by erosion.

Alta.	Flux.	Red Bird.
American.	Garfield.	Red Rock.
Aztec.	Great Silver.	Santa Cruz.
Basin.	Hampson.	Sonoita.
Blue Nose (Abe Lincoln).	Hardshell.	Standard.
Blue Eagle.	Hermosa.	Sunnyside.
Brown.	Humboldt.	Thunder.
Buffalo.	Invincible.	Trench.
Christmas Gift.	January.	Volcano.
Cotton Tail.	Josephine.	Wieland.
Dewey.	Lead Queen.	World's Fair.
Elevation.	Morning Glory.	

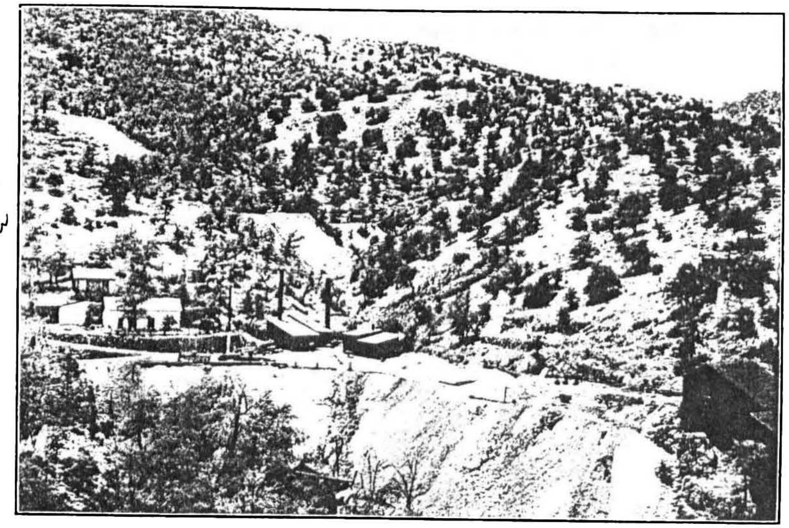
WORLD'S FAIR MINE.

The World's Fair mine is near the center of the western part of the district, 2 miles west of Harshaw, on Alum Gulch, at an elevation of about 4,680 feet. (See Pls. I and II, in pocket.)

It was located in 1879 by a Mr. McNamee, who shipped a considerable quantity of ore from it and is said to have abandoned it in 1881. In 1883 William Moran relocated the property and in 1884 sold it to Frank Powers, the present owner, for $100. Mr. Powers is reported to have soon shipped a few carloads of ore of 25 tons each, which brought from $8,000 to $25,000 a car, and by 1903 it was said that $600,000 worth of ore had been blocked out in the mine ready to ship. Since its acquisition by Mr. Powers it has been worked at intervals only[1] but has always produced considerable rich ore, which was mined or milled and shipped as desired. In 1907, for instance, the production was $74,210 worth of ore, in lead, copper, gold, and silver.[2] During the year 1910 the production was $42,730.82.[3] In 1912 a shipment of a few carloads, mostly very rich

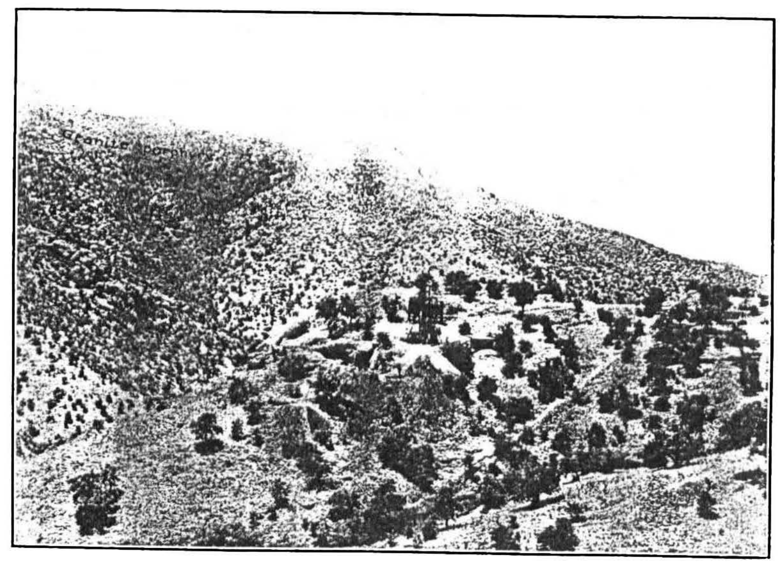
[1] U. S. Geol. Survey Mineral Resources, 1905, p. 155, 1906; idem, 1906, p. 170, 1907.

U. S. GEOLOGICAL SURVEY BULLETIN 582 PLATE XVII



A. WORLD'S FAIR MINE.

Mill at lower right. Looking S. 70° W.



B. FLUX MINE.

Three R Mountain of granite porphyry in left background. Contact fault scarp of granite porphyry and rhyolite crosses left field. Looking S. 55° W.

ore, is reported to have been made to the Selby smelter. Early in August, 1914, the mine was said to be shipping two carloads of rich ore a week to Douglas.

The property comprises a group of eight claims and is reported to have produced more than $1,000,000, of which over $500,000 was in high-grade ore. Several hundred thousand dollars' worth of medium-grade ore, it is said, now lies on the dumps. It is reported that the owner has received several offers for the mine, ranging as high as $500,000 to $600,000,[1] but that the price asked has been $1,000,000, of which 10 per cent was to be paid down before anyone would be allowed to enter the mine to make an examination. In 1913 the mine was reported to have been sold or bonded to the Copper Queen Co. for $800,000. Early in 1914 the tax commission of the State of Arizona was reported to have valued the mine at $155,000 and to have collected $7,000 in taxes based on this valuation. More recently it has been reported that Charles E. Knox, president of the Montana-Tonopah Mining Co., of Tonopah, Nev., and A. Y. Smith, formerly manager of the Prince Consolidated, of Pioche, Nev., have taken over the mine, and are shipping about 50 tons of ore daily.

The mine is said to be developed to a depth of 600 feet and is the deepest mine in the district. It contains about 15,000 feet of drifts, tunnels, stopes, shafts, and winzes. The owner was absent at the time of visit and the mine was closed. The main entrance to the mine is a crosscut tunnel at an elevation of 4,680 feet, from which, it is reported, a winze has been sunk to a depth of 600 feet with drifting 1,000 feet each way from the winze on the vein at levels spaced 100 feet apart.

The principal equipments are a 10-stamp mill supplied with concentrators, etc., which made an apparently unsuccessful run of three months in 1897 and has been idle ever since. There is also a steam hoist within the tunnel and power drills.

The topography is rough, as shown in Plate XVII, *A*, and the canyon on the north below the property is impassable, so that the mine is reached by 1½ miles of wagon road of easy grade descending the canyon on the south from the county highway at a point a mile west of Harshaw.

The country rock, as shown in figure 31, is a small area of diorite which forms the northward continuation of the Harshaw belt, but which at the mine is almost surrounded, overlain, and intruded by rhyolite and is more or less pyritic and mineralized. The rhyolite, which is also considerably mineralized and altered, seems to be similar to that at Red Mountain, with which it is apparently connected.

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Just across the canyon east of the mine the surface is underlain by a purple altered andesitic volcanic rock composed almost wholly of oligoclase-andesine and a little biotite or altered hornblende.

The deposits, to judge from the location of the workings, are about all on or associated with the contact of the rhyolite intruded into the diorite. The workings trend north-northwest and the deposits seem to dip about 80° WSW. into the mountain, but in the mine the dip is said to be about 45°. From the main entrance, which is located about 40 feet above the floor of the canyon, the openings and croppings extend for one-eighth of a mile or more southward and through a vertical range of about 400 feet, which together with the 600 feet of depth the vein is said to have in the mine gives for the deposits a known vertical range of about 1,000 feet. The croppings are irregular, however, and in places difficult to identify and follow.

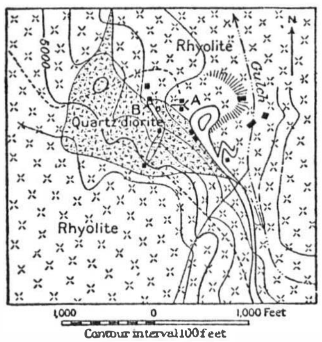

FIGURE 31.—Geologic map of the vicinity of the World's Fair mine.

The croppings range from 10 to 14 feet in width, and the average width of the vein in the mine is said to be about 6 feet, nearly all of which is good workable ore. The metalliferous minerals are said to occur mostly in the rhyolite or hanging-wall side of the contact. A considerable portion of the openings to the south of the mine are on the north-south rhyolite dike cutting the diorite. The croppings of the dike are 15 to 25 feet wide and consist of a reddish-yellow siliceous rhyolite. The valuable metals in the ore are silver, gold, lead, and copper, silver predominating. The gangue of the vein is commonly said to be quartz, but in most of the ore seen on the dump barite seems to equal the quartz in amount, and in some run of mine specimens it is the chief or only gangue mineral, quartz being inconspicuous or absent. The barite gives to much of the ore a sparry aspect and is particularly prominent as seams, blades, and plates filling fractures and cavities, denoting that much of it is of late or postvein age.

In the upper workings the ores, it is said, were mostly rich lead-silver sulphides, but below water level, in the unoxidized zone, where they maintain or exceed their surface tenor, they carry besides galena considerable copper, mostly in the form of tetrahedrite or gray copper, with some chalcocite and antimonial silver, in places rich in gold. In fact, a considerable part of the ore seems to be antimonial silver. There is also a sprinkling of finely disseminated chalcopyrite and pyrite. The ores from the deeper part of the mine are reported

to average about 20 per cent in copper and 500 ounces in silver and $15 in gold to the ton. Judging from about 500 tons or more seen on the dump the ore is mostly hand-sorted and well graded, seemingly by screens, into sizes ranging from that of a walnut up to that of a 10-inch bowlder. It is then shipped direct to the smelter at Selby, Cal.

CHIEF GROUP.

The Chief group of copper prospects consists of 12 claims adjoining the World's Fair property on the southwest and near the Three R group on the northwest. It is owned by E. E. Bethel, of Patagonia. It is opened by shallow shafts to depths of 50 feet or more, aggregating about 500 feet of work. It is said that recently the group was leased to the Calumet & Arizona Copper Co. for $75,000 for a period of two years and that it is being developed at a substantial rate.

HUMBOLDT MINE.

Near the head of Alum Gulch, about a mile south of the World's Fair mine and 1½ miles west of Harshaw, are several small mines—the Humboldt, Red Bird, and January—which have been productive and whose geologic and mineralogic features are similar to those of the World's Fair mine, the deposits being associated with the rhyolite intruded into the country-rock diorite.

The Humboldt deposit, on the ridge between the two forks of the canyon, was discovered in 1885 by William Harrington and James Gillespie, who soon worked it and took out lead-silver ore. It was worked mostly in 1887 to 1889 and has produced about $10,000 worth of ore. On the dumps there are about 5 tons of ore which shows dark fine-grained galena, sphalerite, and seemingly a little tetrahedrite in a quartz gangue. On November 30, 1912, this mine, together with its group of claims, is said to have been purchased for $10,000 by the Phelps-Dodge Co., which planned to operate it and ship the ore to the Copper Queen smelter at Douglas.

The mine is developed by about 700 feet of work, which includes a 160-foot shaft inclined 80° S., located at an elevation of 3,950 feet on the point of the ridge. It is in rhyolite intrusive into diorite, 15 feet south of a contact which dips 85° S. Water stands within about 15 feet of the collar of the shaft.

The ore is lead-silver ore in the shaft and upper tunnel and lead, silver, and copper ore, all sulphide, in the lower workings. It contains considerable pyrite, with which atmospheric action heavily incrusts the surface of the ore on the dumps, the cement presumably being the resulting iron oxide.

About a quarter of a mile southwest of the shaft, on the east side of the gulch, at an elevation of 5,000 feet, is a tunnel in rhyolite,

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8-25

about 30 feet south of the rhyolite-diorite contact, which here strikes N. 45° E. The tunnel is on a slip in the rhyolite that is parallel to the contact and dips 83° NW. At 40 feet from the mouth is a fault striking N. 50° E. and dipping 87° SE. The rock north of this fault is dark and very much altered and seems to be diorite. It contains disseminated pyrite. Along this fault there is 2 feet of crushed material, of which the 2 to 3 inches on the hanging-wall side is very siliceous and shows galena and a little gray copper.

Below this tunnel, at an elevation of 4,910 feet, is a lower tunnel which starts in altered sheared rhyolite and runs N. 55° E. At 20 feet from the entrance a 13-foot crosscut to the south exposes a very siliceous zone 9 feet wide which dips 70° NE. This zone shows disseminated pyrite and chalcopyrite, and in the crosscut the walls are coated with copper and iron sulphates.

On the west side of the gulch 200 feet southwest of the lower tunnel and 10 feet above it is the mouth of a new tunnel, which runs N. 75° W. for about 55 feet in altered silicified rhyolite. It seems to be on a shear zone that dips 80° N. Some ore from the dump shows pyrite, chalcopyrite, and galena disseminated through the siliceous material and concentrated in joint or shear planes. At 30 feet above the mouth of the tunnel is a shaft, the dump of which shows pyrite and chalcopyrite in dark quartz.

In all the Humboldt workings the ore deposits occur principally in rhyolite, 15 to 30 feet from its contact with diorite, in a fault or shear zone that is parallel to that contact. Sulphides occur at the surface and water stands in the lower tunnels and in the old shaft at a depth of 150 feet.

RED BIRD MINE.

The Red Bird mine and the January mine, described below, are on patented claims. They are owned by the Blue Flag Mining Co., of Summit County, Colo., and have produced considerable ore but have since been idle for some time.

The Red Bird, also known as the Uncle George or Norton mine, is just east of the Harshaw and World's Fair road, at an elevation of 4,900 feet. It is opened along a dike of rhyolite that dips 78° NE. in the diorite and extends from the mine for about a quarter of a mile down the road and stream to the northwest. The dike is 15 to 20 feet wide, and the diorite for 4 feet from the contact on the northeast or hanging-wall side contains considerable manganese. Alum and sulphur are being leached from the rhyolite and the dump, which is large, indicating that the work is extensive. Owing to a cave-in underground examination could not be made. The mine is said to have produced a fair amount of ore, some of which was very rich.

JANUARY MINE.

The January mine is about one-third of a mile north of the Red Bird, on the northeast side of the canyon and the World's Fair road. It is said to have been worked in the early seventies under the name of Pádrez, but has been held since 1882 by the Blue Flag Mining Co. The total production is estimated to be about $12,000. A pocket of argentite found near the surface on the northeast corner of the claim is said to have produced 10,000 ounces of silver.

Two old shafts are located on a continuation of the Red Bird dike or vein, and where opened the vein is 6 to 7 feet in width. It strikes N. 30° W. and dips 75° NE. About 50 feet east of the vein is a vertical timbered shaft, but it contains no ladders. Water stands about 80 feet below the surface. The material on the dump at this shaft consists mostly of diorite, but the dike or vein has been cut either by this shaft or in a crosscut from it. Considerable good-looking ore was noted on the dump. It contains mostly galena, sphalerite, pyrite, and argentite in a quartz gangue stained with limonite and a little lead carbonate. It is said that ore of this class averaged 35 per cent in lead and 60 ounces to the ton in silver.

TRENCH MINE.

The Trench mine is about 1¼ miles northwest of Harshaw and a quarter of a mile southeast of the Red Bird mine on an eastern tributary of Alum Gulch just below the 5,000-foot contour. It is on or near the World's Fair road one-third of a mile off the stage road. The deposit was discovered in the fifties or earlier and was worked in 1859 by Col. Titus.[1] It was patented by J. B. Hagan prior to 1872. In the middle and late seventies it was extensively worked by Señor Pádrez.[2] In 1880 the present owner, the Hearst estate, of California, purchased the mine and sunk a 400-foot shaft, which is the most extensive piece of work on the property, and in the middle eighties Hagan & Tevis took out a great deal of rich ore. In 1889 Powers and partners took out and sold to the Crittenden smelter two carloads of ore which averaged 40 per cent lead and 60 ounces to the ton in silver and netted $4,400. At present writing it is said that W. A. Clark has a bond on the property and is operating it with a force of 20 men.

The mine is said to have produced a large amount of high-grade lead-silver ore, much of which has been treated in the old plant now on the ground. The tailings show that a large amount of work has been done, and about 2,000 tons of good-looking ore lies on the dump.

[1] Blake, W. P., Report of the Governor of Arizona, 1899, p. 11.
[2] Hinton, R. J., Handbook of Arizona, p. 126, San Francisco and New York, 1878. Raymond, R. W., Statistics of mines and mining in the States and Territories west of

The deposits are contained in a fissure vein which dips 60° NNE. in diorite that is intruded by rhyolite near by. The vein ranges from 1 foot to 5 feet in width, and is worked interruptedly throughout the length of the claim, the pioneer work having been done on the west part, it is said, to procure lead for the manufacture of bullets. The vein contains chiefly cerusite, pyromorphite, and silver-bearing galena in a gangue composed mainly of quartz, rhodochrosite, and specular iridescent hematite derived from pyrite. The ore is similar in some respects to the Hardshell ore. The vein and ore are banded, porous, and drusy.

JOSEPHINE MINE.

The Josephine mine is about a quarter of a mile northwest of the Trench mine, at about the same elevation, near the World's Fair mine road. The deposit was discovered in the middle seventies but was not worked until about 1885. Operations then continued until 1890. In 1899 it was relocated by the present owners, Messrs. Farrell, Powers, and Morrison, who have done considerable work on it. It has produced $750,000 worth of ore, of which $375,000 was taken out during the period from 1893 to 1897, when about three carloads a month were shipped.

The mine is developed by about 3,500 feet of work, extending to a depth of 500 feet on the dip of the vein. Most of the work was done in 1893 to 1897.

The mine is on the northwesterly continuation of the Trench vein, which is opened at intervals between the two mines and dips about 45° N. in the same diorite country rock, with intrusive rhyolite near by. The vein is said to widen in the lower part of the Josephine mine.

The ore here is about all sulphide. Most of that which has been produced is said to average 60 per cent in lead and 45 ounces to the ton in silver, and on the lower levels the ore contains also about $2.50 in gold. Some very rich ore running 1,800 ounces or more in silver to the ton, it is said, was taken out on the west toward the rhyolite butte. The mine is reported to contain in sight 80,000 tons of ore that averages 5 per cent in lead and 5 ounces to the ton in silver.

SUNNYSIDE MINE.

The Sunnyside mine is 1¼ miles southwest of the January mine and 2½ miles west of Harshaw, on the upper part of Alum Gulch, at an elevation of about 5,800 feet. The property comprises a group of eight claims (fig. 32). It was located in 1897 by R. Farrell, the owner. During the first half year of his ownership, with a force of 16 men working in the shafts, he shipped five carloads of copper carbonate ore that brought returns of $5,000 in copper and silver. Early

8-26

in 1912 the property was reported to be bonded to L. D. Ricketts, of Cananea.

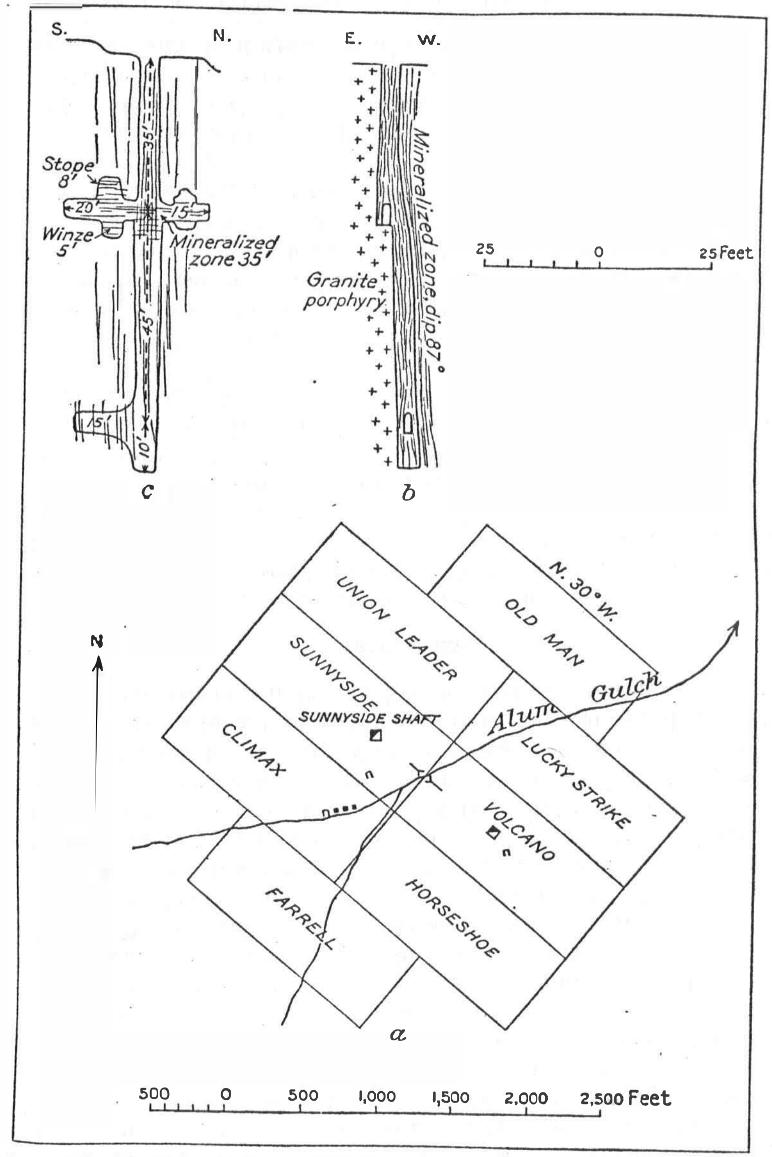

FIGURE 32.—Map and sections of Sunnyside mine. *a*, Claim map of group; *b*, cross section of shaft and ore zone; *c*, longitudinal section of shaft and ore zone.

The deposits are contained mainly in a mineralized zone about 200 feet wide in granite porphyry, which trends N. 50° W. across the claims. This zone consists of belts of sheared and silicified country rock which in places shows copper carbonate ores associated with limonite and quartz. The belts are opened principally by several shafts to depths of about 90 feet. From the Volcano shaft, sunk to a depth of 30 feet on a siliceous belt which dips 70° SW. and carries copper carbonates, were shipped two carloads of ore that averaged 9 per cent in copper and 2 ounces to the ton in silver.

In the Sunnyside shaft, which is 90 feet deep, an 8-foot stope in a drift to the south yielded 22 tons of malachite ore that averaged 20 per cent in copper and carried a little native gold and some silver. The malachite is well crystallized, individuals as much as one-eighth of an inch in length being noted on drusy surfaces, and in the more massive parts of the ore fibrous rosette forms are prevalent. In the same drift just under the stope is a 5-foot winze from which has been taken about 15 tons of oxidized ore that is said to average 14 per cent in copper and 5 ounces to the ton in silver. This ore is very fine, soft, dark greenish-gray earthy material and is apparently a mixture of iron oxides with copper carbonates.

To a depth of 40 feet the mineralized zone is composed largely of quartz carrying considerable copper carbonates, but below this depth the shaft passes through soft earthy material containing a few small masses of siliceous rock and a larger amount of iron oxide than is seen at the surface. At a depth of 80 feet in a small south drift another small pocket of the black oxidized copper ore was uncovered. The soft material, through which the shaft extends, is said to average about 2 per cent in copper carbonates. On the dump there are 500 tons of reported 3 per cent copper ore and 15 tons of 14 per cent ore.

STANDARD AND THUNDER PROSPECTS.

Two-thirds of a mile south of the Sunnyside mine and 1½ miles west of American Peak in the extreme head of Alum Gulch are two prospects, the Standard and the Thunder, whose deposits are similar to those of the Sunnyside mine. They occur in shear or sheeting zones in the granite porphyry country rock and contain principally copper minerals. The Standard group consists of 14 claims. Here some chalcocite is reported to have been found at a depth of 20 feet, associated with pyrite and chalcopyrite, in a 40-foot shaft.

On the Thunder group of eight claims the granite porphyry, which in general is silicified and altered and contains widely disseminated pyrite and chalcopyrite, includes northwest-southeast bands or shear zones and also an east-northeast system of faults and joints with flat southerly dip, along both of which the sulphide ore minerals are concentrated. Here all but the first 20 feet of an 82-foot tunnel driven westward in one of these zones is in mineralized soft rock

regarded as low-grade ore and said to average about 0.6 per cent in copper and 2 ounces in silver and 40 cents in gold to the ton. The metallic minerals are pyrite and chalcopyrite, with a little tetrahedrite and molybdenite.

INVINCIBLE PROSPECT.

Beginning at the north foot of the mountains, in the mouth of Alum Canyon,[1] a series of a dozen or more prospects, some of which are on patented ground, extend southward along the course of the canyon and gulch for about 2 miles to a point within three-fourths of a mile of the World's Fair mine. These prospects are accessible by wagon road ascending the canyon and gulch from the north. The topography is rough. The country rock containing the deposits is mostly the rhyolite of Red Mountain, already described.

The Invincible prospect is 2½ miles south of Patagonia, in the north foot of the mountains, at an elevation of 4,200 feet in Alum Canyon. It belongs to the Ivanhoe Mining Co., of Minneapolis, Minn. It is opened by a tunnel 60 feet in length, running N. 25° E. into the base of Red Mountain.

The country rock is a nearly massive porphyritic rhyolite carrying a great deal of disseminated cupriferous pyrite and a little chalcopyrite. It is typical of the Red Mountain mass and is said to contain in general from 1 to 3 per cent of copper and about $1 in gold to the ton. It is cut by a series of joints dipping 25°–30° NNW., in which there is a concentration of nearly pure iron sulphides in veinlets or bands, the widest 1½ inches in width. The tunnel is headed to intersect a 20-foot quartz vein several hundred feet above and 500 feet from the mouth, the iron and copper sulphides in which are said to carry from $5 to $19 in gold to the ton. In the tunnel a good deal of alum and sulphur is being deposited on the walls and a few patches of blue copper sulphate were noted. The surface of the rhyolite is stained a deep red by iron. It is stated that the rock at this place has been tested for the manufacture of sulphuric acid and that the concentrates averaged 33 per cent of iron and 35 to 36 per cent of sulphur.

BLUE EAGLE MINE.

The Blue Eagle mine, belonging to James Hale, of Harshaw, is in Alum Gulch half a mile south of the Invincible prospect, at an elevation of 4,375 feet. The deposit was discovered about 1897 and was acquired in 1901 by the present owner, who in the next year or two worked it and shipped from it to the Douglas smelter about 60

[1] The term "canyon," as here used, refers only to the steep, high, and more or less box-sided portion of the Alum Gulch drainage way, about a mile in extent, lying near the north end of the Patagonia Mountains. The rest of this drainage way, though portions of it are canyon-like, is by priority of usage designated by the term Alum Gulch.

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tons of hand-sorted ore that is said to have averaged 18½ per cent in copper and 17 ounces in silver and $1.50 in gold to the ton. Considerable ore is in sight in the mine, which is now producing.

The mine is developed by a 240-foot tunnel on the vein, 20 feet each of upraise and crosscut, and a 50-foot winze. Haulage rates from the mine to the railroad are $1.50 a ton.

The country rock is rhyolite porphyry in which the deposits are contained in a well-banded quartz vein that strikes east and stands vertical. The croppings are coated with alum, sulphur, and some blue copper sulphate. The vein is about 2½ feet in width and carries good-looking copper ore but branches somewhat in feathery form. There is said to be present also an associated 8-inch vein or shoot, rich in black copper ore. The metallic minerals are well-banded bornite, pyrite, chalcopyrite, and argentite, contained in a quartz gangue. Some oxidized ores are associated with sulphides at the surface.

HAMPSON PROSPECT.

The Hampson prospect is about a mile southeast of the Blue Eagle prospect and three-fourths of a mile north of the World's Fair mine, at the end of the wagon road ascending Alum Gulch, on an eastern tributary that lies in the southwest base of Red Mountain, at an elevation of about 4,600 feet. It is on a fault fissure in the red porphyritic rhyolite, and an area of sharply upfaulted diorite 800 feet wide lies only 20 feet distant on the south, the formational contact being parallel with the fissure. Sheeting common to both the rhyolite and the diorite dips 45° E.

The ledge is opened by a 60-foot crosscut tunnel, 100 feet of drift, and two shallow winzes which owing to the steepness of the slope give a considerable depth. The fissure dips steeply to the south and ranges from 9 inches to 3 feet in width. It contains mostly crushed, altered, and in part soft rhyolite and rhyolite gouge with some quartz and in places a 3 to 4 inch quartz vein or stringer, all more or less impregnated with pyrite and a little chalcopyrite, black copper sulphide, and some carbonates of iron and copper, in which, however, the percentage of copper as a whole must be small.

FLUX MINE.

Location.—The Flux mine, at one time called the Goshen mine, is 4 miles south of Patagonia and 2½ miles from the railroad, about a mile within the mountains from their north edge, in the head of Flux Gulch, a parallel southwestern tributary of Alum Gulch about half a mile southwest of the Blue Eagle mine, at an elevation of about 4,800 feet (Pl. I). It is reached by a good wagon road of easy grade.

8-28

History and production.—The Flux is reported to be an old Mexican mine and to have been located in the early fifties. In 1858 ore from it was smelted in the adobe furnace in Alum Gulch, near Sonoita Creek, and later, it is said, the mine furnished lead used for ammunition in the Civil War. It was relocated in 1878. It and the Hardshell mine together are reported to have shipped more than 50,000 tons of ore, most of which came from the Flux mine.

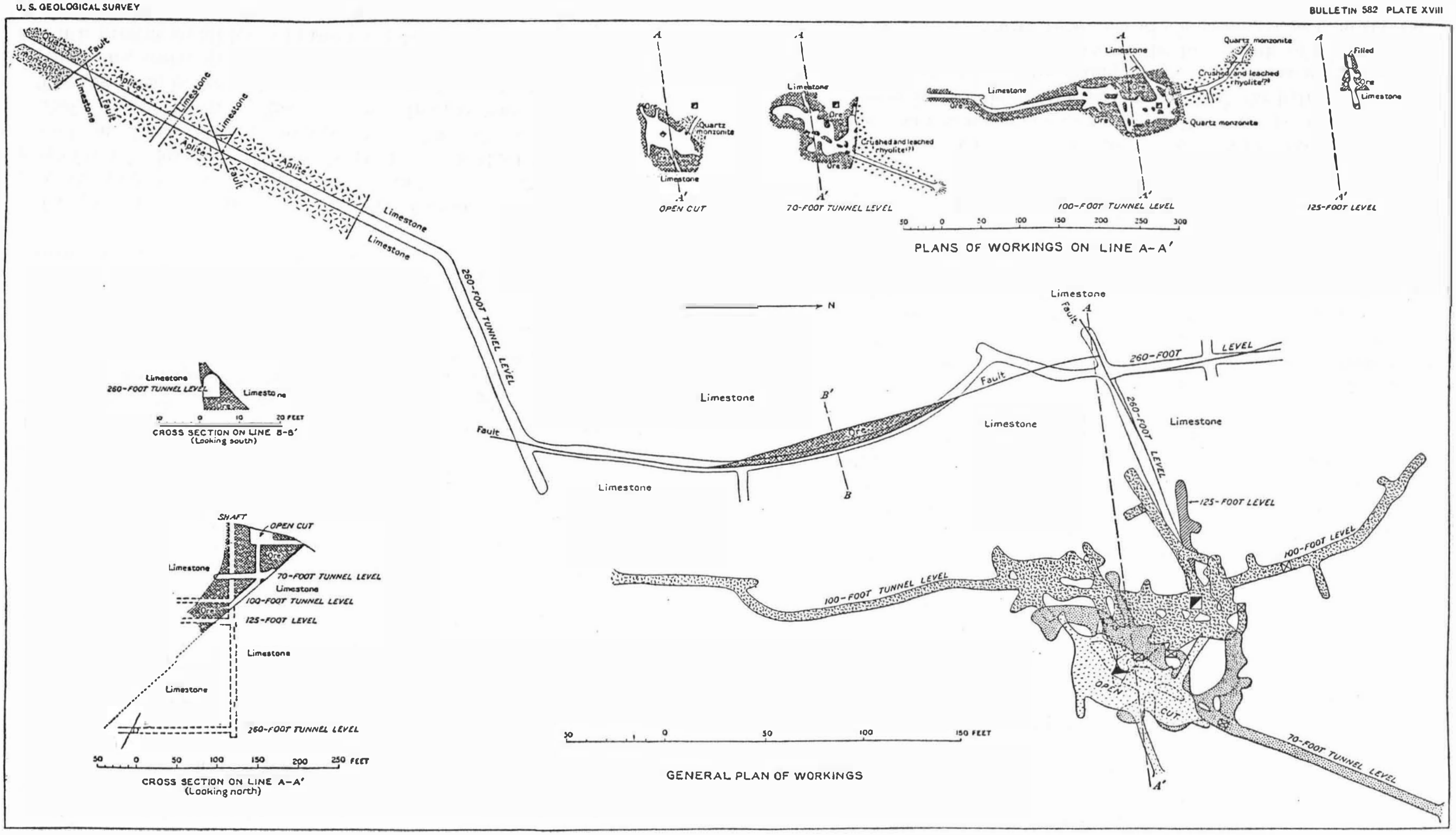
It was worked about 1882, and several thousand tons of ore was shipped to the Benson smelter. Later it was taken up by R. R. Richardson and partners, of Patagonia, under the present location title, which dates from January, 1897. During that year it produced nearly 1,000 tons of ore. Still later, through purchase, the title passed to Mr. Richardson, who is the present owner.

In 1896 the property, together with other Hardshell mines, was bonded to the Arizona Gold & Copper Co., which built the smelter at Patagonia, more fully referred to under "Hardshell mine." This company took from the Flux mine about 2,000 tons of ore, made a payment of $10,000 on the two mines, and after smelting the ore at Patagonia relinquished the property.

Besides the ore treated by the Alum Gulch, Patagonia, and Benson smelters, about 10 carloads of high-grade galena ore, averaging from $60 to $100 to the ton, were shipped to El Paso in 1904. In 1905 Benjamin Heney, of Tucson, took a bond on the mine, organized a company, and did much work on it, and by extension of time he still controlled it in 1909. He sunk the mine from 110 to 260 feet in depth, did about 800 feet of tunneling and drifting, passed from the oxide into the sulphide zone at a depth of about 250 feet, and in 1909 suspended operations. In October, 1914, the property was said to be bonded to California people, who will install a mill. It comprises a group of 11 claims.

Development and equipment.—The mine is developed by more than 5,000 feet of work, about all concentrated on the Flux claim, at the mine, where several veins or lodes seem to come together in the south shoulder of Flux Ridge in a large deposit that was first mined in an open cut just southeast of the shaft. The work consists mainly of tunnels, shafts, drifts, crosscuts, and stopes and is distributed on four levels, 70, 100, 125, and 260 feet below the surface, as shown in the cross section in Plate XVIII. This plate also shows the ground plan of the levels and some of the main workings, together with the ore deposits and the geology on the separate levels somewhat more in detail.

All the levels are entered by adit tunnels and the topography is such that another can still be driven at 400 feet below the collar of the shaft. The work includes a 260-foot main shaft, an 800-foot west



PLAN AND SECTIONS OF WORKINGS OF FLUX MINE.

tunnel, a 500-foot south tunnel, and 200 feet of crosscut on the second and fourth levels.

The lower tunnel connects with the shaft by a 120-foot crosscut on the 260-foot level. Most of the stoping, as shown in Plate XVIII, is on the 70-foot and 125-foot levels, from which most of the underground ore has been produced. There is also much open-cut work, for instance, the cut or pit east of the shaft, 75 feet long, 22 feet wide, and 15 feet deep. Most of the upper work is old and was done in the most irregular manner.

Topography and geology.—The topography, as shown in Plate XVII, *B*, is hilly but not rugged. As the ores are exposed at the surface in the upper end of the steep, narrow north-south ridge and a canyon or gulch several hundred feet deep lies on either side and a saddle almost as deep at the adjoining end, nature has all but mined the deposits herself.

The oldest rock formation at the mine is a small area or nucleus of principally Paleozoic limestone with some associated conglomerate and shale. These sedimentary rocks are intruded by quartz monzonite (?) and granitic aplite and together with them are surrounded, overlain, and intruded by the Tertiary rhyolite or so-called porphyry, while but a few hundred yards distant, in or near the deep gulch on the west, occurs the great fault contact between the rhyolite of the Flux mine and the granite porphyry of Three R Mountain, which probably also intrudes the Paleozoic beds in the vicinity of the mine. The course of this fault, which is about N. 30° W., is approximately followed by the 2½-mile canyon near by on the west and is marked by a boldly cropping silicified reef extending for several miles across the country from a point about three-fourths of a mile southwest of the World's Fair mine to the north base of the mountains.

The general structure common to the formations of the region is a sheeting which dips 40° NNW. and is well shown in the north end of Flux Ridge where the road ascends the hill. Prior to the advent of the sheeting, however, the older rocks were variously disturbed, as is shown by their variation in character and attitude.

The limestone is exposed mainly on the southeast slope of the hill at the mine, seemingly dipping off southeastward into the gulch, and it is present on all levels in the mine, being especially prominent in the lower ones. In places it is highly crystalline, crushed, brecciated, and altered. The west or lower 800-foot tunnel, 50 feet above the gulch, starts in quartz monzonite but soon passes into crystalline limestone, in which it extends throughout the rest of its course to the main shaft. The south tunnel starts and extends for 250 feet in highly crystalline limestone, somewhat crushed and brecciated, to the shaft, where the limestone gives way to rhyolite fault breccia.

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The shale, which is dark greenish and is not known to occur in the mine, is well exposed in the road cut on the top of the ridge just northwest of the camp. It dips to the southwest.

The quartz monzonite occurs at the portal and in the forepart of the west tunnel. It is a dark altered, highly sericitized and crushed granitoid rock. It is medium grained and is composed mainly of quartz and orthoclase, including some microcline, with hornblende and a little acidic plagioclase. That it is intrusive into the sedimentary rocks is inferred from its contact with the crystalline limestone in the lower tunnel.

Later the rock mass at the mine was seemingly intruded transversely by an east-west dike of aplite locally called quartzite and greatly resembling that rock. The aplite occurs in the large open cut on the west, where the ore deposits lie in association with it, as does also much milky-white quartz. It is apparently present also in the forepart of the lower tunnel. It is purple or reddish gray, fine to medium grained, with chiefly greasy-lustered quartz, and is more or less silicified. On the weathered surface it is stained reddish and yellowish by iron and altered. The microscope shows that it is composed mainly of quartz and orthoclase with a very little oligoclase and a little hornblende or biotite and that the feldspars are mostly sericitized and considerably kaolinized.

The rhyolite as exposed in its less altered form in the east slope of the hill west of the trail and about 100 feet above it is a normal gray pyritic rhyolite and on the weathered surface is stained reddish brown by iron, somewhat like the rhyolite of Red Mountain. At the mine, however, it is considerably brecciated and somewhat tuffaceous and by replacement seems to form the main repository for the ore.

Ore deposits.—Though several veins or ledges seem to center at the mine, particularly from easterly directions, the deposits occur principally in or associated with a main north-south shear zone or lode, the Flux lode, which approximately coincides with the axis of the ridge. The lode is said to have a known extent of 1½ miles. On the south it extends beyond claim No. 7 to the Powers and Keep properties, a mile distant, and on the north for half a mile to a point beyond the California claim, which is patented ground owned by Allison Bros. The portion of the lode south of the mine is said to be associated with limestone which accompanies it in the form of a reef, but to the north it lies mainly in rhyolite, in which openings on the California ground, for instance, show silver-lead ore similar to that of the Flux mine.

At the Flux mine the lode dips 45° W. and ranges from 30 feet or more in width at the surface to about 8 feet in the bottom of the mine, as indicated in Plate XVIII. This comparatively great width at the surface, however, should probably be regarded as a local enlargement of the mineralized zone by contributions received from the feeders coming in from the east and seemingly from the transverse aplite dike. The southeasterly foot wall of the less altered rhyolite probably retarded the circulation of the ore-depositing solutions.

The lode seems to be composed mainly of crushed altered, silicified ore-bearing rhyolite that may perhaps represent a dike. The entire mass in the upper workings from the surface down to the 125-foot level is said to have been ore, and much good ore, probably several thousand tons, seems to be still available.

The ore contains lead and silver with considerable associated iron and in the lower part of the mine a very little copper and zinc. The ore which has been produced was about all oxidized and averaged $12 or more to the ton.

The ore, especially the oxidized ore, is stained reddish brown and yellowish by hematite and limonite and some lead carbonate. It is mostly siliceous, rough, porous, or cellular and honeycombed, the feldspar having been dissolved out of the replaced rhyolite which forms the gangue. Some of it is chiefly a friable mass of crystalline gray and whitish cerusite or other lead carbonates and iron, with a very little quartz, which is mostly pyramidal, as shown in the north tunnel, and with it are associated the secondary silver minerals, mainly argentite.

In the bottom of the mine, however, on the 260-foot level, a body of sulphide ore has been opened. Here the lode or vein narrows to 8 feet in maximum width, the ore shoots are generally short, and the ore minerals, as shown on the dump of the tunnel, are principally galena, pyrite, a little chalcopyrite, and considerable sphalerite. According to later reports an important body of zinc ore has been opened at greater depth, where also the copper minerals increase in amount.[1]

The deposit in the open cut, 75 feet long, 22 feet wide, and 15 feet deep, located east of the shaft, is all in mainly altered, mineralized, or iron-stained rhyolite or ore whose contact with the unaltered rhyolite or rhyolite breccia on the north dips 75° SE. All the material removed from the cut was ore, which was treated in the Patagonia smelter and shipped elsewhere. The southeast side of the workings is still all in ore, which to judge from other openings and croppings near by probably extends 50 feet farther southeast.

The north tunnel runs S. 20° W. in rhyolite breccia, and as it nears the ground beneath the open cut enters and continues in a 6 to 8 foot ore shoot dipping 40° W., or toward the shaft. It has been stoped by an upraise to the east and mined by an incline to the west. The mine, it is said, now has about 50,000 tons of $10 ore in sight.

[1] Eng. and Min. Jour., Jan. 15, 1910.

The ore contains about equal values in lead and silver, being about two-thirds lead and one-third silver, and averages $1 to the ton in gold.

From the roof in the inner part of the south or 260-foot tunnel and adjacent parts of the crosscuts hang great masses of closely spaced acicular or filiform silky white cerusite about a foot in length.

A partial record of the ore shipments made from February 23 to August 27, 1897, shows 942.8 tons of ore, which averaged about 17 per cent in lead and 20.5 ounces to the ton in silver. Other shipments of about 450 tons made from August 16, 1900, to January 23, 1905, showed lead about 30 per cent, iron 8 per cent, manganese 1½ per cent, sulphur 4 per cent, and silver 30 ounces to the ton. At present, however, the average run of mine ore contains about 7 ounces to the ton in silver and 15 per cent in lead. The ore contains also much iron, which makes it a very good flux, and for this reason much of it was formerly packed to the Mowry smelter, 6 miles distant, and used as flux in smelting the more refractory ore from other mines. Some of the lead ore, it is said, smelts easily on a common domestic stove.

According to the estimates of a mining engineer who examined the mine for an outside company there is in the upper levels about 5,000 tons of ore averaging about 19 per cent in lead and 4 ounces to the ton in silver, with an average value of $19.20 to the ton, and in the 100-foot level 8,000 tons averaging about 30.5 per cent in lead and 10 ounces to the ton in silver, with a value of about $32.60 to the ton. In the 125-foot level there is a 12-foot vein averaging 14 per cent in lead and 5.4 ounces to the ton in silver, with a value of $15.45 to the ton. The siliceous ore in the lower workings is reported to average about 11 per cent lead, 30 per cent silica, 30 per cent iron, 2.5 per cent manganese, 14 per cent zinc, 15 per cent sulphur, and 6 ounces to the ton in silver, from which it would seem that the mine should prove to be a profitable producer of lead and silver ore of concentrating grade.

The deposits of the Flux mine owe their origin in part and probably in large part to solutions that accompanied and followed the intrusion of the rhyolite, but those occurring in the limestone may in part have been derived from solutions that accompanied the Mesozoic intrusives, of which the monzonite, aplite, and granite porphyry occur at or near the mine.

AZTEC GROUP.

The Aztec prospect is 2 miles south of Patagonia in the northwest slope of Red Mountain, in the upper part of Aztec Gulch, a northeast tributary of Alum Canyon, at an elevation of about 4,850 feet. The property, comprising a group of 24 claims, is owned by R. R. Richardson, of Patagonia, and covers a large area of mineralized

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or partly mineralized rhyolite which is medium to coarse grained, partly porphyritic, and in places crudely and dimly banded and bedded.

The principal exposures are in the southern part of the group, on claims Nos. 8 and 11. Here the rhyolite is more or less heavily impregnated with pyrite and chalcopyrite and is coated with copper glance, bornite, and malachite. The latter minerals are particularly concentrated as secondary replacement deposits in a 12-foot lode or ore bed which dips 75° SE. and is said to have an extent of 2,000 feet, mostly to the northeast of the main opening. The lode is opened by an open cut and an inclined shaft and tunnel, each about 30 feet in extent.

In one or more places the openings show the deposit to be at least 50 feet in width and to have a horizontal extent of more than 100 feet. Some of the ore is banded or consists of shoots of relatively pure secondary chalcocite and chalcopyrite 1 inch in maximum width and containing inclusions of orthoclase and quartz of the replaced rhyolite. A microscopic section of the medium-grade ore or partly mineralized rhyolite shows the rock to consist mainly of orthoclase, tridymite, quartz, muscovite, and a little glass. Embedded in the rock in the form of grains and irregular small masses is a mixture of chalcocite and chalcopyrite, some of which, owing to the complete manner in which it is inclosed in the rock matrix, appears to be primary. Nearly everywhere the ore minerals are surrounded by a fringe of muscovite or embedded in a mass of it, and the feldspar and quartz show a tendency to a radial arrangement around the ore.

ELEVATION GROUP.

The Elevation group is 2½ miles southeast of Patagonia, in the northeast slope of Red Mountain, at an elevation of about 5,000 feet. It was located in 1890 by Mr. Weatherwax and relocated in 1892 or 1893 by Jacob Johnson, Pete Hansen, and F. R. McAlstin, the present owners, who have done most of the development work on the group. It is opened by a 600-foot crosscut tunnel at an elevation of about 4,775 feet and by drifts and crosscuts at 4,975 feet. The tunnel is tracked.

The country rock is the rhyolite of Red Mountain, locally capped and seemingly intruded by andesite. The deposits contain chiefly copper and lead minerals. At the lower workings they are associated with an east-west vertical fault or shear zone which lies 450 feet in from the mouth of the tunnel. The zone contains dense chertlike quartz or very siliceous rhyolite and a 5-foot band of breccia and gouge which carries pyrite, chalcopyrite, and galena. Between this fault and the relatively unaltered andesite near the mouth of the tunnel is 50 feet of gray-white soft altered andesite, in which

occur disseminated sulphides. Beyond the fault, toward the face, the formation is very much broken up and altered rhyolite porphyry comes in. This rock contains widely disseminated pyrite and chalcopyrite, which are concentrated along some of the fissures and are locally coated with chalcocite.

The upper work is located about 600 feet northeast of the lower tunnel and 200 feet higher. It consists mainly of an old 50-foot shaft, 100 feet of drift, and 220 feet of crosscuts and opens a silicified brecciated fault zone 25 feet or more wide in which are shown disseminated pyrite and chalcopyrite, and which is said to average 2 per cent in copper for the entire width. On the south wall there is about 13 inches of quartz containing pyrite, chalcopyrite, and galena, which is said to average 16 per cent in copper, 10 per cent in lead, and 30 ounces to the ton in silver. The zone lies in the altered rhyolite porphyry and is supposed to cross the projection of the lower tunnel about 25 feet beyond the breast of the drift.

In September, 1914, a good body of lead-silver ore was said to have been opened at the 700-foot station in the tunnel.

CHRISTMAS GIFT MINE.

The Christmas Gift mine is half a mile east of the Elevation group and a quarter of a mile west of Harshaw Creek and the United States Geological Survey bench mark 4223, at an elevation of 4,500 feet. It was worked in 1887 by Frank La Monte and is now controlled by the Bland Mining Co., of Kansas City, Mo.

At least two carloads of ore are known to have been shipped from this mine and are reported to have averaged 90 ounces in silver to the ton. The property is opened by three shafts, the west one of which is timbered and is said to be 100 feet deep. The country rock is dark-red to black andesite. It is cut by a fissure that strikes N. 65° W. and dips 87° SW. The ore from the dump is very siliceous and is cream to lemon-yellow in color, apparently from lead carbonate and iron oxide.

HARDSHELL MINE.

Location, history, and production.—The Hardshell mine, one of the most important mines in the district, is about a mile south-southwest of Harshaw, in Hardshell Gulch, at an elevation of about 5,150 feet. The deposit was discovered in 1879 by David Harshaw and José Andrade by observing large bowlders of ore in Hardshell Gulch. In 1880, when but little more than the necessary development work had been done on it, the mine was purchased by the present owner, R. R. Richardson, of Patagonia. The property then consisted of four claims. It now contains 23 claims, aggregating about

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400 acres. In 1881–82 Mr. Richardson did 200 feet of work on the Hardshell No. 2 claim, and in the 10 years following he did considerable work in various places on No. 1 claim to find the ledge which was the source of the rich bowlders but was unsuccessful and finally, in 1890, abandoned the property. Later he located two claims, the Hardshell Nos. 1 and 2, the rest of the adjoining country having been at this time located and relocated by various parties. By relocation and purchase he acquired the remainder of the group. Finally, about 1895, he discovered ore on the Hardshell No. 1 by sinking a 40-foot shaft near the present inclined shaft, and continued sinking in the ore body to a depth of 230 feet.

In 1896 Mr. Richardson bonded the property to Mr. Fitzgerald, of the Empire Mining & Milling Co., who sunk the incline to the 400-foot level and took out 4,000 tons of ore, of which about 3,000 tons was shipped to the El Paso smelter and most of the remainder was treated in the Patagonia plant, some shipments being also made to Colorado. This company, which was later known as the Columbia Co., built the smelter at Patagonia mainly for treating the ores from the Hardshell and Flux mines, but the smelter also did custom work. It was a 90-ton plant installed at a cost of $125,000. The plant was operated for about three months, handling about 50 tons of ore a day. The company took out most of its Hardshell ore in 1896 and 1897, after which the property reverted to Mr. Richardson, the owner. He then installed a 50-ton concentrating plant or mill, which, however, handled but a little over 30 tons a day. It was operated from late in 1899 to 1901, about one and one-half years, producing in all about 15,000 tons of ore, including some rich galena ore shipped to the El Paso smelter.

Late in 1905 the Hardshell and Flux mines were bonded to Mr. Heney, of Tucson. In 1906 and 1907 he sunk 100 feet deeper, made the 200-foot crosscut, and sunk the rear 100-foot winze. The winze was all in ore, which he took out. Since 1907 Mr. Heney has held the property by extension of time. Recently this mine, it is said, is being worked on a small scale.

Development and equipment.—The mine is developed by more than 3,000 feet of work, which is concentrated on the Hardshell No. 1 and adjoining Hardshell No. 3 and Camden claims. The workings consist of a 500-foot shaft, inclined 30° (fig. 33), sunk on the vein, 2,000 feet of drift, and several hundred feet of winzes and raises, besides a large amount of irregular stoping, as indicated on the mine map (fig. 34). About the latest work of importance is 250 feet of drifting from the bottom of the incline and a 100-foot winze, inclined 30°, sunk from the 325-foot level. There is also an additional 1,000 feet of work, consisting mainly of shaft and drifts, on the Hardshell No. 3 claim, about half a mile from the mine.

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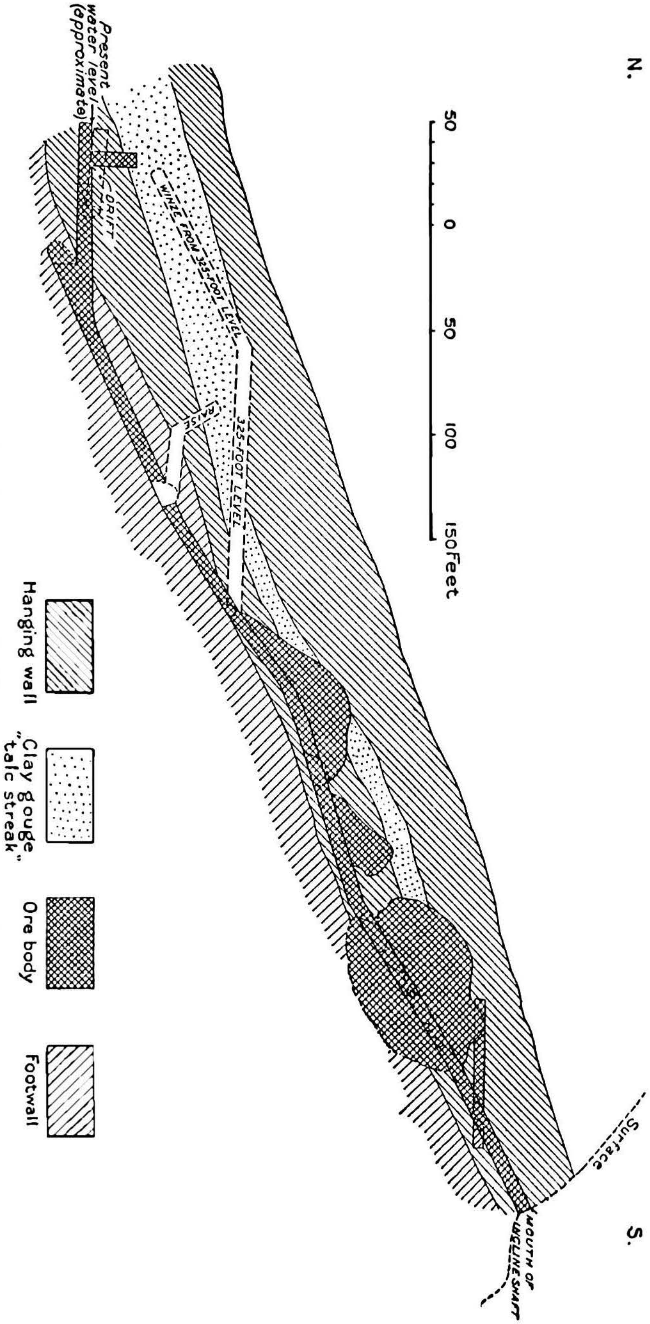

FIGURE 33.—Cross section of Hardshell mine on line of main shaft.

The equipment consists principally of a 40-horsepower steam hoist and a 50-ton concentrating mill. An excellent permanent camp with comfortable adobe buildings is conveniently located on the stage road about half a mile from the mine.

Topography and geology.—The topography is mountainous but not rugged. The mine is opened in the steep north slope of Hardshell Gulch about 60 feet above the gulch and is reached by a wagon road of easy grade.

The prevailing rock at the mine is rhyolite, locally known as porphyry, which, as shown on Plate II (in pocket), connects with the rhyolite area of Red Mountain. It occurs in heavy beds or flows about 3 feet in thickness and contains intercalated beds of quartzite, which it seems to have penetrated as intrusive sheets. The two formations are apparently conformable and dip 30° N. The quartzite also occurs in massive or heavy beds, as seen at the second raise and elsewhere in the deep parts of the mine, and on the east top of Hermosa Hill. It is a fine-grained or dense pale olive-green rock and in places resembles hornstone. It seemingly belongs to the Paleozoic limestone and quartzite series, which, as shown on the map, forms the country rock in American Mountain and the nearer foothills a short distance south of the mine. A little limestone and conglomerate are also reported to have been found in some parts of the mine. Diorite occurs in the gulch below the mine and in the surrounding hills, especially to the north.

The rhyolite is a medium-grained reddish-gray rock having a microfelsitic to glassy groundmass with flow structure in which are a few small phenocrysts and smaller intermediate forms, principally of orthoclase and quartz, with the orthoclase about all altered to sericite or kaolin. Water stands in the shaft at about the 400-foot level, and the mine makes about 200 gallons of water a minute.

Ore deposits.—The deposits occur chiefly in a shear-zone lode of rhyolite, and this rock, altered, partly replaced, and silicified, forms the principal part of the gangue. In a few places the more ferruginous phase seems to replace the quartzite, but as a rule the deposits do not appear to be particularly associated with the quartzite or any of the other sedimentary rocks.

The lode is from 10 to 60 feet wide and averages about 30 feet. It dips about 30° N., conformably with the quartzite and the interbedded rhyolite. On the hanging-wall side is a sheet of light-brown or whitish, more or less consolidated kaolin or clay gouge, which ranges in width from a few feet near the surface to 30 feet in the deep part of the mine, as shown in figure 33, and which seemingly represents a plane of extensive movement. On the footwall, which is hard, impervious rhyolite, there is in many places an intervening veinlike deposit from 1 to 2 feet thick of ferruginous manganese-silver ore that

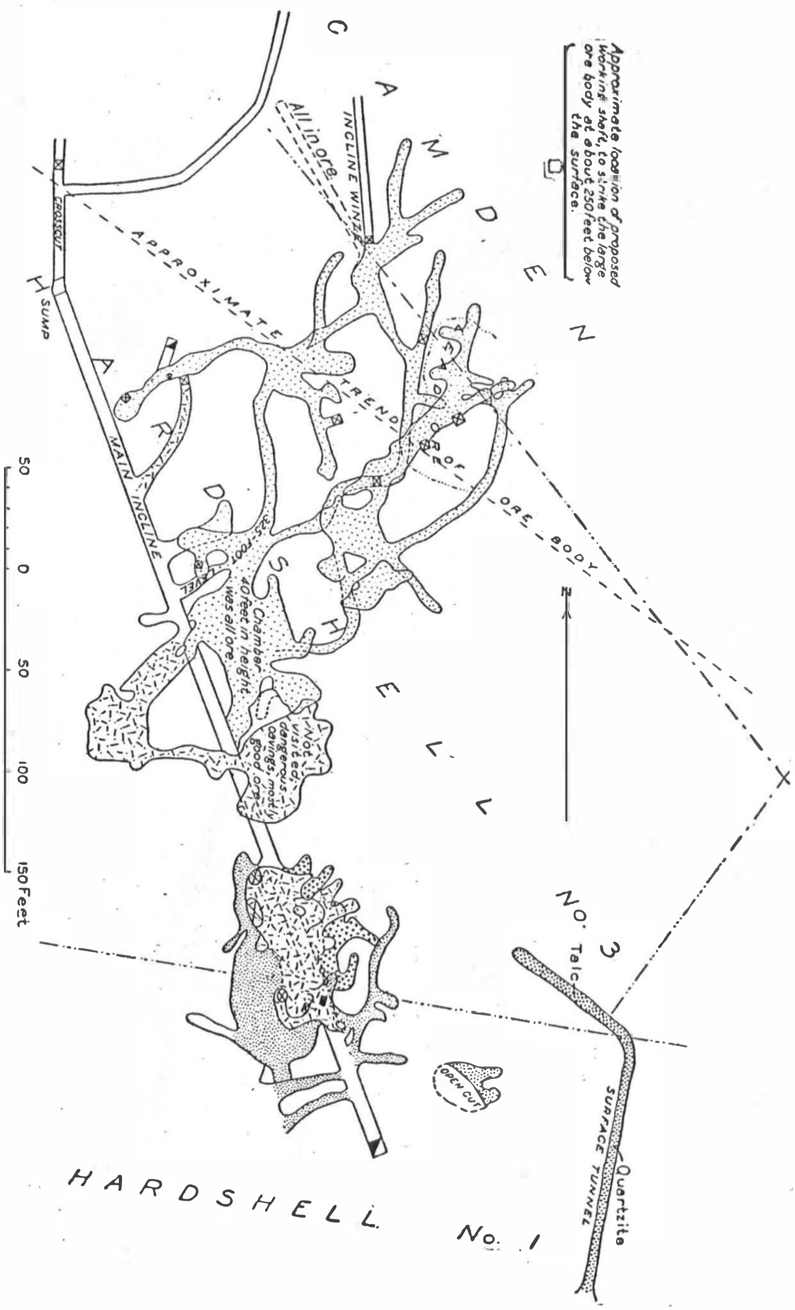

FIGURE 34.—Plan of underground workings, Hardshell mine.

averages, it is said, about 40 per cent in manganese and 15 ounces to the ton in silver and is reported to be a valuable factor as a flux.

In the lode the deposits, as shown in the cross section of the mine (fig. 33), are concentrated in irregular bodies or ore shoots which pitch to the east. The general distribution of the deposits, so far as now exploited in a belt about 300 feet wide along the strike and nearly 600 feet deep on the dip of the vein, is indicated on the level map (fig. 34).

The drift on the lower level, which is mostly in the footwall, has not yet found ore, but the 60-foot winze, whose lower part is but 40 feet east of the drift, is all in ore, which is leached above the water line, 12 feet above the bottom of the winze. An ore body is said to have been encountered in the last drifting in the bottom of the main shaft but could not be satisfactorily examined on account of the rapid influx of water.

About 2,100 tons of ore produced between February 24 and October 11, 1897, averaged, it is said, 15.1 per cent in lead and 7 ounces to the ton in silver. According to the smelter records of the shipments of about 3,000 tons to the El Paso smelter, from March 24, 1898, to January 23, 1905, the shipments in 1900, amounting to about 900 tons, ranged in value from $15 to $30 to the ton and averaged about $24 to the ton, with lead figured at $4 a hundredweight and silver at 62 cents an ounce. Some of these shipments, however, were crude concentrates from the small mill which was operated on the ground. The mill assays of this plant show the ore there treated to have averaged about 9 per cent in lead and 12 ounces to the ton in silver. Though the mill failed to save much of the metal content of the ore, a fair profit was earned. The smelter sheets giving the analyses of the 3,000 tons of ore shipped to El Paso show that the ore contains also about 30 per cent silica, 8 per cent iron, 5 per cent manganese, and 0.4 per cent sulphur.

Considerable ore of concentrating grade, estimated by some at about 100,000 tons, is in sight in the mine. The estimate of one mining engineer is 20,000 tons between the surface and the 200-foot level, and 10,000 tons from the 200-foot to the 325-foot level, besides which there are about 4,000 tons of shipping grade and 5,000 tons in the tailings dump at the mill. The ore in the dump is said to contain about 6 per cent in lead and 6 ounces to the ton in silver.

Besides the Hardshell vein there are several other veins on the property. Among them are what is regarded as the southeasterly extension of the vein worked in the Trench mine, the well-known pioneer producer. An old shaft and surface stope on another vein, on claim No. 2, yielded several carloads of silver ore of shipping grade. Here the vein is chiefly crushed, altered, and mineralized rhyolite. It is 3½ feet in average width and dips 70° N. in fine-grained

quartzite. The ore mineral, like that of the Hermosa mine near by, is principally cerargyrite. On the Camden claim an open cut shows the rhyolite dipping 40° NNW., and it contains a 16-foot body of low-grade silver ore in the red altered oxidized portion. This ore body or bed is also encountered in a cut tunnel driven some 40 or 50 feet farther down the slope to the north.

ALTA MINE.

The Alta mine is one-third of a mile north-northwest of the Hardshell mine, about midway between the Hardshell camp and mine, in the mouth of a southwestern tributary of Hardshell Gulch, at an elevation of about 5,050 feet. It is on open ground and easy of access by a wagon road ascending the gulch by way of Hardshell camp.

The Alta is an old mine. It was worked in 1877 and 1878, the ore being treated in a lixiviation plant at Harshaw. In 1879 a new company opened the mine more extensively, and in 1880 and 1881 this company shipped considerable ore to a small mill called the Boston, on San Pedro River, near Charleston, Ariz., about 3½ miles from Fairbanks and 9 miles from Tombstone. About all the Tombstone ore, it is said, was milled at the Boston mill in those days.

Later other operators shipped a quantity of what is locally known as "lixiviation plumbago" ore at a profit of several thousand dollars. In 1897 the mine was acquired by the present owner, the Melba Mining Co., of New York. It was worked with good results for a year or two but has since lain idle and is now dismantled. It is regarded as a good property, however, and is patented. The mine is opened to a depth of 300 feet or more by shafts and drifts. The size of the dump shows that a large amount of work has been done, probably about 4,000 feet, most of which seems to lie within an area about 150 feet square.

The country rock is the dark-reddish medium-grained quartz diorite or quartz monzonite, and at the mine it is cut by a 20-foot dike of light bluish-gray flow-banded rhyolite breccia, which, as seen in the gulch on the east and in the road, is heavy bedded, dips 40° NNE., and weathers yellowish brown with limonite stain.

Extending over the top of the tank hill to the west of and 100 feet above the mine, the diorite along the footwall side of the dike forms a broad band of silicified croppings which stand up in low relief, suggesting that the faulting that produced the fissure now occupied by the dike was probably normal. Slickensides show also postvein movement.

The deposits are obviously associated in origin with the rhyolite dike and seem to occur in its hanging-wall side or in the adjoining portion of the wall-rock diorite, which is silicified and mineralized for 200 feet back from the dike and in which an inclined shaft reported to be several hundred feet in depth descends to the north. Horizontally the lode seems to extend for at least a quarter of a mile westward, to a point on the county road just south of Hardshell camp.

The ore is principally silver-bearing galena contained in a gangue of quartz and reddish fluorite, mostly replacing rhyolite. To judge from the composition of the material on the dump it contains also considerable pyrite, specularite, sphalerite, a little chalcopyrite, malachite, and embolite (silver chlorobromide).

At a depth of 250 feet there was encountered a body of high-grade ore 2 to 3 feet wide, said to average about 37 per cent in lead and 2 ounces in gold and 15 ounces in silver to the ton and to resemble the ore of the Lead Queen mine. This ore shoot, or a similar one 2 feet in width, is said by the two foremen who were last in charge to continue in the deeper part of the mine where a drift had been run on it for 45 feet with no indications of decrease in volume or grade when operations ceased. It is also reported that in the deeper part of the mine occurs a rich 4-inch ore shoot of pyrargyrite, or ruby silver.

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HERMOSA MINE.

The Hermosa mine is about three-fourths of a mile south of Harshaw, a thriving camp and town of which it was the making. It is about one-third of a mile southeast of the Hardshell mine, in the easterly slope of the same ridge, at an elevation of 5,000 to 5,500 feet. It is easy of access by wagon road ascending the gulch from Harshaw.

The mine was first located in 1877.[1] In 1878 or 1879 it was sold to the Hermosa Mining Co. of New York. This company, which later became the Prietus Mines Co., one of the strongest companies of Sonora, built a 20-stamp mill at Harshaw, operated the mine from October, 1880, to November, 1881, with 150 men, and ran the mill for 18 months, producing during that period about $1,000,000 in silver chloride ore, all of which was amalgamated directly on the ground and the bullion shipped. The company held the property for several years thereafter, but did no work. It sold the mill for $18,000 to the Quijotoa Mining Co., of Quijotoa, 80 miles west of Tucson, and in 1887 sold the mine for $600 to James Finley, of Tucson. Mr. Finley, beginning in 1890, worked the mine for about two years on a moderate scale, treating the ore at first in a 3½-foot Huntington mill at Harshaw and later in a 5-foot mill which he installed. He worked mostly near the surface, above the company's stopes, and took out $150,000 in silver chloride ore. In 1891 he bonded the mine for $50,000 to Senator McGoverney, of Canon City, Colo., who worked it for five months with the Finley mill and took out $15,000, mostly from the stope on the second level west of the original shaft.

[1] Most of the information on history and production is given by Mr. N. A. McDonald, who has been in charge of the property for the last 20 years.

In 1892 Mr. Finley resumed operations and in three months took out $10,000 from the continuation of the McGoverney work. After this, up to 1903, $25,000 was taken out of the mine by lessees, among whom was the Hermosa Mining Co., of Guthrie, Okla., which in 1902 remodeled the mill, put in a new 5-foot Huntington mill, and produced $7,000 in a 22-day run. This company did considerable work in the mine, but it was about all dead work, consisting principally in driving the 900-foot tunnel below the former company's old stopes, and depleted their treasury before ore was reached.

With the death of Mr. Finley and the decline in the market value of silver in 1903, work ceased. In 1906 the present owner, James Cochran, of Bradford, Pa., acquired the property by purchase from the Finley estate, but it has not been worked since. The property is patented. The estimated total production of the mine is about $1,500,000 in silver.

The mine is developed to a depth of about 500 feet below the surface at the top of the ridge by 7,000 feet or more of work, principally drifts, stopes, and tunnels distributed mainly on five levels. The first, second, third, and tunnel levels are spaced 50 feet apart vertically, and the fourth or lowest level is 170 feet below the tunnel level. The four upper levels are connected by three upraises and the four lower levels by one upraise. The tunnel level contains a 600-foot crosscut and extends through the ridge, having both a south and a north entrance. It is all in rhyolite breccia, and from its west drift is sunk a 300-foot winze.

The country rock is an ash-gray rhyolite which is mainly breccia and is locally called by miners from Colorado "Cripple Creek breccia." It is crushed, recemented, and locally closely banded by flow structure. It is also secondarily banded, largely with quartz, and is more or less altered, stained dark reddish or yellowish-brown by iron, and mineralized. It is practically all oxidized, no pyrite or sulphide being found at any point. The mine is dry.

The deposits occur mainly in a more or less tabular sheet or main lode contained in a shear or fault breccia zone in the rhyolite. The lode ranges from 1 foot to 20 feet or more in width and dips 33° N. It is in general highly oxidized, though to a somewhat less degree in the deeper part of the mine than near the surface.

Paralleling the main lode at a distance of 50 feet on the north at the surface is another or subordinate lode known as the North vein.

It has a steeper dip, and for that reason is on the tunnel level but 30 feet distant from the main lode, which it is supposed to intersect in depth.

The ore mineral is cerargyrite, or horn silver, and except a little molybdenite stain and iron and manganese oxides the ore contains no other metal. The mine is the only exclusively silver mine in this part of Arizona.

The ore has been formed by a process of metasomatic replacement in the altered, mineralized, and in part silicified rhyolite gangue, the depositing solutions having dissolved out the less resistant rock minerals. Much of the ore is highly altered and stained yellowish, black, and reddish by limonite, psilomelane, and hematite. Some of it has been made porous by the dissolving out of the pyrite. Comminuted fine-grained quartzite contained in it denotes that the sedimentary rocks probably occur near by. The source of the ore seems to be hydrothermal solutions that attended and followed the faulting and shearing which took place subsequent to the eruption and intrusion of the rhyolite.

The ore in general is of low grade, averaging for the most part about 5 ounces in silver to the ton—for instance, in the main tunnel, where the lode is 6 feet wide and is about all ore—but there are also some very rich pockets scattered throughout the lode. It is said that the ore can be mined and milled for $3 a ton. During the periods of operation 87 to 90 per cent of the metal content was extracted, and the silver bullion was 0.998 fine. The present mill can handle 50 tons a day.

The mine seemingly still contains much ore which extends in depth beyond the present lower workings. It is said that when the Hermosa Mining Co. of New York ceased work the ore in the bottom of the mine was becoming basic with iron, but this seems unlikely, for the increase in iron with depth, if any, is small, and the iron is all in the oxide form. At no point was any sulphide observed. That there is a decrease in the value of the ore, however, in the bottom of the mine seems probable, and a further decrease is to be expected at water level or at the sulphide zone, which, to judge from conditions in the neighboring Hardshell and other mines, should soon be reached. This fact should be borne in mind in considering the view held by some who have examined the property, that there is still the making of a great mine here and that it should be opened to a depth of at least 1,000 feet. It is also probable, from the geology of the surrounding country, that the underlying quartzite will be encountered at a depth less than 1,000 feet, and the persistence in this formation of the ore tenor found in the rhyolite is certainly not to be expected.

SALVADORE MINE.

The ground of the Salvadore mine adjoins that of the Hermosa mine on the west and is situated in the east slope of the same ridge. It was discovered, located, and patented at the same times as the Hermosa mine and was likewise mined by the Hermosa Mining Co. of New York. It has produced about 1,000 tons of good-grade ore, averaging 30 ounces in silver to the ton. It contains about 1,000 feet of development work, including a 200-foot tunnel, a 50-foot shaft, drifts, crosscuts, and stopes.

Though located almost on the projected course of the Hermosa vein, the mine is thought to be on another vein, seemingly separated from the Hermosa vein by up-faulted quartzite. The deposits occur in the rhyolite and are similar to those of the Hermosa mine, but the ground is harder and costs more to mine. The ore, however, is cleaner and is said to mill easier than the Hermosa ore.

WIELAND GROUP.

At a point about midway between Harshaw and Red Mountain and about a mile east of the World's Fair mine, on the Harshaw Creek side of the divide, occur a dozen or more small mines and prospects, for which the Wieland group and camp, owned mostly by George Wieland and Theodore Gebler, and lying at an elevation of about 4,900 feet, forms a sort of nucleus or center. The properties are mostly reached by wagon road from the stage road 1½ miles distant on the east. The topography is generally rough and the country rock is mainly calcitic andesite which is intruded by rhyolite. Locally some older silicated limestone and altered shale are also present. Among the properties are the Great Silver, Basin No. 1, Dewey, and Red Rock.

GREAT SILVER MINE.

The Great Silver mine, according to report, in 1882 and 1883 produced and shipped two carloads of ore which averaged 52 per cent in lead and 35 ounces in silver and $1.90 in gold to the ton. The work on this claim and the adjoining Milford claim shows a strong siliceous vein or ore bed which dips 30° N. in the andesite. It consists of an altered mineralized sheet of intrusive rhyolite from 2 to 3 feet thick, largely replaced by heavily iron-stained quartz and gypsum, which are the principal gangue minerals, especially next to the hanging wall. The ore mineral is dark, highly argentiferous galena.

On the Great Silver claim the vein is opened by a 50-foot drift tunnel, whence it is stoped up 60 feet to the surface. In the tunnel it is underlain by andesite containing about 2 feet of soft decomposed vein material.

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BASIN NO. 1 PROSPECT.

The Basin No. 1 prospect is about a quarter of a mile west of the Great Silver mine, at an elevation of 5,060 feet, just east of the Alum Gulch divide. It is opened by a tunnel which runs 188 feet N. 64° W. on a fault fissure in andesite that dips 70°–80° SSW. It follows the south or hanging wall of the vein, which is marked by 2 to 8 inches of chocolate-colored gouge. Slickensides on the wall pitch 15° E. The ore occurs in lenses or shoots that apparently pitch westward on the vein. The first lens is cut at the mouth of the tunnel, the second at 45 feet from the mouth, and the third at 90 feet. The lenses are as a rule about 2½ feet in maximum width, and thin down to 6 inches or less in the distance of 20 feet. A 30-foot shaft in the first lens shows the ore to be 5 feet wide. At 140 feet in from the mouth of the tunnel a 20-foot vertical winze is sunk in the hanging wall and intersects the vein at the bottom, showing 10 inches of ore.

The ore is entirely oxidized material, being a mixture of azurite, malachite, limonite, cuprite, and chrysocolla with crushed and altered andesite, a little quartz, and some potash feldspar. There is a carload of ore on the dump, which was sampled by the Copper Queen Smelter Co., it is said, and gave returns of 7 per cent in copper, 1 to 1½ ounces to the ton in gold, and a little silver. Besides this carload, the rest of the dump, about 800 tons of ore, is said to average 4 per cent in copper.

DEWEY PROSPECT.

The Dewey claim of the Wieland group covers a vein 600 feet south of the Basin No. 1 prospect. There is an old caved shaft on the west end of the claim and an open cut near the center. The cut shows a 2-foot vein containing cuprite, malachite, azurite, and chrysocolla between good andesite walls, with gouge on each side. The vein dips 75° NNE. The shaft also is on it.

BUFFALO GROUP.

The Buffalo group, owned by James Cochran, of Bradford, Pa., is just southwest of the Wieland group. It was formerly known as the Jefferson group. It comprises five claims and contains two east-west persistent veins about 600 feet apart.

The most extensively developed property of this group is the Lead Queen mine, located on the south vein of the group. It was discovered in 1897 by Sullivan & Powers, purchased by Mr. Wieland, and later sold to a New York syndicate, which was subsequently organized into the Jefferson Mining Co. This company, however, ceased operations in March, 1902. In 1910 it was reported that the property

was being extensively developed by the T. E. Munn Mining Co., of San Antonio, Tex., which was shipping from a newly opened 3-foot ore shoot considerable ore that averaged 21 per cent in copper and 20 ounces in silver and $4.50 in gold to the ton. The total production is about 500 tons of ore, of which Mr. Wieland produced 200 tons in 1898 to 1900 and the Jefferson Co. 100 tons in 1901. About 30 tons of second-grade ore lies on the dump.

The mine is developed to a depth of 166 feet by about 1,200 feet of work, including besides the shaft drifts, crosscuts, and stopes on two levels. Water now stands at 70 feet below the surface in the shaft. The country rock is dark-purple porphyritic andesite. The lode or vein containing the deposits, like all others in this camp, dips north-northeast. The croppings are not prominent but weather evenly with the country-rock surface, and the course of the vein is indicated by only a little stain at the grass roots, which just below the surface gives way to lead-silver ore, which, in turn, at a depth of 40 to 50 feet, is succeeded by ore containing lead, silver, and copper. The ore is about all sulphide, though much of it is yellowish with carbonate and chloride of lead, and in places it is associated with a barite gangue. In general it averages about $50 to the ton and contains 56 per cent lead, 9.2 per cent iron, 2.8 per cent copper, 2 per cent zinc, and 55 ounces in silver and from $1 to $2 in gold to the ton. The copper occurs mostly in chalcocite.

AMERICAN MINE.

The American mine is 1½ miles south-southwest of Harshaw, half a mile southwest of the Hardshell mine, about a quarter of a mile east of the Mowry stage road, in the short, steep gulch at the northwest slope of American Peak, at an elevation of about 5,400 feet. The deposit was discovered about 1880 and has produced more than $80,000 worth of ore, of which the better grade was shipped to Douglas and the rest concentrated at Harshaw in the old mill below the Park place. The mine is said to have been leased recently to a Tucson man who is installing machinery.

The mine is developed to a depth of 112 feet by about 500 feet of work, which includes three 90-foot shafts, all connected by drifts on the 90-foot level.

The mine is on what seems to be the contact of silicified limestone, or quartzite, with intrusive porphyritic brecciated rhyolite. The dominant structure in the sedimentary rocks dips steeply to the southeast, and the rhyolite shows a north-south vertical flow structure and banding. Rhyolite occurs in considerable amount in the north slope of American Peak south of the mine. Blue limestone is said to form the hanging wall on the north in the mine, and the Paleozoic limestone is well exposed in the mountain above and in the

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gulch below the mine toward the road. Water standing in the shaft is said to be rain water.

The vein containing the deposit seems to trend west-northwest, and dips to the north. The openings extend interruptedly west-northwest for a length of 150 feet and a width of about 50 feet. Prominent and auspicious-looking croppings of iron and manganese stained quartz and replaced silicified rhyolite occur northwest of the mine, and large bowlders from the croppings are strewn down the gulch.

The vein is normally about 3 feet in width but is said to widen to 10 feet or more in places in the mine, forming pockets or lenses which carry good ore that probably in part represents replacement bodies in the wall rock. Most of the ore mined, or more than $50,000 worth, occurred in such a lens which is likened to the "hull of an ocean vessel tilted 45° on its side." It was 75 feet in length and 14 feet in width and dipped to the north. About all the ore mined was obtained between the surface and the 90-foot level, mostly from the oxidized zone, but it contained also sulphides. The metals contained in the ore are silver, copper, iron, zinc, and lead. The ore minerals are cerargyrite, argentite, chalcopyrite, pyrite, sphalerite, and galena.

The shipping ore is said to average about 12 per cent each in lead and zinc and 100 ounces in silver and $9 in gold to the ton. The smelter sheet of a shipment of 31,230 pounds of the ore made to the El Paso plant showed the following recoveries, silver being quoted at 55¼ cents and copper at 9 cents:

Silver, 62 ounces	$32.86
Copper, 1.2 per cent	2.16
Iron, 4 per cent	.20
Zinc, some.	

BLUE NOSE MINE.

The Blue Nose, also known as the Abe Lincoln mine, is 2 miles southwest of Harshaw, near the south line of the district just west of the Mowry stage road, on open ground. It is owned by R. R. Richardson and Neil McDonald. It has produced $250,000 in lead-silver ore. About 3,000 tons of good-looking ore lies on the dump, the size of which shows that much work has been done. The mine is developed to a depth of more than 200 feet, mainly by shafts and drifts. Work ceased, it is said, because the poor equipment then on the ground was unable to handle the water.

The country rock is the Paleozoic limestone and quartzite series and it is intruded by dark-greenish, slate-colored dense glassy rhyolite, seemingly in the form of intrusive sheets. The rocks dip about 40° NW. and are sliced by a prominent sheeting that dips 80° SE.

Water, which seemingly is ground water, stands at about 200 feet below the surface.

The deposits occur in a vein or lode which dips 40° NW., about conformable with the inclosing rocks. It is about 4 feet in width. The footwall, a sheet of the dense dark rhyolite, is pyritic, being impregnated with small crystals and grains of pyrite and chalcopyrite. The ore occurs in pockets, mostly in a white talclike substance. Most of the ore produced is said to have occurred in a dipper-shaped body.

PLACER DEPOSITS.

The only placers known in the Harshaw district occur about 2 miles southwest of Patagonia, between Sonoita Creek on the northwest and Alum Canyon on the southwest. Here the Quaternary gravels underlying the mesa-like area, which is about a mile square, contain placer gold and are workable under favorable conditions. They are said to contain also native lead. They were worked by A. J. Stockton and other pioneers by jigging in the early days.

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PATAGONIA DISTRICT.

GENERAL FEATURES.

Location and settlements.—The Patagonia district is on the Sonoran border in Santa Cruz County. It covers the southernmost part of the United States portion of the Patagonia Mountains and lies south of the Harshaw and Palmetto districts, already described. It is about 12 miles broad from east to west and 8 miles from north to south. (See Pl. I, in pocket.) On the west the boundary of the district for 4 miles north of the Mexican line follows Santa Cruz River. On the east it roughly follows the upper or western edge of the wash or valley plain of the river, which toward the north coincides with the west or upper boundary of Meadow Valley Flat. The northern boundary, starting on the west, follows the divide north of Canada de la Paloma to the crest of the Patagonia Mountains on American Peak, whence it continues eastward across the Harshaw Creek drainage basin to Meadow Valley Flat.

The principal settlements are Mowry, Washington, and Duquesne, all good-sized camps located in the eastern part of the district. A daily mail and stage service is maintained between these camps and Patagonia, on the railroad 16 miles to the north, which is the shipping point for the mines east of the main range. Washington and Duquesne also have intermittent stage service to Nogales, about 18 miles to the west. It is said that a new wagon road will soon be built from Patagonia to Washington and Duquesne, passing near the Three R properties, the Chief mine, and the Volcano group. This road will shorten the route to the railroad by several miles and will give the mine owners an easy down grade for hauling their ore into Patagonia for shipment.

Mowry has a concentrating mill and smelter, and at Washington there is an elaborate concentrating plant and a 50-ton smelter.

Of the other camps in the district, Four Metals, O'Connors, and Benton are on the east side of the range, and Old Soldier, Gross, Golden Rose, and Buena Vista on the west side. Besides the mining camps there are many small ranch houses in this region. The roads and trails between the various parts of the district are good. A telephone line extends from Mowry to Patagonia and another from Washington and Duquesne to Nogales.

Topography.—The principal topographic feature of the district consists of the Patagonia Mountains, which extend across the district in a north-south belt about 7 miles in width, occupying the middle and almost the whole of the eastern part and forming the divide whence the drainage is discharged to the east and to the west into widely different sections of Santa Cruz River. The mountains average about 5,500 feet in elevation, but ridges in the southern part exceed 6,000 feet and two peaks rise to about 7,000 feet. On the north the mountains are low and broad or spreading; on the south they are contracted into a single narrow ridge, whence on either side the surface declines 1,500 feet in a distance of less than $1\frac{1}{2}$ miles. The topography is accordingly rough and much of it is rugged. The mountains, as shown in Plate XX, are sparsely timbered with mesquite and live oak of moderate size. West of the mountains is a broad eroded valley plain gently sloping to the Santa Cruz. The upper limit of this plain is approximately at the 4,300-foot contour, from which the rise to the crest of the range is rapid. On the east in the northern part of the region the slope from the divide to the Santa Cruz is gradual, the descent along the Mowry Wash, the main drainage line, being only 800 feet in 10 miles. In the southern part of the district Duquesne is situated at about the upper limit of the valley flat of the Santa Cruz. Westward from this camp, which has an elevation of 5,350 feet, the mountains rise to an elevation of 7,200 feet in a distance of 3 miles.

A peculiar topographic feature of this part of the area is Guajolote Flat, which is a rather level parklike area situated at an

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elevation of 5,800 feet. It is much above the general elevation of the region, and there are only a few peaks that rise higher than it within a radius of a mile and a half. The flat drains to the east, although it lies well to the west of the axis of the range.

Geology.—The rock formations, beginning with the oldest (see Pl. II, in pocket), are Paleozoic sediments, consisting of limestone, quartzite, and shale; Mesozoic intrusive rocks, comprising quartz monzonite, granite porphyry, diorite, and gabbo; Mesozoic sediments, consisting mainly of arenaceous limestones and shales; Tertiary rhyolite; and Quaternary gravels and wash. Their general relations are shown in cross-section *G–H*, Plate III (in pocket). All the formations except the Mesozoic sediments contain mineral deposits.

The most widely distributed hard-rock formation is the quartz monzonite, which has been described on page 60. It extends across the district in a north-south belt about 6 miles wide on the north and forms almost the whole of the Patagonia Mountains, especially the axis and west slope. It is intrusive into the Paleozoic sediments, as is shown at Mowry, Washington, and Duquesne. It is quite possible, however, that the belt mapped as quartz monzonite may include also some granite.

The formation next in abundance is the granite porphyry, described on page 64. It crosses the district in an interrupted north-south belt about a mile wide in the eastern foothills of the Patagonia Mountains and also in a north-south quadrangular area of about 2 by 3 miles in the western foothills toward the north. It is intrusive into the Paleozoic sediments, the quartz monzonite, and the diorite, and is economically important on account of its relation to the ore deposits.

The Paleozoic sediments occur in two areas, one at Mowry and the other at Washington. The Mowry area is roughly quadrangular in outline and extends from the Mowry mine to a point about 3 miles to the northwest. It is occupied mainly by limestones, some of which have furnished the fossils described on pages 49–50, but it contains also some shale and quartzite. The Washington area is crudely lenslike in outline. It trends north and has a length of 2½ miles and a width of about a mile. Washington is located at the middle of its eastern edge. It is occupied mainly by white crystalline limestone which has yielded no fossils but contains mineral deposits.

The Mesozoic sediments occur on the east slope of the range, in the northeastern part of the district, in interrupted areas extending for about 2 miles north, south, and west from Mowry. They have yielded the fossils described on page 53.

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The quartz diorite occurs as small stocklike masses and dikes intruding the quartz monzonite, as to the west of the Golden Rose mine and at the O'Mara or Old Soldier mine. The gabbro intrudes the Paleozoic limestone, principally at and near Mowry. The rhyolite occurs in irregular patches in the northeastern part of the district, on the upper east slope of the range, along the contact of the granite with the overlying Mesozoic rocks, into both of which it is intrusive, and it seems to be the interrupted southerly extension of a larger body of rhyolite in the Harshaw district on the north.

LODE DEPOSITS.

DISCOVERY AND MODE OF OCCURRENCE.

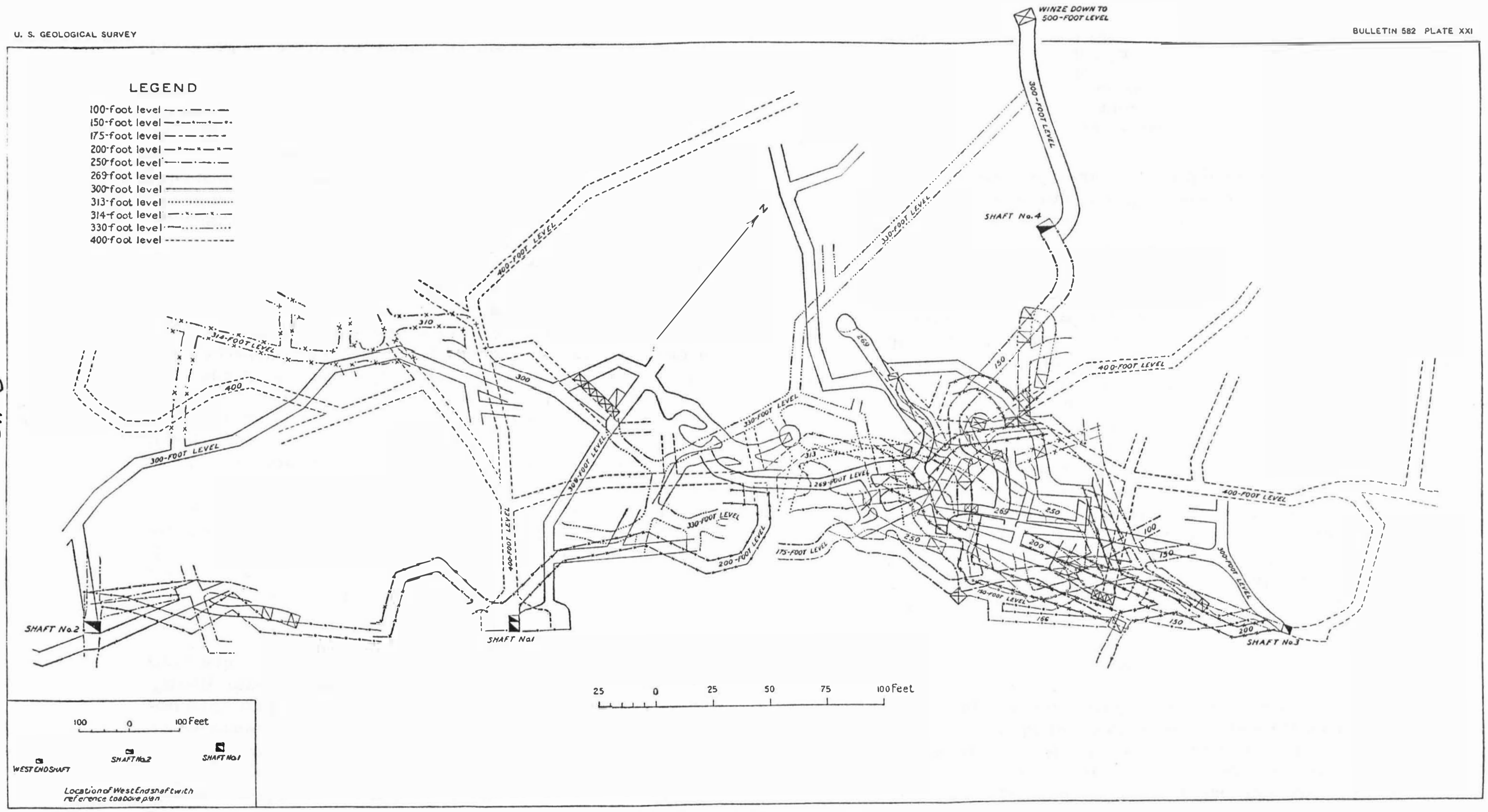
As in the Harshaw district on the east and the Santa Cruz Valley on the west, mineral deposits were discovered in the district in the early Jesuit days by the padres and the Mexicans, but detailed records of these discoveries are not at hand. The Mowry mine was worked by Americans in the middle part of the last century, as were also several smaller properties. Since then production has continued intermittently from different properties down to the present time.

The deposits are practically all contained in a belt 6 miles wide extending in a northwesterly direction across the district. They carry mostly silver and lead but are in part copper deposits. As a rule they occur in fissure veins similar to those in the districts already described and are present in all the Mesozoic intrusive rocks and also in the Paleozoic sedimentary rocks, where they are generally associated in origin with intrusives. At the Washington and Duquesne camps, however, the deposits are mostly of contact-metamorphic origin.

MINES AND PROSPECTS.

The district contains over 40 mines and promising prospects, the most of which are named in the following list. Many of them have been productive and a number are still producing. Most of the mines are small.

Augusta.	Four Metals.	New York.
Belmont.	Gladstone.	North Mowry.
Bennett.	Golden Rose.	O'Connor.
Benton.	Holland.	Off Pointer.
Big Lead.	Isabella.	O'Mara (Old Soldier).
Blades.	Jaballna.	Pocahontas.
Bonanza.	Kansas.	Pride of the West.
Brooks.	King.	Proto.
Buena Vista.	Lone Star (San Joaquin).	Silver Bell.
Champion.	Marché.	Shamrock.
Chance.	Morning Glory.	Tibbetts.
Ella.	Mowry.	Winifred.
Empire.	National.	



PLAN OF WORKINGS OF MOWRY MINE.

MOWRY MINE.

Location.—The well-known Mowry mine, originally called the Patagonia mine and later the Mowry silver mines, is located at Mowry, in the northeastern part of the district, 9 miles south of Patagonia. It is near the Patagonia-Washington stage road, in the south base of Mowry Hill, on open, gently sloping ground at an elevation of about 5,500 feet.

History and production.—The mine was located in the early fifties and worked in the usual primitive way by Mexicans, but it had been known to the Jesuits long before. It was relocated in 1858 and was purchased in 1859 by Lieut. Sylvester Mowry, of the United States Army, who was then stationed at Fort Crittenden and who is said to have expended about $200,000 in the purchase of the mine and its equipment with reduction plant and other improvements.[1] Lieut. Mowry operated the mine successfully for about four years, employing about 120 men, and shipped $1,500,000 worth of ore, mostly to San Francisco and to London and Europe by way of Guaymas, Mexico, 25 tons of the ore being sent to Europe as sample specimens in 1862. Some bars of the lead and silver bullion from the reduction works sold in England at $200 a hundredweight. Much of the ore was smelted and some bullion was refined in the reduction plant, which consisted of 12 adobe smelters and yielded $4,500 a week on the ground. The ore was transported to Guaymas, nearly 300 miles distant, by wagon.

A portion of the silver refined at the mine in an English cupel furnace was molded into bars worth from $2 to $300 each, and used as a circulating medium instead of money in payment of current expenses. The litharge refuse from the furnaces was sold to neighboring mines in Sonora and used as a flux in treating their refractory ores. Operations were ruthlessly interrupted in 1862, and the mine was seized by the United States Government owing to the charge that it was furnishing lead to the Confederate Army for ammunition.

In the early seventies, according to Raymond,[2] the mine was worked intermittently by jumpers, who installed an engine with good results, but it was practically abandoned after gophering and subsequent caving had ruined the workings.

Fish & Silverberg, of Tucson, acquired the mine by relocation, took out about $75,000, and in the early eighties sold it to Steinfelt & Swain, merchants in Tucson, who in the late nineties, by the expenditure of $100,000, opened the old workings and are said to have taken out $80,000 and found enough additional ore to render the mine easily salable at a profit.

[1] Raymond, R. W., Mineral resources of the States and Territories west of the Rocky Mountains, 1868, p. 447, 1869.
[2] Raymond, R. W., Statistics of mines and mining in the States and Territories west of the Rocky Mountains, 1873, p. 313, 1874.

In 1904 the Mowry Mines Co., composed essentially of the present owners, purchased the property. This company operated the mine for a short time, installed a concentrator and smelter of 100 tons daily capacity, and shipped some lead-silver bullion to New York.[1]

In 1907 the Mowry mine and plant were operated with 200 or more men until late in the year. Some sinking was done and a considerable quantity of concentrates and crude ore containing lead, silver, and gold was shipped.[2] Until about this time the Mowry was, next to Tombstone, the most important lead producer in southern Arizona.

In 1909 the Mowry mine, together with the Alto mine, in the Tyndall district, was taken over by the present owner, the Consolidated Mines, Smelter & Transportation Co. This company is authorized to build a railroad from Mowry to Patagonia and to operate stores at Mowry and Alto, while the mines are operated by a subsidiary company, the Santa Cruz Mines & Smelter Co., with headquarters in New York. The property comprises a group of twenty patented claims.

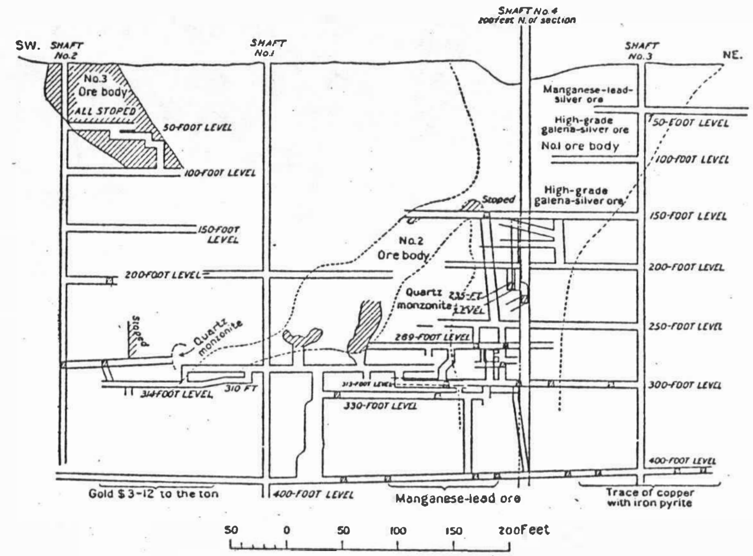


FIGURE 36.—Longitudinal section of Mowry mine.

Developments and equipment.—The mine is opened to a depth of 500 feet and is developed by about 12,000 feet of work, consisting principally of 2,500 feet of shafts, 6,000 feet of drifts and crosscuts, and 3,000 feet of stopes distributed mostly on 13 levels as shown on the level map (Pl. XXI) and the longitudinal section (figs. 36 and 37). The west end shaft, shown in figure 37, is 190 feet southwest of

[1] U. S. Geol. Survey Mineral Resources, 1905, pp. 138, 156, 1906.
[2] Idem, 1907, pt. 1, p. 178, 1908.

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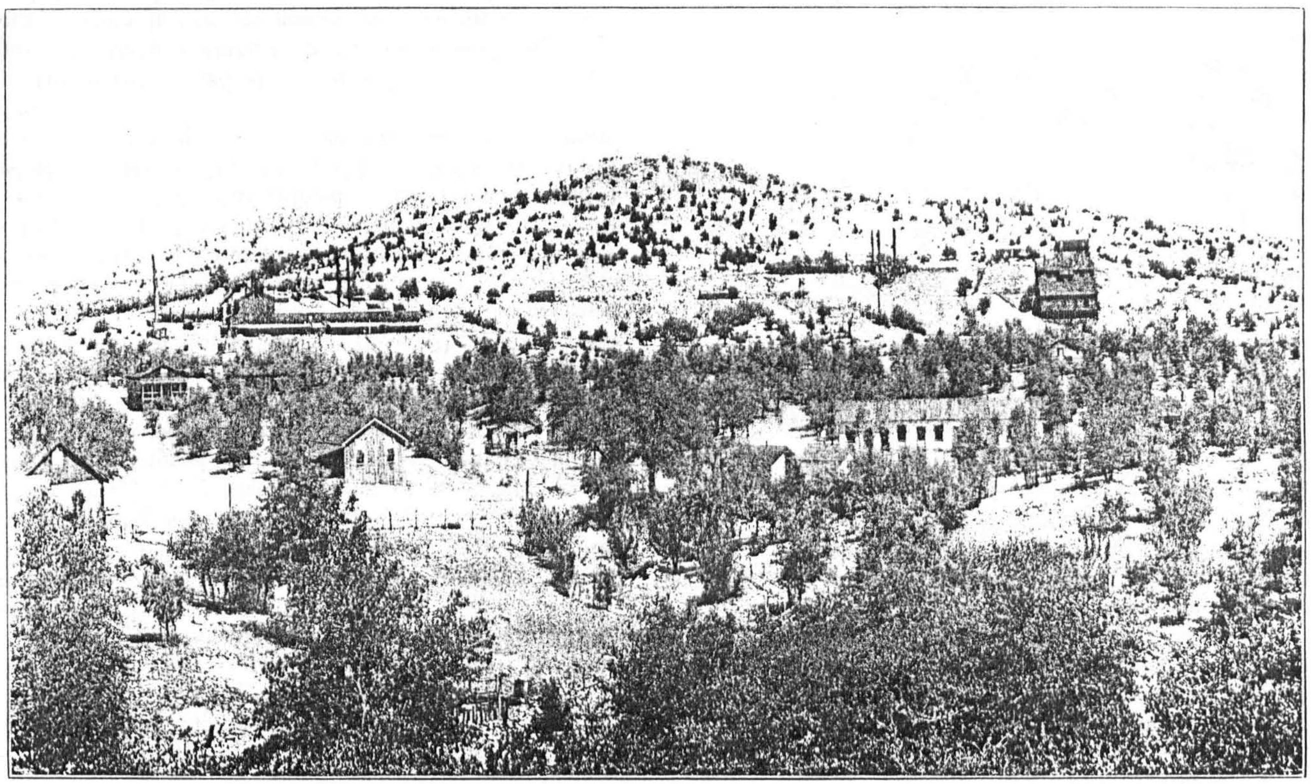

MOWRY MINE AND PART OF CAMP.

Mill at right, smelter at left. Looking north-northeast.

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shaft No. 2, shown on Plate XXI. The main shaft is sunk to the depth of the 500-foot level. Drifts are opened down to the 400-foot level, and most of the ore has been stoped down to the third and fourth levels for 600 feet to the east and to the west on the vein, but the deeper workings have not been so extensive.

Some portions of the ore bodies were worked by a system of square sets and overhead stoping, and others by the caving and filling method. By the caving system 80 per cent of the ore mined was

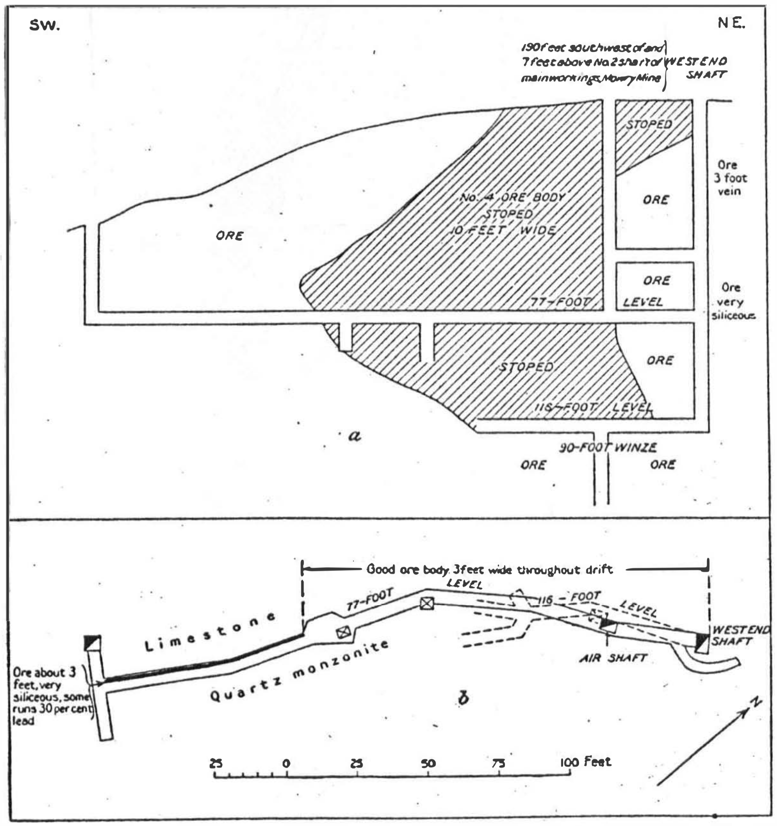

FIGURE 37.—Workings at west end of Mowry mine. *a*, Longitudinal section; *b*, plan.

removed without timber, powder, or filling and without working under an unsupported back.

The equipment at the time of the writer's visit comprised a smelter and a concentrator, each with 100 tons daily capacity. In September, 1914, however, the concentrator was reported to have been destroyed by fire caused by lightning. The smelter is of the lead-silver blast-furnace type. There are also three steam hoists, two 10-horsepower gasoline hoists, and one 5-drill air compressor.

When in operation the mine employs from 300 to 500 men, about 100 men working underground and the rest in the mill, smelter, etc.

Topography and geology.—The topography, as shown in Plates I and XXII, is gentle. The mine is in the south base of Mowry Hill, on the north side of a small open valley known as Mowry Wash, in which the camp, shown in part in Plate XXII, is pleasantly located. The wash heads half a mile west of the mine and joins Santa Cruz River about 8 miles to the east.

The mine is on an east-west fault contact between the Paleozoic limestone[1] and the Mesozoic quartz monzonite. The latter has hitherto been locally known as granite and macroscopically much resembles granodiorite. The fault, which will be called the Mowry fault, trends N. 75° E. and dips 78° N. and seemingly is normal (fig. 38). The limestone occurs on the north or hanging-wall side of the fault and the quartz monzonite on the south side. The limestone essentially composes the adjoining Mowry Hill, which, as shown in Plate XXII, rises about 300 feet above the mine and seems to represent the northern part of a low dome or anticline whose southern part has been cut off by the fault, for in the east slope of the hill the rocks dip 45° NE. At the top of the hill they dip to the north and in the west slope they dip to the northwest at about the same or slightly less angles. Along the fault they dip 45°–70° N., away from the contact.

At some time later than the faulting the rocks and the fault were disturbed along a fault or shear zone about 200 feet in width, which strikes N. 30° W. and stands about vertical and which, as shown on the Mowry fault at the mine, has offset the formations by a small horizontal displacement, the rock on the east being moved 45 feet to the south. To the east of this later fault, which will be referred to as the north-south fault, the limestone for a short distance strikes N. 45° W. and dips 50° NE.; west of it the strike is N. 45° E. and the dip more regularly to the northwest at about 28°. To the north up the slope the zone dies out just below the top of Mowry Hill, apparently passing into undisturbed cherty limestones that strike N. 85° W. and dip 43° N. On the south, where the fault zone is about 250 feet wide, it is composed of a red iron-stained silicified breccia, apparently composed mainly of chert pebbles, which at the top of the hill seems to run into a bed of dark-gray cherty limestone that continues northwestward down the west slope of the hill.

Away from the locally disturbed beds along the north-south fault the limestones are unaltered, dark blue-gray in color, thin to heavy bedded, and in places cherty. To judge from the occurrence in the east slope of the hills, which affords the best exposure, though the

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

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section is incomplete, they aggregate at least 800 feet in thickness, of which about 330 feet is shown in the mine. They contain many

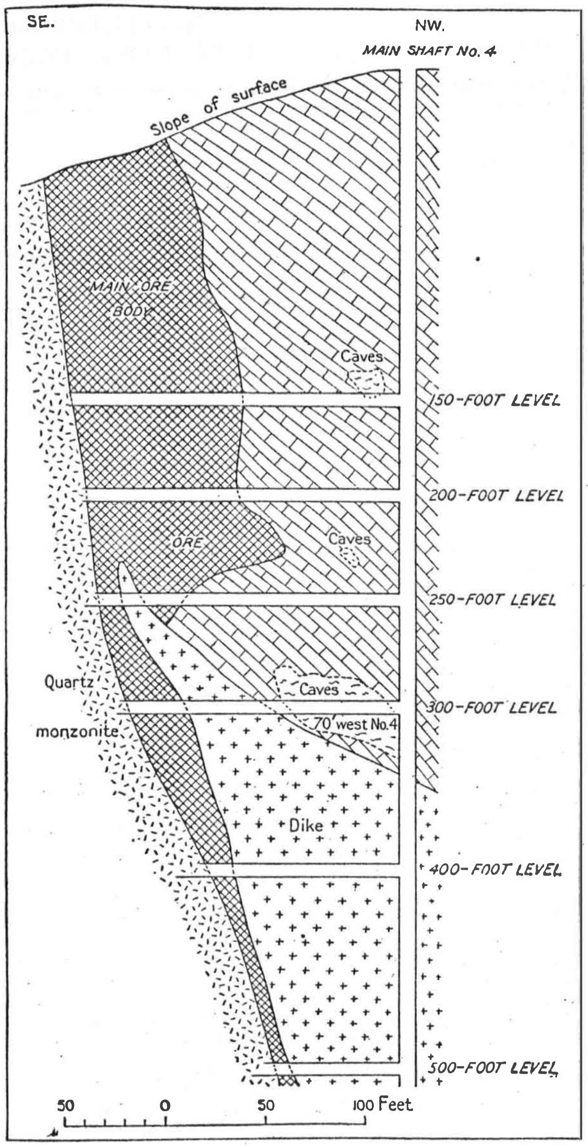

FIGURE 38.—Cross section of Mowry mine, showing fault and vein.

traces of fossils, but most of them are only poorly preserved. These limestones have supplied most of the fossils described on pages 49–51, which fix the age of the rocks as Pennsylvanian.

The limestone is much purer along the north-south fault than away from it, but along the Mowry fault some of the limestone has been metamorphosed to a fine-grained marble. The limestone contains also some interbedded quartzite.

The quartz monzonite south of the Mowry fault is a reddish-gray, massive, porphyritic granitoid rock with phenocrysts of feldspar an inch in diameter. It is composed mainly of orthoclase, oligoclase-andesine, and quartz in about equal amounts, the orthoclase including some microperthite and microcline. Considerable dark silicate is present, some as biotite but most as hornblende, which, however, is nearly all altered to heavy dark-green masses consisting principally of chlorite or allied decomposition products and oxide of iron. Apatite is present as an accessory, and some pyrite, marcasite, and chalcopyrite occur as secondary minerals. The rock on the whole is considerably altered, especially the soda-lime feldspars, which are highly sericitized. The analysis of this rock (No. 2, on p. 61) agrees fairly well with its microscopic determination as a quartz monzonite. It belongs to the Mesozoic intrusive rocks, and is regarded as intrusive into the limestone. Its outcrop belt has a considerable width at Mowry, whence it extends interruptedly southward to the main area of quartz monzonite in the Patagonia Mountains northwest of Washington. For 60 to 100 feet back from the Mowry fault the rock is much altered and stained with iron and manganese, and along the fault it is sheared and crushed, and the nearly parallel shear planes dip steeply to the south away from the fault.

Cropping out at several points in the camp southwest of the mine and seemingly intruding the limestone along the Mowry fault in the deep part of the mine, as shown in figure 38, is a dark-greenish or nearly black massive medium-grained crystalline rock locally known as basalt, and in the mine, where it approximately parallels the fault and vein, it is known as the "500-foot lime dike." Microscopic examination, however, shows it to be an almost typical gabbro. It is composed mainly of labradorite or closely allied basic soda-lime feldspar, augite, or other pyroxene and contains considerable magnetite and iron, some biotite, and seemingly olivine, with accessory apatite. The rock on the whole is highly altered. The augite, whose abundance in places is indicated by the form of the crystal casts, is mostly changed to green amphibole, smaragdite, and chlorite, and the feldspars are greatly kaolinized and altered to epidote. Calcite and magnetite are present as secondary minerals, the former occurring both in isolated crystals or grains and in macroscopic veinlets and seams on joint planes and fracture lines, together with a few seams or veinlets of secondary quartz. The chemical analysis of this rock, given on page 69, showing it to be high in potash, agrees with the microscopic determination of the rock and compares well with the published analyses of gabbros. This gabbro from surface exposures appears to be younger than the quartz monzonite. It is well exposed in the camp southwest of the mine, on the main road about halfway between the Phelps place and Mowry post office, where the quartz monzonite is regarded as the country rock but is covered by wash and débris so that the actual contact between the two rocks is not revealed. It also seems to outcrop at a point about 1¼ miles south of the mine, on the Washington stage road, where the quartz monzonite or a similar granitoid rock is intruded by dikes of a dark rock, which was thought to be the gabbro but which received only a field examination. The gabbro is also said to outcrop at a point about a thousand feet east of the mine, where it is very much altered.

Water was encountered at the 300-foot level in the mine and now stands about 250 feet below the surface. On the 400-foot level the mine makes about 200 gallons of water a minute.

Ore deposits.—The deposits are valuable for their lead and silver content. They occur on the north or hanging-wall side of the Mowry fault, on the contact between the limestone and the quartz monzonite, primarily in a fairly continuous 6 to 8 foot ore body or tabular lode or vein which strikes N. 75° E. and dips 78° N. This is probably the body seen by J. Ross Browne, who visited the mine in 1864 and described the vein as about 4 feet in width.

The croppings, consisting mainly of oxides of manganese and iron, kaolin, and some argentiferous galena, extended interruptedly along the contact fissure for half a mile or more and continuously along the 600-foot stretch now occupied by the mine openings, being especially prominent over the ore bodies. From the surface or base of the croppings the vein extends downward to the bottom of the mine in a continuous tabular sheet and was ore-bearing almost throughout, the ore minerals being lead carbonates and galena. At the mine, therefore, the deposit has a known horizontal extent of 600 feet or more. It is separated from the monzonite footwall by a 2 to 6 foot tabular sheet of argillaceous gouge (fig. 38), whose width, it is said, varies roughly in proportion with that of the adjoining ore body. West of the mine, as shown by openings just beyond the smelter, this ore body has the form of a quartz vein about 8 feet wide.

Most of the ore bodies, however, occur apparently as replacements of the adjoining limestone, principally in an area of crescentic outline in ground plan, with its outer or convex edge extending 100 feet or more back from the fault and fissure into the limestone. In this area the ore bodies occur mainly in the shape of large, nearly vertical lenses lying parallel with the fault contact. The largest body, said to be crudely cylindrical in cross section, is at the intersection of the two faults, mainly east of the north-south fault. Associated with the ore bodies in the upper levels are pockets of cerusite that carry as

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many ounces in silver as units of lead. Besides these lenticular ore bodies, there are also ore sills or beds from 1 to 10 feet in thickness following the bedding planes in the limestone for several hundred feet from the fault or main bodies. The limestone here dips 45° N., away from the fault. The deposit at the North Mowry mine (p. 305) is regarded as probably one of these sills.

The ore consists mainly of the argentiferous ore minerals, cerusite, coarse galena, anglesite, and bindheimite, all contained in a manganiferous and ferruginous gangue consisting principally of psilomelane and massive pyrolusite and hematite. The manganese and iron together are said to form about one-fifth of the ore body in volume. There is but little if any quartz, and a remarkable feature is the absence of zinc. The ore is mostly oxidized down to or below the 300-foot level, and scarcely any sulphide other than galena, not even pyrite, was found above this level. Copper and iron sulphides first began to appear on the 400-foot level. Much of the ore is a friable argillaceous mixture of silver-bearing cerusite and anglesite, with calcium carbonate, hematite, psilomelane, and pyrolusite, and in many respects is similar to the ore deposits at Leadville, Colo., but the lead carbonates occur also in the indurated siliceous form. The ore is said to become less manganiferous and more siliceous with increasing distance from the gabbro dike.

The galena is in the main coarsely crystalline. It occurs in lenses and masses of considerable size embedded in the manganiferous gangue, and when associated mainly with pyrolusite, as in the lower workings, it is said to form the richest ore, averaging several thousand ounces in silver to the ton. Much of the ore is mottled white, yellow, and greenish, with cerusite and anglesite, bindheimite, and malachite, respectively, and associated with it, beginning on the 300-foot level, is also a little wulfenite. On the 400-foot level vanadinite and arsenopyrite appear. The bindheimite, which is a yellow hydrous antimonate of lead, is apparently a secondary product probably derived from the alteration of jamesonite or possibly some antimonial silver mineral not yet observed in the ore.

At a depth of about 235 feet the limestone gives way to the gabbro, which, as shown in figure 38, becomes the hanging wall and continues as such to the bottom of the mine, the quartz monzonite being the footwall. The vein or ore body in general narrows downward from this depth and seemingly deteriorates in value. In the lower workings the ore is to some extent associated with the gabbro, but it does not maintain the development which it has in the limestone above, nor, to judge from the regularity and apparent smoothness of the hanging wall extending from the 250-foot to the 500-foot level, as shown in figure 38, does the gabbro form by any means as favorable a repository for the deposits as the limestone.

The presence of the gabbro seems to have facilitated oxidation and increased the amount of iron, for between the 200-foot and 300-foot levels the ore, vein matter, gouge, and adjoining wall rock are all highly oxidized and stained red with iron ore. The galena is altered and largely changed to cerusite, which is more plentifully present than it is just above the upper limits of the gabbro. The manganese of the gangue, however, which continues from the surface to the bottom of the mine, is relatively unaffected. The 400-foot level in general is characterized by an abundance of calcite and kaolin, in addition to the usual manganese and iron minerals.

The ore in general, it is said, averages about $40 to the ton, but much of it is very rich, especially the galena ores, which carry about 68 per cent of lead, are variably argentiferous, with 100 to 4,000 ounces of silver to the ton, and contain about $1 to the ton in gold and a trace of copper.

At about the 150-foot level occur several veins or sheets of manganese, which in one place unite and form a large body with a corresponding increase in the amount of good ore.

The main ore body, known as No. 1, of which figure 38 is a cross section, is located at the northeast corner of the intersection of the north-south and Mowry faults. It is roughly pipe-shaped or elliptical in cross section in the upper part of the mine and seemingly terminates just below the 250-foot level or flattens into a tabular sheet but 4 or 5 feet in width in the lower part of the mine. It consists, especially in the upper part of the mine, of alternating vertical coarse bands, tabular sheets, or veins of manganiferous and ferruginous material. Much of the richest ore of the mine came from this body between the surface and the 300-foot level, or about the ground-water line. It contained principally argentiferous galena, which carried about 68 per cent in lead and 400 ounces to the ton in silver, and some samples contained as much as 6,000 ounces of silver to the ton.

Ore body No. 2, shown in part in figure 36, connects with ore body No. 1 just above the 150-foot level and pitches along the dip of the contact at an angle of 40° W. down to about the 315-foot level, where the ore becomes oxidized and leached, like the ore in ore body No. 1. The ores in this body are mainly cerusite and other carbonates of lead, and where mined averaged about 40 per cent in lead and 25 to 300 ounces to the ton in silver.

Ore body No. 3 is opened near the surface, as shown in figure 38, and is also encountered in the deep part of the mine by a crosscut extending westward from shaft No. 4 on the 400-foot level, where it is on the north-south fault. It is similar to ore body No. 2 in consisting mainly of carbonates of lead. It dips west and at the surface connects with ore body No. 4.

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Ore body No. 4 contains also lead-silver silicates where the siliceous ores appear.

Source of the ores.—From the nature and structure of the ores and ore bodies and the general absence of the metallic minerals in the surrounding rocks from which they might be segregated, the ores seem most likely to have been deposited by ascending metal-bearing solutions that came up along the Mowry fault. First was deposited the 6-foot tabular vein occupying the fissure next to the quartz monzonite footwall, seemingly as a true fissure vein, and from it ore deposition by metasomatic replacement extended stage by stage northward into the hanging-wall limestone, forming successively the nearly vertical tabular ore shoots or bands alternating with similar intervening bands of the manganese-iron gangue. Where the invading solutions found the limestone easier of penetration and more soluble, as along the bedding planes, they followed or descended these planes, whose dip slope was admirably adapted for facilitating the process, and there formed the ore beds or sills.

As the gabbro seems to be intrusive into the quartz monzonite and into the limestone, the solutions which deposited the ores were probably those that followed its intrusion, a view which seems to find support in the basic nature of the deposits and the paucity or absence of quartz. The solutions were probably thermal and deposited the ores at considerable depth, chiefly as sulphides of lead, manganese, and iron. The ore minerals subsequently became concentrated and oxidized to their present state down to the bottom of the mine. Although, so far as the present examination indicates, it is possible that the ore deposits may be due to the quartz monzonite, the marked difference in the character of the deposits and especially of the gangue and its metamorphic minerals from those of the Washington-Duquesne camp, which owe their origin to the intrusion of the same or a similar quartz monzonite in a similar limestone, strongly suggests that the deposits at the Mowry mine owe their origin to the gabbro.

Future of the mine.—The present company is hopeful of finding good ore bodies in the quartz monzonite by deep sinking and by extending the workings southward, especially on the north-south fault, although, so far as learned, no ore has yet been found in the quartz monzonite in this district. The abundance and purity of the pyrolusite in the gangue suggest that this mineral may prove a useful by-product.

NORTH MOWRY MINE.

The North or Old Mowry mine, which is a part of the Mowry property just described, is about a third of a mile northeast of the Mowry mine, in the east base of Mowry Hill, on open, gently sloping ground at an elevation of about 5,500 feet. It has produced some ore, which was mostly lead carbonates, associated with highly decomposed oxide of manganese and iron. Its deepest opening is a 120-foot shaft. The country rock is the Pennsylvanian limestone, which here is heavy bedded and dips northeastward and in which the deposits occur in one or more of the northward-dipping sills or replacement ore beds that have been described and in joint planes in the adjoining limestone. The sills, which now outcrop at the surface, were probably at one time connected with the Mowry vein at some distance above the present surface, but the connection has since been removed by erosion.

MORNING GLORY MINE.

The Morning Glory mine is 1¼ miles west of the Mowry mine and one-third of a mile southwest of the stage road, on the north side of a shallow gulch that drains northward into Alum Gulch, at an elevation of about 5,600 feet. It is easy of access by a wagon road ascending the gulch. The deposit was discovered late in the eighties by David Neal, who, with A. S. Henderson, soon took out considerable silver ore, which he roasted at Mowry or leached. On reaching the sulphide zone, which then seemed to contain mostly pyrite, he abandoned the mine.

About 1895 or 1896 the mine was relocated by Richard Farrell and wife, from whom it was acquired in 1908 by the present owner, C. B. Wilson, of Helvetia. At the time of visit Mr. Wilson was sinking on the property, which then had about 2,000 tons of low-grade ore blocked out or in sight. Since then the mine has been an almost steady producer on a moderate scale and has shipped during a considerable part of this period two carloads of ore a week. The production in 1907 is given as $13,371 from copper sulphide ore which yielded 54,486 pounds of copper and 3,788 ounces of silver.[1]

Recently the mine is reported to have 50,000 tons of good copper-silver ore blocked out, which is said to average about 75 per cent in iron and sulphur combined, and about 3.5 per cent each in copper and silver.

The mine is opened mainly by a 200-foot shaft, inclined 45°, and contains three levels, 50, 100, and 150 feet below the surface, on which it is developed by shafts and stopes for a horizontal distance of about 200 feet.

The country rock is the Paleozoic limestone, which dips 40° WNW. It is in part silicated, cherty or flinty, and locally pyritic and seemingly contains some interbedded strata of quartzite. It is overlain in the surrounding hills by the Mesozoic sedimentary rocks. Oxidation extends to a depth of about 40 feet. The mine makes about 2,000 gallons of water in 24 hours.

[1] U. S. Geol. Survey Mineral Resources, 1907, pt. 1, p. 178, 1908.

The deposits occur principally in a so-called vein or ore bed, which dips 40° WNW., conformably with the inclosing rocks. The footwall is greenish-gray silicated and in part epidotized limestone or quartzite with very finely disseminated pyrite. The ore bed is from 4 to 10 feet in width and seems to represent a mineralized sheet or sill of intrusive rhyolite or "porphyry," which for the most part has been completely replaced. It contains mainly pyrite and chalcopyrite, with a little chalcocite and in places sphalerite. Some hematite and specularite are present near the surface, where the deposit is crudely banded. The gangue minerals besides the altered rocks are quartz and calcite in moderate amount, with a little barite.

The ore in general is oxidized and principally free-milling down to the 50-foot level, but in the north end of the mine, which contains considerable zinc, oxidation extends much deeper. The ore is chiefly of low grade, but a considerable part of it is said to yield about 17 per cent in copper and 15 ounces to the ton in silver. Some of it carries principally zinc, but the sphalerite seems to be restricted to the upper levels, where in places it constitutes a relatively pure ore containing, it is said, 60 per cent or more in zinc. If smelting facilities were installed in the district or freight rates were slightly lower this ore would be of commercial value for its zinc content.

The ore of this mine is in demand by the smelters in Sonora, across the Mexican boundary, for its sulphide content, which is useful in smelting their more basic ores. During 1912 the ore was being mostly shipped to the Pioneer smelter, at Sahuarita, the owners of which are said to have recently taken a bond on the property.

Besides the ore bed above described, which has been the source of the ore produced, there is also near the bottom of the shaft a younger undeveloped 4-foot vein which dips 45° S. and cuts the ore bed diagonally. This vein contains ore similar to that of the ore bed except that it averages a little higher in copper and carries but little zinc.

The ore was probably formed by hydrothermal solutions that accompanied or followed the intrusion of the rhyolite, which occurs near by in dikes and masses.

ENDLESS CHAIN MINE.

The Endless Chain mine, consisting of a group of claims and openings, is one-third of a mile north of the Morning Glory mine, in the side of a similar open gulch about a quarter of a mile west of the stage road, at an elevation of 5,400 feet. It is owned by the Endless Chain Mining Co. of Oklahoma and has shipped some ore. The deposits occur mainly in what seems to be a 2½-foot ore bed in Paleozoic slaty, dense light-gray brecciated pyritic quartzite, dip-

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ping 70° SE. They are opened by an inclined shaft and drifts and a little farther downstream by a tunnel, called the Cunningham tunnel. The ore contains chalcopyrite, pyrite, some tetrahedrite, and a little chalcocite. Some of it is banded.

AUGUSTA MINE.

The Augusta mine is 1¾ miles northwest of Mowry, about 750 feet west of the stage road. The deposit was discovered in 1878 and relocated in 1905. It is opened by a 110-foot shaft and contains some drifts. Ore shows in some of the workings. The deposit is a sort of compound vein or group of parallel stringers. Some chloriding has been done here. The known production is about 100 tons of ore said to average about 57 per cent in lead, 10 per cent in zinc, and 40 ounces in silver and $3.50 in gold to the ton.

O'MARA MINE.

The O'Mara or Old Soldier mine is located in the north-central part of the district, about 3½ miles west of Mowry, on the west slope of the Patagonia Mountains, in the northwest side of the head of Canada de la Paloma, at an elevation of 5,500 feet. It is connected by a good trail with the stage road 2½ miles distant on the east. The camp is about half a mile southeast of the mine and 450 feet lower in the bottom of the canyon.

The mine was first worked in 1888. It is now owned and is being worked in a small way by the Chicago & Patagonia Copper & Gold Mining Co., with headquarters at Chicago and Nogales. The property comprises a group of 19 claims covering the north head of Canada de la Paloma. It was idle in 1909.

The mine contains about 2,000 feet of development work and is opened to a depth of 188 feet by two shafts, 200 feet of drifts on the 80 and 180 foot levels, a 187-foot crosscut on the 180-foot level, and several winzes, as shown in figure 39. The main shaft is 250 feet south of the vein on its hanging-wall side. The second shaft, 140 feet deep, is sunk on an incline 70° SE., following the vein.

The deposits occur in a 5-foot vein near the middle of a lentil of quartz monzonite 1 mile wide, intruded into the much larger body of the older quartz monzonite that occupies the basin-like head of the valley on the east and the mountains to the northwest. Fibrous black tourmaline intergrown with quartz is developed along the contact of the two rocks, mainly in the older. The intrusive is a fine-grained granitoid rock composed of orthoclase and andesine-labradorite in about equal amounts, with quartz, biotite, hornblende, a little magnetite, and secondary chlorite, hematite, and epidote. Water is encountered at about the 100-foot level. On the 80-foot level the

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vein is offset by a seemingly almost flat-lying fault above which the rocks have been moved 12 feet or more to the northwest, the fault being normal.

The vein contains principally quartz banded with pyrite, chalcopyrite, and bornite, and these sulphides also impregnate the wall rock. The ore is said to average $10 to $20 to the ton in gold, silver, and copper. About 80 tons of the ore lies on the dumps. Some of it shows excellent intergrowths of pyrite and quartz. The croppings are mostly not prominent. The latest work is an 80-foot shaft sunk in the gulch to the east of and 300 feet lower than the mine. It is said to expose a 5-foot vein, which lies about parallel with the main vein in the mine and contains similar pyrite-chalcopyrite ore,

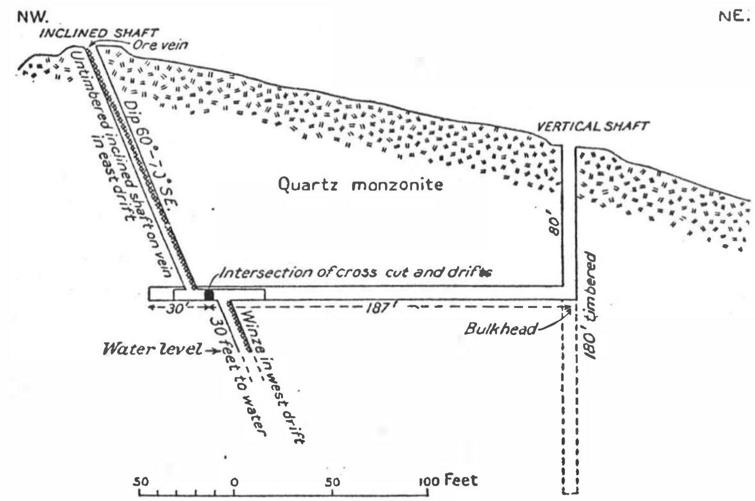

FIGURE 39.—Cross section of O'Mara mine and vein.

which assays 10 per cent in copper and 21 ounces in silver and $2 in gold to the ton. The deposits were probably formed by hydrothermal solutions that circulated soon after the intrusion of the quartz monzonite, or they may be due to the later granite porphyry, large areas of which, as shown in Plate II (in pocket), occur about 1¾ miles distant on the northeast and the southwest.

MAY PROSPECT.

The May prospect, belonging to S. M. Bailey, of Nogales, is in the border of the granite porphyry outcrop farther downstream on the south side of Canada de la Paloma, at an elevation of 4,500 feet. It is opened by a short tunnel on a fault in the granite porphyry that strikes N. 85° W. but shows no mineralization. The fissure is filled with yellowish gouge about 4 inches wide and dips 50° W. The tunnel was driven on the supposed favorable indications of a small pocket of galena found in an open cut in a north-south fissure at the surface.

NATIONAL MINE.

The National mine is 1¾ miles southwest of the O'Mara mine, in the western foothills of the Patagonia Range, on the north bank of Canada de la Paloma, at an elevation of about 4,500 feet. It is at the north end of a series of properties comprised in a belt about a mile wide, which extends from this point southward through the foothills across Paloma, Wild Hog (Jabalina), and Providencia canyons for a distance of 2½ miles and which may be referred to as the Gross belt. The deposits are mainly lead-silver veins, which strike east at about right angles to the axis of the range. They occur chiefly in the granite porphyry which occupies most of the foothills as far as Providencia Canyon, the underlying diorite cropping out in several places. The Gross and Golden Rose camps, the principal settlements, are located respectively near the middle of the western border of the belt on Wild Hog Canyon and near its south-central part on Providencia Canyon. They are reached by a wagon road ascending the canyons and connecting with Nogales, the principal supply point, 14 miles to the southwest.

The topography of the belt is rough, but the properties are mostly accessible with wagon by way of the washes or canyons from the west. The belt and its foothills are separated from the main mass and steep slope of the range by a sort of piedmont valley or longitudinal pass which extends northward for 6 miles to and beyond the Jarilla mine and seems to represent the line of a piedmont fault along which the range has been uplifted on the east. This valley naturally facilitates transportation in a north-south direction along the range.

The discovery and location of the principal veins in this belt began about 1899 or 1900, a leading pioneer in the work being George Gross, at present an extensive operator. About the only patented claim in the belt is the Providencia claim, near the Golden Rose mine, in the southern part of the belt, of which the Wilson, Moody & Morris property is an extension.

The National mine is at the foot of the mountain side, in less steeply sloping ground. It has been a moderate producer and shipped six carloads of ore in 1907. At the time of visit about 20 tons of ore lay on the dump. The mine is mainly in coarse granite porphyry near the contact of that rock with the diorite which it intrudes, and which, in turn, is intrusive into quartz monzonite, that crops out near by on the northeast.

The mine is opened by a 200-foot vertical shaft which contains about 400 feet of drifts and is equipped with a gasoline hoist. The

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vein dips 70° S. and is associated with the granite porphyry contact. The ore on the dump shows a considerable quantity of copper minerals, and the ore is said to become copper ore in depth.

The National No. 4 prospect, a few hundred yards to the south of the mine on the opposite side of Canada de la Paloma, in the brow of the hill, is opened by a 90-foot drift and a 90-foot inclined winze and shows a 2-foot siliceous galena-silver vein which dips 50° S. in the granite porphyry and is partly associated with a fault-shear zone. The gangue in this vein is principally firmly cemented quartz breccia. The ore, some of which lay on the dump, is said to assay 65 per cent in lead and 60 ounces to the ton in silver. The croppings about 35 feet south of the tunnel mouth are considerably iron stained.

ISABELLA MINE.

The Isabella mine is about half a mile north of the Gross camp, on the National mine trail, at an elevation of about 4,400 feet, at the head of Wild Hog Canyon, in the southerly slope of a long east-west ridge. It was located in June, 1904, by the owners, E. E. Bethell and partners. It is on a 2½-foot east-west vertical quartz vein between granite porphyry on the north and diorite on the south. Both of these rocks are altered near the vein, which is traceable on the surface by croppings and openings for nearly half a mile. The croppings consist of drusy banded quartz with limonite, psilomelane, and what appears to be earthy lead carbonate. The developments comprise cuts and shallow shafts. Some ore on the dump of a 50-foot shaft, sunk on the vein on the Victor or west claim, contains a little galena.

CHANCE PROSPECT.

The Chance prospect, owned by the Jabalina Mining Co., is east of the Isabella mine. It is opened by a 150-foot tunnel and a 50-foot shaft.

SHAMROCK PROSPECT.

The Shamrock or Gross Gold Vein prospect, owned by George Gross, is in the upper part of Wild Hog Canyon one-eighth of a mile north of the Gross camp, at the point where the trail to the National mine leaves the gulch. It is opened by a 140-foot tunnel, a drift, an upraise, and a 40-foot shaft. The deposits occur in a quartz vein which dips 60° SE. and lies mainly in intrusive granite porphyry near the contact with the diorite, which is exposed at places in the footwall. The vein contains quartz and crushed altered rock stained reddish with limonite and manganese oxide and is said to have yielded very rich gold-silver ore near the surface.

JABALINA PROSPECT.

Starting in Wild Hog Canyon at the Gross camp, at an elevation of about 4,300 feet, the Jabalina vein extends eastward through the adjoining hills for a quarter of a mile or more in granite porphyry, the croppings being exposed through a vertical range of about 200 feet. The sheeting structure in the containing granite porphyry dips to the east-southeast. Where opened by a 25-foot shaft near the top of the hill adjoining the canyon the vein dips steeply to the south. The vein is 9 feet in width and is composed of coarsely banded mineralized brecciated quartz, altered rock, and ore carrying lead and silver. About 5 tons of ore resembling that at the Shamrock prospect, just described, lies on the dump. Much of it is stained black with manganese and some is coated with greenish and brownish crystalline pyromorphite.

BIG LEAD MINE.

The Big Lead mine, also known as the W., M. & M. mine, is in an east-west gulch half a mile south-southeast of the Gross camp, on a granite porphyry dike and shear zone cutting the diorite. It is opened by shafts and drifts. The lode is about 25 feet wide and contains a 3½-foot vein. It strikes N. 75° E. and stands about vertical, the dip being steep to the south near the surface and steep to the north in the bottom of a 75-foot shaft. The ore occurs in shoots about 5 inches in width in which the ore minerals are chiefly galena and chalcopyrite with associated silver and gold, contained in a quartz gangue.

The San Joaquin prospects, seemingly on this same vein farther west, are said to be opened by 500 feet of work, including a 160-foot tunnel.

SPECULARITE PROSPECT.

A prospect about three-fourths of a mile west of the Golden Rose mine, seemingly in the diorite, consists mainly of deposits of specularite, which occurs plentifully in large bunches mixed with a more or less siliceous gangue and is suitable for fluxing, for which it is utilized.

GOLDEN ROSE MINE.

The Golden Rose mine is located in the south-central part of the belt, about a quarter of a mile north of the Golden Rose camp, at an elevation of about 4,500 feet. It is 250 feet above Providencia Canyon, a quarter of a mile to the southeast, and is reached by a wagon road of easy grade. It is owned by the Greenwell-Arizona Mining Co., with headquarters at Wooster, Ohio, and Nogales. It has been working steadily for some time with a small force of men

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and has made shipments of ore. The company is planning to install a 50-ton concentrator.

The property contains three claims. It is opened by a 100-foot shaft and a few hundred feet of drifts and crosscuts, giving 150 feet of backs, and has a whip hoist. There is a small supply of good water in the canyon above the camp.

The deposits are contained in a 16 to 20 foot lode which strikes N. 70° E. and dips 80° S. in fine-grained dark iron-gray quartz diorite. Granite porphyry is intruded into the diorite on the east, toward Providencia Canyon, and to the intrusion the deposits probably owe their origin. The diorite at the surface is weathered down.

The lode is composed of quartz, altered rock, and ore. The main ore shoot within the lode is said to average 3 feet in width and in places is 12 feet in width. The ore contains gold, silver, lead, and copper minerals in a crudely banded gangue of quartz and altered rock which is more or less porous and honeycombed. It is said to average $12.50 to the ton. The principal sulphide minerals noted are chalcopyrite, galena, and stephanite. Some pyrite and a little specularite are also present. The microscope shows some of the ore to be very closely banded, with bands consisting mostly of quartz, about one-fortieth of an inch in width, alternating with similar ones composed principally of the metallic minerals.

BENNETT MINE.

The Bennett mine is a quarter of a mile southeast of the Golden Rose mine, in the southeast bank of Providencia Canyon, at an elevation of about 4,300 feet and is easy of access. It is opened principally by a 200-foot shaft and a short tunnel drift. It is on an east-west fault fissure in quartz monzonite, which is intruded by diorite. In the quartz vein contained in the fissure the ore occurs in fairly persistent stringers and shoots, ranging from 1 to 4 inches in width, and consists mainly of coarse massive pyrite and chalcopyrite freely banded with quartz.

GROSS COPPER PROSPECT.

At and in the hill northeast of the Bennett mine and in fact occupying the northwestern part of the triangular area bounded by Sycamore Canyon on the south and east and Providencia Canyon on the northwest, just across Providencia Canyon from the Golden Rose mine, the quartz monzonite which is reddish, medium to coarse grained, and somewhat sheared, is impregnated with evenly disseminated small crystals, masses, and grains of chalcopyrite and pyrite and contains sparingly also molybdenite, which has much the same habit as the other minerals. These minerals seem to be primary and of magmatic origin. They are very persistent throughout the mile or more of the northwest slope of the mountain examined opposite the Golden Rose mine, where in prospecting for copper the ground has been opened at intervals by shafts and tunnels from 10 to 80 feet in depth, and the same conditions are reported to prevail over most of the area above described, which occupies 2 square miles or more, with the surface rising 800 feet above the canyon.

The Gross copper prospect occurs in this formation at the mouth of Guajolote Canyon about 1¼ miles northeast of the Golden Rose mine. It was opened by a shaft 80 feet deep, which was sunk in the quartz monzonite with the hope of finding the copper minerals more concentrated at depth, and in October, 1914, valuable discoveries of extensive copper deposits were reported to have been made.

BUENA VISTA MINE.

The Buena Vista mine is half a mile southeast of the Bennett mine in a south branch of Providencia Canyon, at an elevation of about 4,800 feet. The vein was located in 1895 by Michael Maloney, who shipped about 500 tons of ore that is reported to have averaged 28 per cent in copper and 20 ounces in silver and $2 in gold to the ton;[1] also 24 tons of ore which gave 120 ounces to the ton in silver and 30 per cent in lead. These shipments were made in 1897–98. In 1900, Mr. Maloney sold the mine to the Black Mountain Mining Co. of Prieto, Mexico. It has since become the property of the Banco del Oro Mining Co., of Magdalena, Sonora, Mexico, with headquarters in Chicago. The property contains four claims, on which this company has done considerable development work, and in 1909 there was about 20 tons of ore in the bins ready for shipment.

The property is developed by about 4,000 feet of work contained in three tunnels and their winzes on suitably spaced levels between elevations of about 4,700 and 5,000 feet, as shown in figure 40. Two of the tunnels, of which the lower is 415 feet in length and the other 670 feet, are drifts on the main vein. The other is a crosscut which opens a parallel vein.

The deposits occur in half a dozen or more quartz veins and associated bands of crushed mineralized rock, all contained in a fault shear zone in the quartz monzonite, with intrusive diorite cropping out 400 feet to the northeast of the lower tunnel and granite porphyry near by.

The veins and shear zone dip about 60° SE. The main vein is shown in the lower drift, driven in the granite footwall of the zone, at an elevation of 4,755 feet.

The 140-foot crosscut tunnel, situated 300 feet northeast and 50 feet above the lower drift, besides crossing numerous small fissures and

[1] Oral communication from J. A. Straith.

mineralized slips, shows in the face a 4-foot iron-stained zone of crushed granite and quartz carrying pyrite, chalcopyrite, and a little molybdenite.

The vein in the upper tunnel, which is about 145 feet above the lower tunnel and 100 feet below the crest of the ridge, varies from 2 to 6 feet in width and is separated from the granitic country rock by gouge. It is filled mainly with quartz and calcite, containing pyrite, chalcopyrite, and bornite, and small amounts of azurite and malachite are seen in the gouge material. Besides copper the ore is said to carry gold and silver.[1] In the vein the metallic minerals are

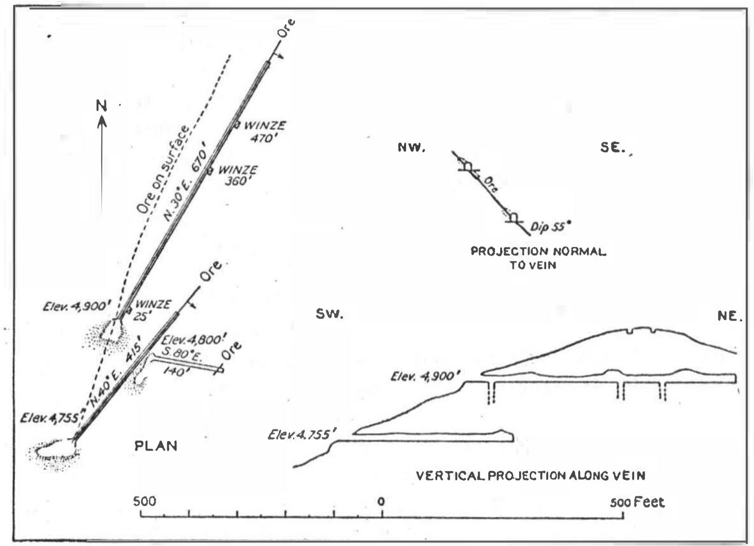

FIGURE 40.—Plan and projections of Buena Vista mine.

found next to the walls and favor the hanging wall, and accordingly they were deposited during the early stages of fissure filling. The pyrite and chalcopyrite are coated with black sulphide of copper and in places show the iridescent colors of covellite. Copper and iron sulphates are being deposited in the workings. In the face of the drift the wall rock is sheared and altered and contains disseminated pyrite. The drift contains some stoping at various points and three inclined winzes sunk on the vein to depths of 40 to 100 feet. Some surface work in the saddle above the drift shows a strong quartz vein with galena and a little chalcopyrite. A tunnel (not visited) to the north of the saddle is located on the same vein.

[1] Report of the Governor of Arizona, 1903, p. 112.

KING PROSPECT.

The King prospect is half a mile northeast of the Buena Vista mine and about a quarter of a mile south of Providencia Canyon. It is opened mainly by a 40-foot shaft and a drift. The drift was not enterable but to judge from the size of the dump must be extensive.

The deposits apparently occur in a 10-inch iron-stained banded quartz vein which dips 70° SE. in coarse quartz monzonite and which as seen in the shaft carries pyrite, chalcopyrite, and bornite, with some malachite and azurite, extending to a depth of 15 feet below the surface. About 5 tons of copper ore containing principally these minerals lies on the dump.

MARCHÉ PROSPECT.

The Marché prospect is in Providencia Canyon, one-eighth of a mile northeast of the King prospect and 1½ miles east of the Golden Rose camp, at an elevation of about 4,550 feet. It is opened by two tunnel drifts driven in opposite directions on different sides of the gulch, of which the southerly one is 90 feet in length. It is on a 2-foot quartz vein which dips 35° SE. in quartz monzonite. The vein is composed mainly of iron-stained quartz and crushed rock or gouge and contains some malachite and azurite. No sulphides were noted.

GLADSTONE PROSPECT.

The Gladstone prospect is on the north side of Providencia Canyon about half a mile northeast of the Marché prospect, at an elevation of about 4,700 feet. The property comprises a group of claims. It is opened by a shaft near the center of the group and is said to have shipped a number of tons of ore, containing mainly chalcopyrite and black copper sulphide, that averaged 28 per cent in copper.

PROTO MINE.

On leaving the foothill or Gross belt just described and ascending the slope which rises eastward to Guajolote Flat, the observer encounters a different set of fissures and veins which strike more nearly north, almost at right angles to the course of the veins in the Gross belt. In the quartz monzonite ridge, followed by the trail leading from the Gladstone prospect northward up to Guajolote Flat, there are distributed through a distance of 1¼ miles in a vertical range of 1,000 feet half a dozen or more mines and prospects, including the Proto mine, located just west of the trail at about the 5,000-foot contour. This mine is opened by a series of tunnels and shafts. It is on a 2½ to 5 foot vein which dips 80° E. into the mountain, with a dike or intrusive mass of diorite forming the footwall and the quartz monzonite country rock the hanging wall. The vein at the surface is highly iron-stained. The principal ore mineral is chalcopyrite. One of the shafts, which is 100 feet or more deep, contains water. Openings of considerable extent, seen across the broad head of the canyon to the north but not visited, seem to be on this same vein.

FOUR METALS MINE.

Location.—The Four Metals mine is a mile east of the Proto mine, in the head of Providencia Canyon on its north side, on the south edge of Guajolote Flat, at an elevation of about 5,400 feet. It is 3 miles northwest of Washington and 2½ miles southwest of Mowry. The camp, which is a village of about 100 Mexican laborers and a few whites, is three-fourths of a mile to the north, on Guajolote Flat, at an elevation of 5,800 feet. Two good wagon roads connect the camp with the stage road 2 miles distant on the east, one at a point half a mile south and the other at a point a mile northwest of Mowry, and by the latter road Patagonia, on the railroad, is 16 miles distant. Nogales is 13 miles west of the mine, and the Washington-Nogales wagon road is half a mile away.

History and production.—The deposit, known as the Guajolote lode, was discovered by pioneers in the sixties or before, but not developed for some time. Browne[1] states:

> The Guajolote lode, 4 miles west of the Mowry mines, is a lode varying from 1 to 6 feet in width on the surface. At the bottom of a shaft of 60 feet there is a vein of metal 3 feet wide. The ore is chiefly sulphurets of silver and there are traces of gold.

Later the property was owned by George Gross, from whom it was bought about 1904 by the present owner, the Four Metals Mining Co. of Arizona, with headquarters at Mowry, Ariz., and Blandinsville, Ill. In the following year this company opened it with over 2,000 feet of work.[2]

In 1906 a shipment of ore containing copper, gold, and silver was made,[3] and beginning in 1907 more extensive development work was done, including the driving of the Red Hill 712-foot lower crosscut tunnel, cutting the vein, and the taking out of considerable low-grade ore, of which several thousand tons now lies on the dump. During the winter of 1908-9 80 men were employed at the mine. Since that time some work has been carried on intermittently by two small forces of men. The property comprises a group of 35 claims.

Developments and equipment.—The mine is developed by about 3,000 feet of work, consisting mainly of crosscut tunnels, two of

[1] Browne, J. R., Mineral resources of the States and Territories west of the Rocky Mountains, 1867, p. 449, 1868.
[2] Heikes, V. C., U. S. Geol. Survey Mineral Resources, 1905, p. 156, 1906.
[3] Idem, 1906, p. 171, 1907.

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which, connected by an upraise, extend north and south for more than 1,200 feet through the hill, as shown in figure 41.

The company buildings accommodate 20 men, and the camp contains Mexican buildings sufficient for about 150 persons. Water for domestic use and for stock is supplied by a 20-foot well, and much of the oak timber on the flat is suitable for mine use.

Topography and geology.—The mine is in a small hill, known as Four Metals Hill (fig. 41), surmounting a steep ridge which descends from the Guajolote Flat 1,000 feet southeastward into the head of Providencia Canyon in the horizontal distance of three-

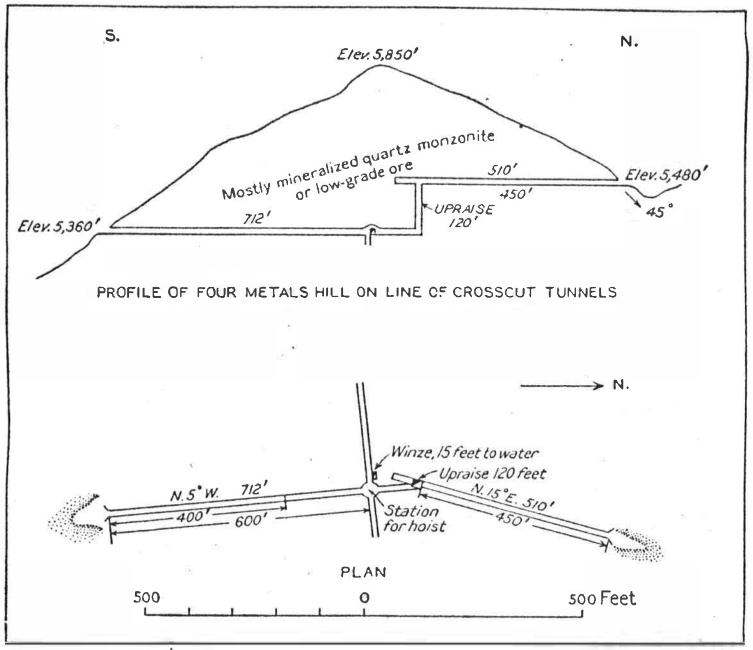
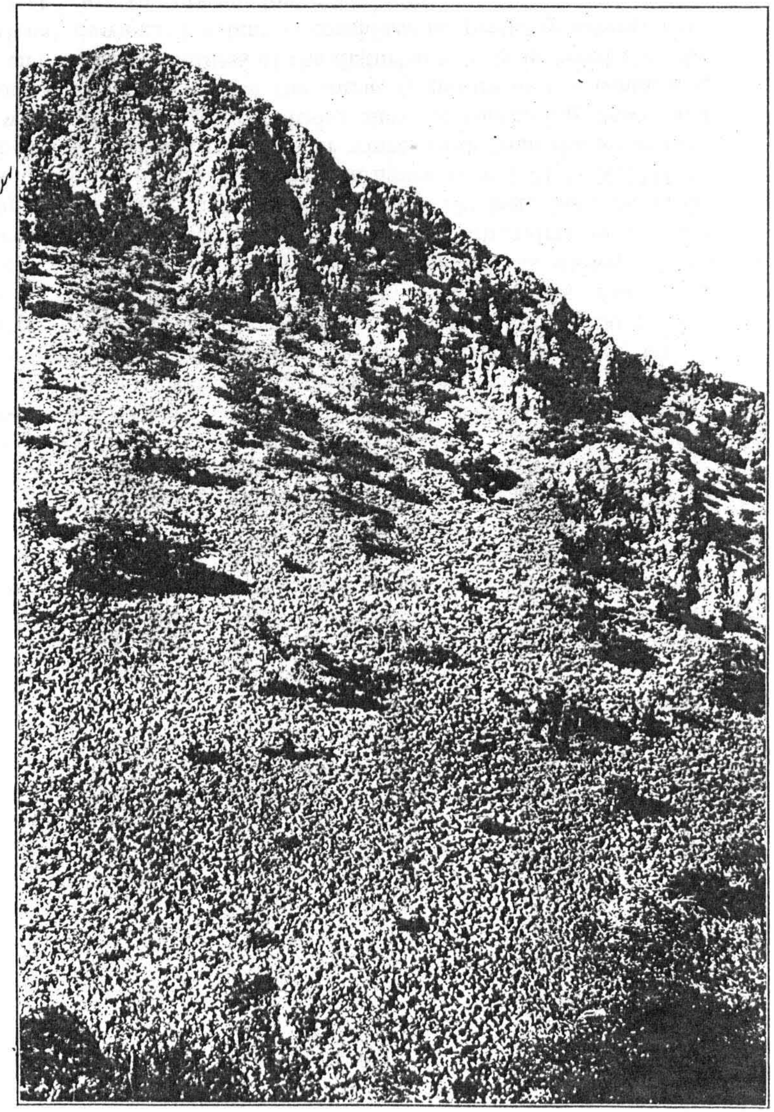


FIGURE 41.—Profile and plan of Four Metals mine.

fourths of a mile. On the northeast the hill and the ridge are separated from the mountain mass by a tributary gulch about 300 feet deep; on the south the surface from the top of the hill declines steeply 950 feet into the canyon in a horizontal distance of a third of a mile, or at an angle of about 27°. The hill is slightly oblong parallel with the ridge, with a basal or shorter diameter of about 1,200 feet, as shown in figure 41.

The deposit occurs in a stocklike body of the younger quartz monzonite or "porphyry," which forms Four Metals Hill and intrudes the older quartz monzonite. The intrusive quartz monzonite is the usual reddish-gray granitoid rock described on page 64. It



CROPPINGS OF COPPER DEPOSITS OF FOUR METALS MINE.

In mineralized shear zone in quartz monzonite. Looking northeast.

Ny 1.58% Schrader

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is granular and medium grained and is composed mainly of oligoclase and orthoclase in about equal amounts, with considerable biotite, magnetite, some hornblende, and quartz. It is intruded in the south fault zone of the Guajolote block, where it, together with some of the adjoining older quartz monzonite, has since been profoundly sheeted, shattered, crushed, and mineralized. As shown in Plate XXIII, it is sliced by a dominant east-west vertical sheeting about parallel with the fault scarp. Underground it is shattered and traversed by fissures, seams, and fractures trending in almost every direction, and these are largely filled by pyrite and chalcopyrite to such an extent that the rock mass as a whole forms a sort of breccia cemented by the iron content. It is stained a brilliant red on the weathered surface.

In the south or lower tunnel water and soft ground requiring heavy timbering were encountered at a kind of contact dipping to the north at 400 feet in from the mouth, beyond which to the face the intrusive rock is practically all very low-grade ore. Water stands near the top of the 15-foot winze sunk from this level.

Ore deposits.—The deposits are copper-bearing ores, occurring in the mineralized intrusive quartz monzonite. The ore minerals are principally chalcopyrite, with some secondary chalcocite and considerable pyrite, most of which is probably cupriferous. The deposits occur in the form of subordinate veins, lenses, stringers, and seams in the fissures, joints, sheeting planes, and other fractures in the rock, and also to a large extent as metasomatic replacement deposits in the body of the rock itself, notably in the walls of the fissures and fractures, where solid bodies or pockets of relatively pure metallic minerals are of common occurrence. The principal gangue mineral besides the altered rock and pyrite is quartz, which, however, is only sparingly present. The entire hill, 1,200 feet or more in width and 2,000 feet in length, is more or less mineralized and contains a large amount of low-grade ore, as shown by the crosscut tunnels indicated in figure 41. The mineralization extends through a known vertical range of nearly 400 feet, from the croppings at the top of the hill, shown in figure 41 and Plate XXIII, to and below the deepest workings or winzes sunk from the lower tunnel, where the geologic conditions show it continuing downward without diminution. From the intrusive nature of the containing rock and the profoundness of the disturbance it is inferred that the additional downward extent is considerable, probably several hundred feet below the present lower workings.

The entire volume of the hill, however, is not of workable grade, for, as seen in the forepart of the main tunnels, the mineralization is in places sporadic. The best showings are contained in a central belt or zone about 500 feet in width, extending from a point about

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300 feet in from the mouth of the south or lower tunnel to a point somewhat north of the upraise in the north or upper tunnel. From the south edge of this belt, as shown in the lower tunnel, the mineralization is practically continuous for 300 feet to the station room, where a winze is sunk, and also the portion of the zone lying in and near the upraise 100 feet to the north. The drifts extend north and south on a more concentrated portion of the zone, called a vein.

From the conditions in the forepart of the tunnels it is inferred that the metallic contents are probably somewhat leached in the upper part of the hill, but not to any great extent, for the sulphides appear prominently in the croppings at the top of the hill.

The value of the ore lies solely in copper, which occurs principally in the chalcopyrite, to a small extent in the secondary chalcocite, and seemingly to some though probably less extent in the cupriferous pyrite. The chalcopyrite and pyrite occur mostly in the massive and finely crystalline form, but a little is coarsely crystalline, with crystals measuring as much as 0.7 inch on the edge of the cube. The ore contains also a little gold, lead, and silver, but not in workable quantity. A little magnetite is also present, but may be derived principally from the quartz monzonite.

Though the deposits occur in the quartz monzonite, their ore minerals are not primary in this rock as are apparently those in the quartz monzonite near the Bennett mine, already described. They were formed by infiltrating mineral-bearing solutions after the shattering of the quartz monzonite by the uplift of the Guajolote fault block. That meteoric waters have played an important part, at least in the concentration of the veinlike portions of the deposits contained in the fissures and fractures, there is no doubt, but the evidence of metasomatic replacement afforded, for instance, by bands or lenses of ore several inches in width and a number of feet in extent, wholly or in part replacing the hard wall rock, seems to indicate that hydrothermal solutions were probably a factor in the origin of some of the deposits. These solutions may have been associated with the intrusive quartz monzonite magma, or with later intrusions of granite porphyry or rhyolite. Rhyolite intrudes the quartz monzonite at a point half a mile north of the mine. Some of the altered rock seen in the forepart of the north tunnel was provisionally recorded in the field notes as granite porphyry, but it received no further examination.

WINIFRED MINE.

The Winifred mine is 1¼ miles east of the Four Metals mine, 2 miles northwest of Washington, and 3½ miles south-southwest of Mowry, in the head of a small canyon at the southwest head of Mowry Wash, at an elevation of about 6,000 feet. It is connected by wagon road with the Guajolote road, a mile distant on the north.

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It is owned by the Four Metals Mining Co., which purchased it from George Gross in 1905. It is developed by 1,000 feet of tunnels, drifts, and stopes, mostly on the lower level, at an elevation of about 5,725 feet. The lower level contains a 415-foot tunnel driven to the south with 175 feet of drift in which there is a 60-foot winze.

The country rock is the Paleozoic quartzite and shale, which is intruded and overlain by a much-altered vitreous rhyolite porphyry. In the face of the tunnel appears also a dark basic altered intrusive rock, seemingly andesite or diorite, which contains considerable hornblende and magnetite.

The deposits, so far as seen in this work, occur in the upper workings in an irregular, nearly flat-lying body or ore bed, a little to the northwest of and 200 feet above the mouth of the lower tunnel. The ore body dips 20° ENE. and is interbedded in the silicified sedimentary rocks and capped by the rhyolite. It contains mainly limonite, together with the ore minerals malachite, azurite, and cuprite, in a banded quartz gangue. In 1904 Mr. Gross, it is said, shipped from it a carload of ore which averaged 80 per cent in copper.

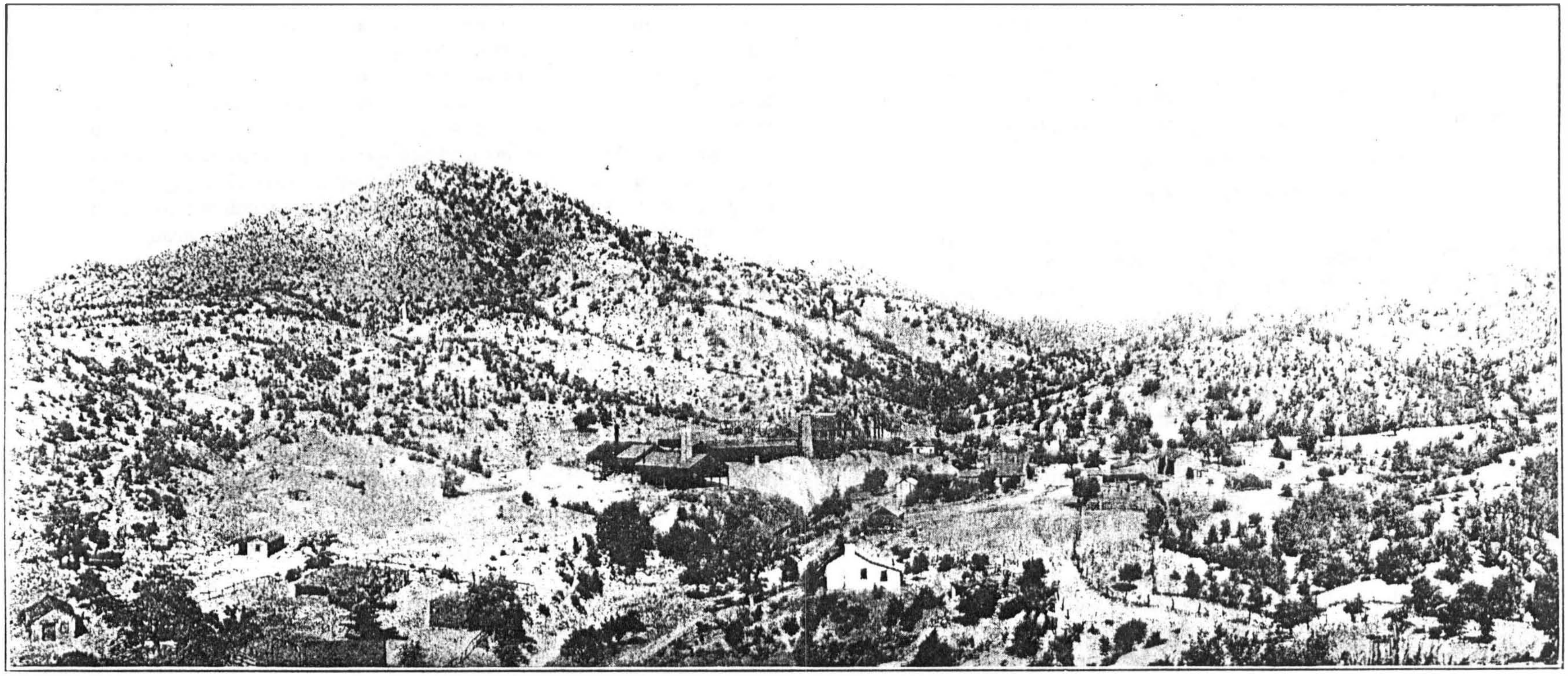
The lower workings are principally in altered rhyolite, underlain by quartzite and traversed by several north-south fissures and an east-west fault which is followed by the drift. They show no indication of mineralization other than a little iron stain on the gouge of the east-west fault, which is about 7 inches in width.

DUQUESNE-WASHINGTON CAMP.

LOCATION AND GENERAL FEATURES.

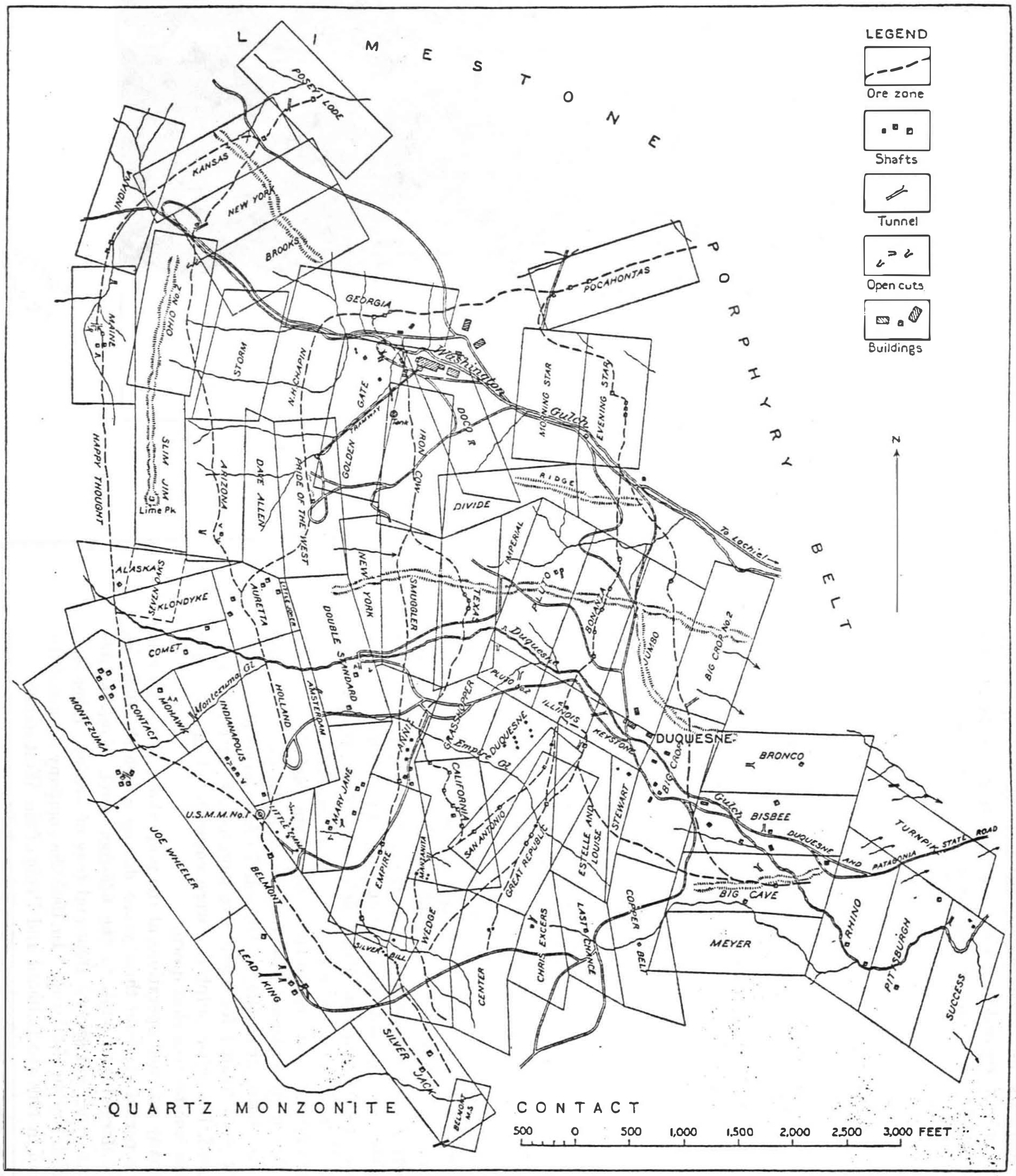
The Duquesne mines, also known as the Westinghouse mines, are located at the Washington and Duquesne camps in the western part of the Patagonia district, about 3 miles south of Mowry and the same distance north of the Mexican boundary. They are situated on the lower eastern slope of the Patagonia Mountains at an elevation of about 5,500 feet. The camps, shown in Plate XX, are three-quarters of a mile apart. The property comprises 80 claims, of which 42 are patented, and covers 1,600 acres of mining ground. It includes about half a dozen mines and a large reduction plant and extends beyond Washington on the north and to points about a mile west and southwest of Duquesne on the south (Pl. XXIV). Washington is the older of the camps, and the area for the last 30 years or more has been known to the mining world as the Washington camp or district. For convenience of reference the area as a whole will here be called the Washington-Duquesne camp.

The property is chiefly owned by the Duquesne Mining & Reduction Co. of Pittsburgh, Pa. The local headquarters of the company are at Duquesne, and the reduction plant is at Washington (Pl. XX).



CAMP WASHINGTON AND DUQUESNE REDUCTION PLANT ON WASHINGTON GULCH.

Pride of the West mine at left (1) and Patagonia Mountains in background. Looking west.



CLAIM MAP OF DUQUESNE MINES AND PROPERTIES.

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HISTORY AND PRODUCTION.

Mineral deposits were found here in the early Mexican days, when some of the ore was treated in a few arrastres just across the Mexican border in Sonora. The ruins of an old adobe smelter used in those days stand in the southern part of the camp on the trail between the Belmont mine and San Antonio Pass. The ore body of the San Antonio mine, near the south end of the camp, was discovered in 1862.[1]

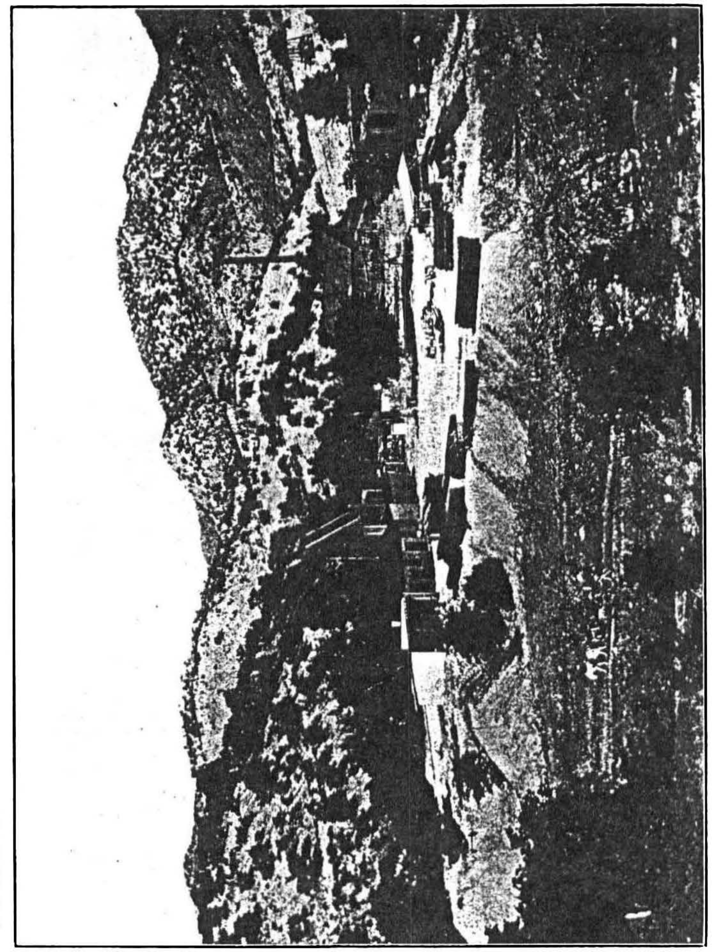
A few white pioneers were settled in the camp in the early seventies or before, Thomas Gardner being among the earliest. In the middle or late seventies considerable work was done in places for the surface silver ore, but as the ores in depth became basic or sulphide ores with copper and zinc, the workings were largely abandoned and quiescence followed for about 20 years, until late in the nineties, when the possibilities of the camp for copper attracted attention. The history of the camp is essentially the history of the Pride of the West and Bonanza mines, and, therefore, the historical sketch of these two mines is given here. The two oldest claims in the camp are the Empire and San Antonio, which were patented in 1870 and 1872, respectively. The Belmont claim is one of the oldest producers. Ore from it was smelted in the adobe smelter south of Duquesne. The present company in the early eighties purchased the Pluto and Illinois claims and later many others, among them the Bonanza in 1889.

The Bonanza mine (Pl. XXV), situated just north of Duquesne, was discovered and located by Thomas Shane and N. H. Chapin in the early eighties or before. They sold the mine to a Mr. Hensley, who discovered a large body of high-grade carbonate ore at a depth of 40 feet but made no shipments worthy of note. About 1889 he sold the mine to the Duquesne Co., which operated it for two years, until sulphide or basic ore was encountered at depth, and then endeavored to discover a process to treat the ore successfully.

In 1896 the company leased a small furnace in El Paso, in which carbonate ores taken from the 40, 60, and 70 foot levels of the Bonanza shaft were treated for about five months, 200 carloads in all being shipped, but when sulphides were encountered in the lower workings the smelter was shut down.

The company resumed operations at the mine about 1899, and continued for a period of about three years, during which the Bonanza shaft was enlarged and sunk to the 635-foot level. Considerable drifting was done, and several thousand tons of ore was taken out, most of which lies on the dump. In 1905 the company acquired the Holland, and in 1906 the Belmont and Pride of the West mines.

[1] Browne, J. R., Mineral resources of the States and Territories west of the Rocky Mountains, 1867, p. 448, 1868.



BONANZA MINE, LOOKING S. 70° W.

The Pride of the West, formerly known as the Washington mine, is one-third of a mile southwest of Washington (Pl. XX). It was located about 1880 by a party of prospectors, who soon began to develop it. Very early in the eighties they leased it to a Mr. Salisbury, who took out considerable ore, which he treated in his smelter at Benson, and from this time on the mine was worked steadily for some years. Later W. A. Clark took a bond on the mine, sunk the Giroux shaft, did other development work, and took out ore occasionally. In 1898 N. H. Chapin leased from his partners their interest in the mine, and for a period of three months shipped daily to the Silver City smelter 30 tons of ore that averaged 12 per cent in copper, or an aggregate of about 3,000 tons. In the early part of 1899, according to Blake,[1] 5,000 tons of ore were shipped and 200,000 tons were blocked out in the mine.

Beginning in April, 1899, C. R. Wilfley, taking an option on a half interest in the mine and purchasing the other half, mined and shipped ore at about the same rate as Chapin had for a like period of three months and then began building a 50-ton mill. This new mill he operated successfully until the spring of 1902 and then enlarged it to 100 tons, and operated the enlarged plant until December, 1903, since when it has been in operation twice for short periods. The camp, with a population of over 1,000 people at Washington alone, reached the zenith of its development about 1901.

At about the time the mill was enlarged the property, then owned by Mr. Wilfley and the Corey brothers, was organized as the Pride of the West Co., with headquarters at Denver, Colo. About 1906 the property was acquired by the Duquesne Mining & Reduction Co., which at about this time or late in 1905, having resumed operations at the Bonanza mine, operated the mill intermittently, trying new processes on the ores, and also in 1907 worked the Pride of the West mine for six months and installed an aerial tram connecting the Bonanza mine with the mill. For several years following 1907 nothing was done but assessment work.

The total production of the Pride of the West mine to 1909 is estimated to be 90,000 tons of ore, of which about 4,500 tons shipped to the smelter averaged 12 per cent in copper and contained a little silver. The production in 1907 was $95,661. Late in 1912 the Duquesne mines were said to be shipping a carload of ore a day.

Although most of the development work has been done on the Bonanza and Pride of the West mines, considerable ore has also been taken from the Holland, Belmont, New York, California, Kansas, and other ground. On the dump at the Bonanza shaft are 15,000

[1] Blake, W. P., Mining in Arizona: Report of the Governor of Arizona for 1899, pp. 64–66, 88–94.

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tons of ore said to average 6 per cent in copper and 18 per cent in zinc, and at both the Holland and the Pride of the West are a few hundred tons of similar ore. The dump at the mill near Washington contains 30,000 tons of ore, said to average 15 per cent in zinc, 1 to 2 per cent in copper, and a trace of lead and to be worth $250,000.

Processes for treating these ores, some of which seem to be very refractory, are now being investigated on the ground.

Since 1899 the company has produced and sold 2,200 tons of ore and concentrates that gave 500,000 pounds of copper, 70,000 pounds of lead, 80,000 pounds of zinc, and 10,000 ounces of silver. The zinc concentrates were sold to the Lanyon Zinc Co. The copper-lead concentrates went to the Copper Queen smelter, at Douglas, Ariz., together with some carbonate ore.

EQUIPMENT AND PROCESSES.

The equipment at the Pride of the West comprises a 50-ton smelter,[1] a 100-ton electric mill with astatic, magnetic, and electric separators, Wilfley tables, crush rolls, a 150-horsepower Corliss engine, a small Atlas engine, a reverberatory mat furnace, and a 60-horsepower Stetson hoist. The plant has shipped considerable matte.

The ore is crushed, sized, and then passed to the Wetherill magnetic machine or to a Dings magnetic separator. Final concentration is made on eight Wilfley tables. A Sutton dry concentrator was tried direct after crushing and sizing and gave good separation of lead from iron and copper.

Next to the mill there is a 100-foot mechanical roaster and a 25-ton reverberatory furnace that has produced one car of matte that averaged 46 per cent in copper. This was made from copper-iron concentrates.

The surface equipment at the several shafts is extensive. At the Bonanza shaft there are two 100-horsepower wood-burning boilers, operating a 6-drill compressor, a 50-horsepower hoist, two 4-inch discharge sinking pumps raising water 600 feet, and three small Cameron pumps. The shaft, which has three compartments, is well timbered and equipped with safety devices. At the mouth are a machine shop, a blacksmith shop, and a sawmill. At the Duquesne shaft, one-eighth of a mile south-southwest of the Bonanza, there is a 12-horsepower gasoline hoist used for sinking a three-compartment shaft to the 100-foot level.

The company plans to operate all the property from a central power plant to be located on Grasshopper Flat about a quarter of a mile west of the Bonanza shaft. The machinery ordered for this plant includes two 125-horsepower Diesel turbines. Two shafts are to be used, one on the Duquesne ground for the central part of the

[1] U. S. Geol. Survey Mineral Resources, 1905, p. 156, 1906.

area and one on the Texas ground for the southern part. The Buena Vista land grant, on Santa Cruz River, 10 miles to the west, has been purchased for a mill site.

During the six months' experimental work in 1907 the ore was taken largely from the Bonanza shaft, though some came from the Pride of the West, Belmont, and Holland claims. While the mill was running the product was 38 tons copper concentrates (12 per cent copper), 18 tons lead concentrates (46 per cent lead), and 107 tons zinc concentrates (35 per cent zinc). In the early part of 1913 it was reported that the company was operating with a large force of men and shipping daily about 50 tons of 14 per cent copper ore. Similar shipments were regularly made in the earlier part of 1914.

TOPOGRAPHY AND GEOLOGY.

The surface in general slopes gently eastward. The topography, as shown on the map (Pl. I, in pocket) and in the photograph (Pl. XX), is hilly and in the western part mountainous but in few places rough. The area is drained principally by Washington and Duquesne gulches, which issue southeastward into Santa Cruz River, 6 miles distant.

The country rock, locally called "quartzite and limestone" (Pl. II, in pocket), consists mainly of limestone with a small amount of quartzite and other sediments occupying a north-south belt 2½ miles long and, between the two camps, about 1¼ miles wide. This belt is almost surrounded by igneous rocks, being bounded on the northwest, west, and south by quartz monzonite, locally called "granite," and on the east principally by granite porphyry. Both of these latter rocks also occur as detached masses and dikes in the belt and are seemingly intrusive into the sedimentary formations. Both the quartz monzonite and the sedimentary rocks are cut by dikes of aplitic granite, as at the Pride of the West mine, and also by diorite (?) dikes. The rocks of the sedimentary belt, like those of the Mowry area, are but the remnants of formations which once had a much wider extent but have since been removed by erosion, and they have been preserved because they were downfaulted or more deeply engulfed in the igneous magmas.

The rocks in general have been much disturbed and apparently overturned but seem to be conformable. They dip steeply to the west, mostly at angles of 60° or more, but locally the dip varies greatly in direction and amount. The older members—the quartzite, some of which is micaceous, and the more altered limestone—occupy the upper position in the section next to the quartz monzonite on the west. The limestone is medium to heavy bedded or massive. In the western part of the camp it lies in crude north-south bands or zones of relatively pure rock, alternating with rock that is impure, metamorphosed, silicated, or cherty. In places it contains some

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interbedded quartzite. The limestone is mostly contact metamorphosed to white and bluish or greenish crystalline marble, much of which is coarse grained. In places the rock is otherwise altered and silicated. At intervals, mainly along the contact with the igneous rocks, particularly the quartz monzonite, and to a less extent as inliers in the sedimentary area, roughly paralleling the bedding of the limestone, occur extensive and well-developed garnet zones from 10 to 100 feet or more in width, containing the usual assemblage of other contact-metamorphic minerals described below under "Mineralogy."

A body of the limestone which has escaped the metamorphic effects of the intrusive granite porphyry within a few hundred feet of the contact, at a point about a quarter of a mile north of Duquesne, is dark bluish, compact, and indistinctly stratified and contains seams or veinlets of calcite approximately parallel with the bedding. This rock is lithologically identical with the dark Pennsylvanian limestone of Sycamore Ridge, in the crest of the Santa Rita Mountains east of Helvetia, and at the Total Wreck mine, in the Empire Mountains. It is seemingly also similar to the Martin limestone (Devonian), at Bisbee, described by Ransome.[1]

From outcrops elsewhere and from the dark-blue color of much of the crystalline limestone and the general bluish or greenish cast pervading the so-called white crystalline part of the rock, it seems probable that this formation, including the portion of it now metamorphosed, may occupy a considerable part of the area of the camp, the bluish and greenish tints being derived from the darker constituents of the unaltered rock.

The most extensive exposure of the quartzite is along the western edge of the sedimentary belt, where it intervenes between the limestone and the quartz monzonite and probably forms the basal member of the sedimentary series.

These sedimentary rocks are at least several hundred feet in thickness; how much thicker it is difficult to say, because they have been extensively disturbed. The Bonanza shaft, 635 feet deep, is all in the limestone.

No fossil remains have been found in the limestone or other sedimentary rocks, but they seem to be Paleozoic and are probably of the same age as the limestone in some of the camps already described, as Mowry or Greaterville. The western and seemingly lower part of the section is provisionally correlated by Crosby,[2] with the Bolsa quartzite and Abrigo limestone, of Cambrian age, in the Bisbee district, described by Ransome.[1]

The quartz monzonite is a greenish-gray, black-speckled granitoid rock with a reddish tinge and weathers reddish brown. It is medium

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

[2] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, pp. 628–629, 1906.

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to coarse grained and locally porphyritic. It is fairly fresh and is composed principally of oligoclase, oligoclase-andesine, quartz, orthoclase, biotite, hornblende, augite, and magnetite and contains considerable pyrite and some titanite. The plagioclase, which is the main constituent of the rock is especially fresh. It occurs mostly in stout or elongated prisms, some 0.3 inch long, and it is well striated, the striations being conspicuous to the unaided eye on the fresh surface of the rock. The biotite is relatively abundant and together with a less amount of green hornblende constitutes about one-fifth the volume of the rock. The orthoclase and quartz, which are later in order of crystallization, occur mostly as filling or interstitial minerals. Some of the augite is bordered by hornblende, which apparently is derived from it by a process of alteration.

The fact that the quartz monzonite is intrusive into the sedimentary rocks is well shown in the southwestern part of the camp, on the north fork of Duquesne Gulch, about 2,000 feet southwest of the Pride of the West mine, near the four-corner post of the Lauretta, Holland, Comet, and Indianapolis claims. Here the sedimentary rocks are thin to medium bedded and dip 60° W., and the sharply welded contact of a 100-foot quartz monzonite dike with the quartzite irregularly but clearly descends the north side of the gulch. A band of greenish-black endomorphic medium-grained crystalline hornblende is developed along the granitic side of the contact, and the sedimentary rock in places is altered to a dense greenish phase resembling hornfels.

A somewhat similar example of the intrusive nature of the quartz monzonite may be seen in the northeastern part of the camp, in the south side of Washington Gulch near the schoolhouse, on the Morning Star claim. Here the endomorphic hornblende is present in the granitic rock, some of the limestone is seemingly changed to calcium silicate and diopside, and the two rocks in general are separated by a 100-foot belt of chalcopyritic blackish fine-grained pressed quartzite or sort of hornfels.

The general coarseness of the quartz monzonite indicates that it was probably intruded into the sedimentary rocks at considerable depth. The granite porphyry on the east, so far as observed in this examination, has been considerably pressed and deformed and consists mainly of a relatively fine grained gray groundmass of orthoclase and quartz in which the phenocrysts of coarser feldspathic constituents are segregated and drawn out into pale-reddish streaks and thin lenses an inch or more in length. Aplitic granite occurs as dikes, some of which are associated with the ore deposits, as at the Pride of the West mine. It is a relatively fresh dull-gray fine or medium grained monzonitic rock, composed mainly of orthoclase and quartz with a moderate amount of oligoclase, a little biotite and hornblende, accessory apatite and zircon, and secondary hematite.

Most of the mines are dry, but in the Pride of the West water stands at a short distance below the 50-foot level. From the Bonanza mine, 635 feet in depth, the water is kept removed by operating the pumps for four and a half hours every five days, a 2½-inch stream being discharged.

MINERALOGY.

The metamorphic minerals occurring in the contact zones of the limestone consist mainly of garnet, quartz, and several varieties each of the amphibole and pyroxene groups, chalcopyrite, pyrite, pyrrhotite, magnetite, tourmaline, and arsenic.

The garnet is dark reddish and brownish green or dark greenish brown with adamantine luster. Much of it is coated on the crystal faces a bright metallic black with oxide of manganese and iron. It occurs in large, relatively pure crystalline masses of medium grain in dodecahedral crystals which are mostly of medium or small size, but some are nearly 2 inches in diameter. The rhombohedral faces of many of the crystals are striated. An analysis of a sample of the garnet collected from the Empire mine, which seems to be representative of the garnet of the camp, is given on page 83, and shows the garnet to be the calcium-iron variety andradite.

The quartz occurs mostly in irregular masses locally developed in association with the garnet along the contact zone and in the impure cherty zones or metamorphic bands in the sedimentary rocks. Here and there it replaces chert and the earlier metamorphic minerals, such as calcite and actinolite, whose crystalline forms are preserved in masses of relatively pure pseudomorphic silica. On the Belmont and Lead King ground, in the southwestern part of the camp, occurs a body of mainly massive vitreous quartz, 100 feet wide, containing bunches or clusters of coarsely crystalline material with some crystals 2 feet in length and 5 inches in diameter. Crosby[1] refers the origin of the quartz mostly to the metamorphism of the chert, but much of it seems to be derived from the monzonite magma or its solutions.

The amphibole minerals are principally hornblende, tremolite, actinolite, and gedrite. Of these, tremolite is the most abundant and is intimately associated with many of the ore deposits as gangue. Its abundance obviously denotes considerable dolomite in the limestone. Gedrite, a greenish-brown magnesium-iron silicate, a variety of the orthorhombic amphibole anthophyllite, with a refractive index of about 1.634, occurs also in association with the deposits.

The pyroxene minerals are mainly diopside, wollastonite, and hedenbergite. Considerable portions of the limestone are locally

[1] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, p. 633, 1906.

altered to diopside, and on the weathered surface show the fine stratification lines of the limestone. The wollastonite occurs principally in association with the cherty portion of the limestone, especially the chert nodules. Hedenbergite occurs as a massive dark yellowish-green mineral in considerable amount associated with the deposits. In the andradite gangue in the Empire mine is a pale-green or colorless pyroxene in radial or fan-shaped bunches, 4 inches or more in length, with which most of the prismatic or columnar crystals approximately coincide but whose specific characters were not determined. It is so thoroughly stained black by oxide of manganese and iron on the surface that it might readily be mistaken for some other mineral. Epidote occurs locally with the garnet. Tourmaline, which is not common as a metamorphic mineral, occurs in aggregates associated with galena in the partly silicated limestone just west of Washington on the Nogales road.

Native arsenic, not certainly of metamorphic origin, was found in the Double Standard mine[1] in reniform masses, some of which weighed several pounds, associated with the contacts between limestone and granite and between limestone and granite porphyry.

ORE DEPOSITS.

The deposits contain principally the base metals copper, zinc, and lead, with some silver and gold. They are, to speak broadly, principally replacement deposits in the limestone. They occur mainly in or near the metamorphic zones along the limestone and quartz monzonite contact and are also associated with the north-south metamorphic zones in the limestone and other sediments away from the contact, where they approximately follow the so-called "ore contacts" indicated on the claim map (Pl. XXIV). The latter zones are probably connected with the quartz monzonite in depth if not at the surface.

The deposits occur mostly in irregular bodies in or near the garnet formation of the zones and the adjoining limestone. Where the deposit is marginal it occurs on the inner or limestone side of the garnet zone and not on the outer or quartz monzonite side. Where quartzite of no very great width intervenes between the limestone and the quartz monzonite, as on the west, where the quartzite is about 200 feet wide, the ore deposit occurs between the quartzite and the limestone and not between the quartzite and the quartz monzonite, the limestone being everywhere the most favorable receptacle for the ore.

The ore minerals are mainly chalcopyrite, bornite, chalcocite, malachite, azurite, cuprite, chrysocolla, sphalerite, smithsonite, cerusite, and the sulphates of lead and copper. They occur chiefly in a

[1] Warren, C. H., Native arsenic from Arizona: Am. Jour. Sci., 4th ser., vol. 16, pp. 337–339, 1903.

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garnet or garnet-quartz gangue, which contains also a varying amount of pyrite and the other contact-metamorphic minerals already described and in some places pyrrhotite and magnetite. The sulphides begin almost at the surface.

From the geologic and mineralogic conditions which have been described and which are discussed more in detail in the sections on the Pride of the West, Belmont, and other mines, it is apparent that the ore deposits are essentially contact-metamorphic deposits and owe their origin to the intrusion of the quartz monzonite and, to a less extent, to that of the granite porphyry, the hydrothermal solutions and pneumatolytic gases that accompanied or followed the intrusion having dissolved out the limestone and replaced it metasomatically or otherwise by depositing the ores and their associated minerals. Some of the minerals, as chalcopyrite, are probably in part at least of pneumatolytic origin.

From the large volume of the limestone which has been replaced by the ore deposits and from the altered condition of the inclosing rock, it is reasonable to infer that certain of the elements composing the metamorphic zone were derived from the limestone. For instance, the magnesium and calcium in the tremolite and other minerals were probably contributed from dolomitic or impure facies of the limestone, but the ore deposits themselves and the bulk of the metamorphic minerals contained in the metamorphic zone, some of which lie in pure white crystalline limestone, are apparently extraneous to the limestone and were introduced by the invading quartz monzonite magma and its attendant solutions and gases. They can not have been supplied in any other way.

It would certainly not be possible for any normal limestone, such as now occurs in the Washington-Duquesne camp or in the limestone area around Mowry to the north, equal in volume to that of the contact-metamorphic zone, to supply the iron constituents, the total amount of which, contained not only in the metallic minerals pyrite, chalcopyrite, specularite, pyrrhotite, etc., but also in the garnet, augite, gedrite, and other iron-bearing minerals, is obviously very great. It is probably due to the plentifulness of the iron contributed by the quartz monzonite that the garnet which is produced is andradite, an iron-bearing variety, instead of grossularite, the iron-free variety, which is most commonly found in other contact-metamorphic zones. That the materials were not derived from the surrounding limestone for any great distance without the contact-metamorphic zone is indicated by the purity of the bordering limestone and by its wholly unaltered condition in many places very near the contact, as north of the Bonanza mine and at the Kansas and Belmont mines, where the limestones within 50 feet of the metamorphic zone and contact are little changed.

For the source of the iron we can, as one possibility, at least in the Washington camp, look to the quartz monzonite, which, being rich in biotite and hornblende and containing considerable augite and magnetite and some pyrite, could supply the iron element, for whose concentration in the deposits the fluid magma and its accompanying hydrothermal solutions and pneumatolytic gases, containing the ingredients, were admirably adapted. Moreover, the hypothesis that the iron ingredients were derived from the limestone would require a most remarkable system of circulation in the limestone and a long period of time to enable the solutions or waters to collect and take the material into solution or suspension before it could be deposited.

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

Besides the examples of metamorphic deposits which have been cited in the description of the mines and those in the pure crystalline limestone, there occurs also just west of the road northwest of Washington a 5-foot north-south vertical garnetiferous metamorphic zone with no indications of impure limestone in the vicinity. In tracing individual beds of the limestone here as elsewhere, away from the intrusive contact, the garnet in the pure beds is not found to differ appreciably in amount from that in the beds which are less pure.

The geologic and mineralogic conditions and apparently their causes are, on the whole, similar to those in the Silverbell district, 40 miles west of Tucson, described by Stewart,[1] who says:

> The intrusion of both alaskite porphyry and biotite granite was followed by the emission of magmatic waters, which sericitized and silicified the alaskite porphyry and granite and produced in the limestone, by the addition to it of silica, iron, and alumina, great masses of garnet, quartz, and wollastonite. Following close upon these solutions came metal-bearing magmatic waters, which impregnated porphyry, granite, and alaskite with cupriferous pyrite and deposited in the garnet zones chalcopyrite and copper-bearing pyrite that make important bodies of contact-metamorphic ores.

The results of more recent and detailed investigations of similar deposits at Mackay, Idaho,[2] including numerous analyses of the limestone, of the silicate rocks resulting from it, and of the intrusive rocks, are essentially in agreement with the conclusion of the present writer, made in the Duquesne-Washington camp, that the great amounts of iron, silica, and alumina represent contributions from the magma and can not have been supplied from the limestone.

[1] Stewart, C. A., The geology and ore deposits of the Silverbell mining district, Arizona: Am. Inst. Min. Eng. Bull. 65, pp. 455–505, 1912.

[2] Umpleby, J. B., The genesis of the Mackay copper deposits, Idaho: Econ. Geology, vol. 9, No. 4, pp. 307–358, June, 1914.

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PRIDE OF THE WEST MINE.

The Pride of the West mine is one-third of a mile southwest of Washington, at an elevation of about 5,700 feet, in the lower east slope of a lobelike ridge descending from the crest of the range, which is a mile distant on the west. It is about 250 feet above the smelter and mill on Washington Gulch, with which it is connected by a tramway ascending a small side gulch in which the principal openings occur, the ground being otherwise open. (See Pl. XX.) The Giroux shaft is on slightly higher ground a little to the southwest. The history, production, and equipment of the mine have already been set forth (pp. 323–324).

The mine is opened by a 400-foot shaft, a 700-foot tunnel driven S. 7° W., and winzes. The tunnel taps the vein at 180 feet below

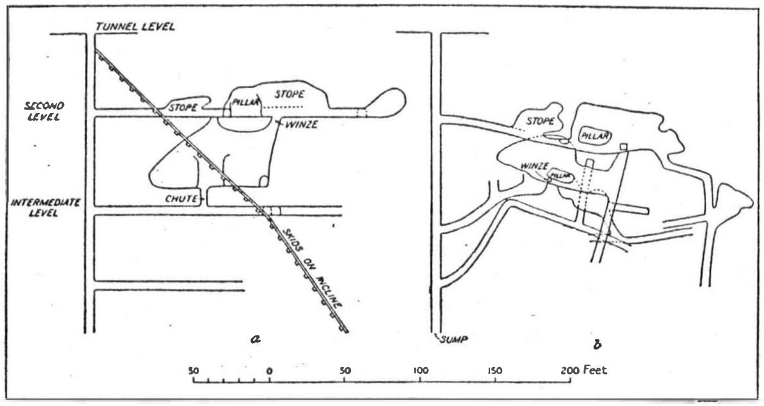

FIGURE 42.—Longitudinal section (a) and partial plan of lower levels (b), Pride of the West mine.

the surface, and from it is sunk a 400-foot winze and a 50-foot inclined shaft containing three levels with drifts and stopes. Plans of some of the workings are shown in figure 42. Some of the stopes are 30 feet wide and 70 feet high, ascending the dip of the deposit. The workings comprise also a large surface cut 32 feet wide and 250 feet long, a 120-foot double-compartment shaft, the Giroux shaft, with a 25-horsepower steam hoist, and a prospect tunnel.

The ore deposit is a contact-metamorphic deposit, as shown in figure 43.[1] It lies in the crystalline limestone along the footwall side of a dike of the quartz monzonite. The dike strikes N. 17° W. and dips about 50° W., but the dip flattens in the lower part of the mine. At the mine the dike is apparently conformable with the limestone

[1] This figure and field notes on the deposit have been kindly furnished by Mr. Waldemar Lindgren.

and is about 60 feet wide, but it widens southward to 250 feet at the Giroux shaft, which is about 200 feet distant, and at a point 500 feet south of the shaft it incloses a horse of crystalline limestone 100 feet long and 20 feet wide, whence it extends southward into the main area of quartz monzonite.

At the mine the dike, especially in the footwall or under side, as shown in the accompanying sketch (fig. 43), is composed of a peculiar siliceous facies of the rock, which is fine grained and resembles aplite, as described on page 328, and it may possibly be a slightly later intrusion than the main body of the dike, but it is monzonitic, contains the same minerals as the rest of the dike, and is apparently derived from the same general magma.

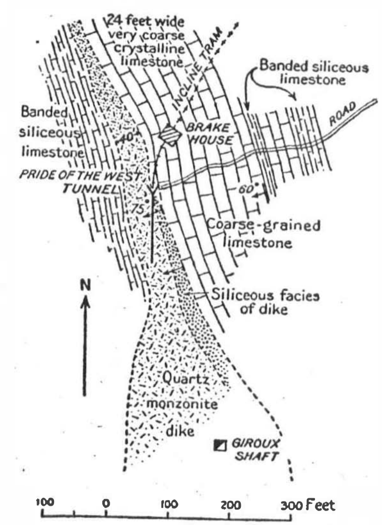

FIGURE 43.—Map showing geology at Pride of the West mine.

The dike separates a body of coarsely crystalline, apparently very pure limestone 200 feet wide, from a considerable mass of siliceous banded limestone on the west side. So far as can be seen, and the exposures are good, all the rock adjoining the east side of the dike consists of this coarse limestone. Close to the dike and north of the tunnel the limestone is extraordinarily coarse. The contact between the dike and the limestone is further well shown in the northwestern part of Washington, about a quarter of a mile north of the mine and 500 feet west of the doctor's house. Here the same coarse limestone adjoins the monzonitic rock and for a width of about 25 feet from the contact is changed to massive garnet. Beyond this is a zone 50 feet wide in which the limestone contains irregular bunches of silicified material and small masses of yellowish-green garnet.

At a point 100 feet northwest of the Pride of the West tunnel and 6 feet east of the dike the limestone is composed of coarsely crystalline white calcite and is very pure, but at the mouth of the tunnel it is silicified or completely changed to diopside. In the vicinity of the mine garnet appears along the footwall side of the dike and the ore deposit, as shown in the mine, forms a zone 30 feet wide, consisting mainly of irregularly mixed coarse calcite, garnet, yellowish-brown zinc blende, chalcopyrite, pyrite, pyrrhotite, and a little magnetite.

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Locally it is vertically banded or bedded. At one place on the 50-foot level 3 feet of very coarse crystalline limestone adjoins the dike, and next to the limestone is a 2-foot zone of sphalerite and garnet. The garnet contains many druses filled with well-developed quartz crystals, some of them a foot in length. In the interstices between the crystals are pyrite, sphalerite, and other ore minerals. At another place in the mine there occurs next to the dike nearly 2 feet of magnetite, which is succeeded by 3 feet of sphalerite mixed with chalcopyrite, which in turn is followed by crystalline limestone containing chalcopyrite.

Garnet and quartz are associated with nearly all the ore. Tremolite is common, and hedenbergite and gedrite are also present in considerable amount intimately associated with each other in bunches or lenses 3 inches or more in diameter. The hedenbergite occurs in the yellowish-green massive form and is penetrated and in part interlaminated by the surrounding yellowish-brown crystalline gedrite.

A microscopic section of the ore shows an intergrown mixture of calcite, pale-brown hornblende in masses and spherulitic radial bunches, diopside, epidote in small, almost colorless crystals and grains, a clear, colorless mineral with good cleavage and low double refraction, a little garnet, chalcopyrite, and specularite.

The deposit is developed to a depth of 200 feet below the tunnel level, but water now stands a short distance below the 50-foot level. On the tunnel level the ore consists almost wholly of sulphides and on the 50-foot level there is no oxidation. In the surface cut, which closely follows the contact, the ores are mostly oxidized and seem to lie exclusively in the crystalline limestone.

At the Giroux shaft, sunk in the dike at a point about 200 feet to the south of the mine to cut a branch given off from the Pride of the West deposit, the contact has been reached underground, and ore with tremolite and garnet has been revealed. On the 80-foot level at 25 feet to the west of the shaft is exposed a 6-foot vein of sphalerite and chalcopyrite which dips steeply to the west.

At the prospect tunnel, 250 feet southwest of the Giroux shaft, on the west contact of the monzonite dike, which here retains its characteristics close to the contact, some pyritic ore with sphalerite, tremolite, and massive garnet is exposed.

That the ore minerals with garnet and quartz replace the pure coarse limestone is shown by the underground exposures, which allow of no other explanation.

The ore is stoped out down to a depth of about 200 feet below the surface. It probably extends to a greater depth, but the deeper portion of the deposit contains so much zinc that it could not be handled at the time the mine was in operation. Most of the zincky ore, owing to the large admixture of calcite or spar, carries only 18 to 20 per cent zinc. The ore in general is said to average about

$30 to the ton in copper and zinc.

BONANZA MINE.

The Bonanza mine is in the eastern part of the camp just north of Duquesne and Duquesne Wash, on gently southward-sloping ground at an elevation of about 5,400 feet (Pl. XXV). Notes on the history, production, and equipment of the mine are given on page 322.

The developments, besides the three-compartment 635-foot shaft, include about 7,000 feet of underground workings distributed on six levels and intermediate upper workings, mainly between the 135-foot level and the surface, approximately as shown on the accompanying map (fig. 44) and in the longitudinal section (fig. 45). The main levels are spaced 100 feet apart vertically, the first level being 135 feet below the surface. The work comprises about 1,000 feet of shafts, 3,700 feet of tunnels, 1,000 feet of crosscuts, over 100 feet of winzes, and 600 feet of raises. There is but little work on the sixth level and not much on the fifth.

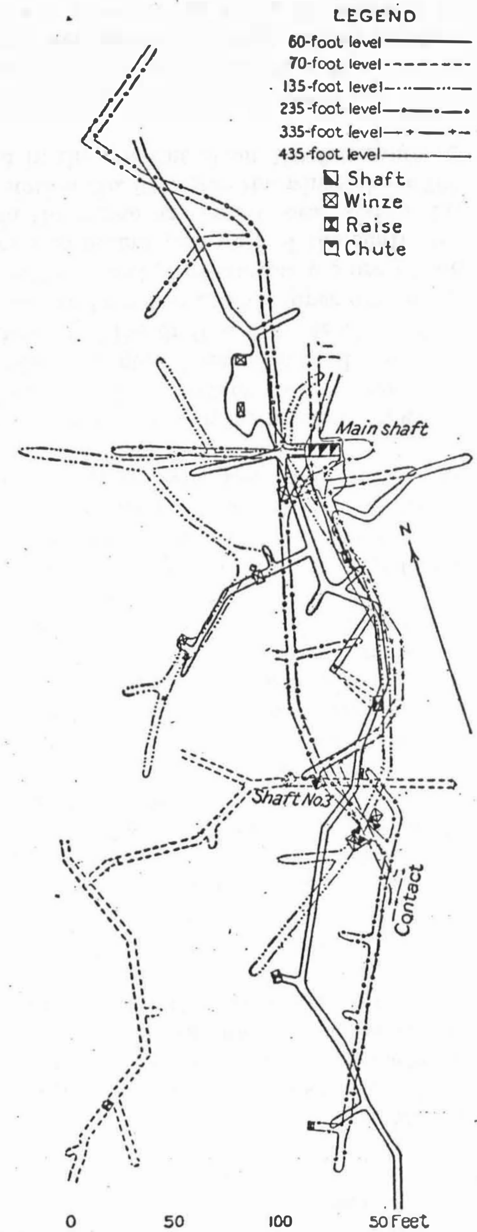

FIGURE 44.—Plan of workings of Bonanza mine.

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Many of the drifts and other workings are crooked or winding, especially in the upper levels, where considerable "chloriding" was done in the early days, and cave-ins have occurred at several places.

The mine is on the contact of the limestone belt of the camp with the intrusive granite porphyry on the east. The deposit trends mainly north and stands about vertical or dips steeply to the east,

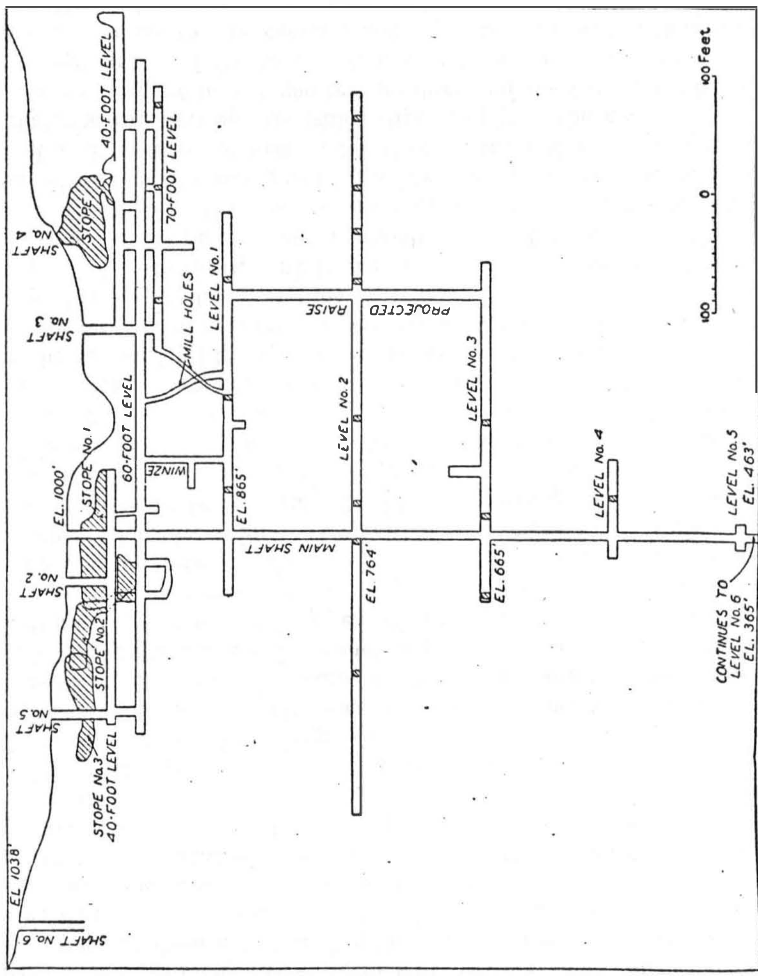

FIGURE 45.—Longitudinal section of Bonanza mine.

tending to parallel the contact. The contact and seemingly the limestone or sedimentary rocks dip to the east or outward. The Bonanza shaft, which is vertical, starts in the granite porphyry a little to the east of the contact, but the lower part of the shaft is about all in coarsely crystalline white limestone. The shaft passes through the

ore zone between the 435-foot and 535-foot levels and the bottom of the shaft is in the limestone about 65 feet west of the contact.

As at the Pride of the West mine, the ore deposits occur in the crystalline limestone, mainly in the usual garnet-quartz gangue. They have been opened through a horizontal extent of about 600 feet and in the vicinity of the shaft to a depth of the 535-foot level. They have been mined chiefly, however, in the oxidized zone in the intermediate workings, which are mostly within 100 feet of the surface and were not extensively examined in this work but which have produced considerable ore.

At 30 feet below the surface the early operators encountered a large horizontal or bedlike body of zinc ore which extends laterally throughout the mine and was not removed at that time.

On the 60-foot level occurs a large body of copper sulphide ore. It is well exposed just southwest of the shaft and is said to be extensive horizontally and vertically. The ore minerals are medium-grained chalcopyrite and sphalerite in a firm garnet-quartz gangue. Much of the ore is said to average 28 per cent or more in copper. The high-grade ore, which consists mainly of chalcopyrite with a little quartz, occurs in bodies or bunches from 1 foot to several feet or more in diameter, surrounded in places by almost pure zinc blende with but a sprinkling of chalcopyrite. In mining, this high-grade ore is kept separate from the low-grade ore.

On the 135-foot level, consisting mainly of a 250-foot drift to the south, the principal showing of ore is about 120 feet south of the shaft, where the ore shoots descend from the 60 and 70 foot levels, mostly without definite walls. The ore here looks well but carries considerable zinc.

On the 235-foot level the main showing is in the north drift, where a zone of ore 15 feet wide begins 15 feet north of the shaft and continues, seemingly in undiminished quantities, about all the way northward to and beyond the end of the drift, a distance of 210 feet. The ore is sulphide and is said to be a fair-grade copper ore, but it contains considerable zinc—not so much, however, as the ore of the level next above. Good ore also occurs just west of the shaft and in the drift to the north, in the winze on the left near station 11. Ore is shown also in entry station No. 211, near the winze about 700 feet south of the shaft, and in the crosscut about 100 feet south of the shaft.

On the 335-foot level, at the shaft, in a large chamber 25 feet high, and in the drift to the south, the ore zone is 20 feet wide. It is limited on the east by a fairly well defined hanging wall which dips 60° E. and apparently contains quartzite, in which the crosscut to the east ends. This ore body, which, owing to cave and fill, could not be examined for more than 50 feet south of the shaft, contains mainly chalcopyrite, sphalerite, pyrite, and a little gray copper and bornite in a gangue composed principally of massive or fine-grained garnet and quartz with other metamorphic minerals. The copper minerals in general are segregated into bunches, but in some places medium to fine grained chalcopyrite and sphalerite in about equal amounts form a very intimate even-grained mixture. In the north drift good ore is exposed in the crosscut and in the upraise about 50 feet west of the shaft.

On the 435-foot level ore occurs at the shaft and in the crosscut of the south drift about 60 feet from the shaft. The ore zone measured from the west side of the drift is more than 25 feet in width and the deposit here contains principally chalcopyrite in a quartz gangue. Farther south in the drift, however, garnet becomes abundant with increasing indications of zinc.

On the 535-foot level the ore zone is exposed in the terminal chamber of the last crosscut of the south drift, about 150 feet southeast of the shaft, in the crystalline limestone. Here practically the entire chamber, about 25 feet in diameter, is excavated in low-grade ore contained in a coarse-grained greenish and blackish garnetiferous gangue with considerable quartz, while farther south occur also some large quartz crystals. Associated with the copper minerals is a little galena.

The average ore of the Bonanza body assays 18 per cent zinc, 6 per cent copper, 1 per cent lead, and 5 ounces to the ton in silver. It is estimated that the 15,000 tons of material on the dump will average 18 per cent in zinc and 5.9 per cent in copper.

HOLLAND MINE.

The Holland mine is in the southwestern part of the camp, nearly half a mile south of the Pride of the West mine and two-thirds of a mile west of Duquesne, on the south fork of Duquesne Gulch, at an elevation of about 5,800 feet. It was located about 1880 by Henry Holland, who, after opening it in a small way, sold it to Dr. Luttrell and others, from California. The new owners mined it until they encountered sulphide ore of lead and iron in garnet. Not being able to treat this ore in their water-jacket smelter installed at Sonora, near the Mexican border, they abandoned the mine. In the early nineties the mine was worked by lessees, who took out much ore. B. Coughlin worked it in 1891 and shipped seven carloads of ore, averaging about 22 per cent in lead, 3 to 5 per cent in copper, and 35 ounces to the ton in silver. The cost of freight and treatment at that time was about $18 a ton.

About 1896 the mine was purchased for $15,000 by F. L. Bartlett, of Denver, and others, and in the next few years they took out considerable ore, which was treated in a concentrator that they built for the purpose about 1 mile southeast of the mine. The ore was crushed in Huntington mills and concentrated on Wilfley tables. This plant recovered most of the lead, zinc, and silver, but not the copper. The zinc was sent to Canon City, Colo., for the manufacture of zinc oxide.

The present owner, the Duquesne Co., acquired the mine in 1905 but as yet has done no work on it. The mine has produced, by estimate, more than 30,000 tons of ore, probably with a greater clear profit, it is said, than any other mine in the camp. A few hundred tons of ore, averaging 6 per cent in copper and 18 per cent in zinc, lies on the dump.

The mine is opened to a depth of 200 feet by four inclined shafts, which descend steeply to the west from the bottom of an open cut 100 feet long and 40 feet wide in the east side of the mineralized zone, and in places the ore is worked out for a width of 20 to 25 feet, except for a few pillars. No timbering has been required.

The mine is in the crystalline limestone near the contact of the quartz monzonite on the west and is probably on the southerly extension of the same general mineralized zone as the Pride of the West. The deposit occupies a zone about 50 feet in width, which dips about 60° W., conformably with the limestone. It has a fairly regular footwall of crystalline limestone on the east, from which it is separated by about 2 feet of gougelike material containing a mineral that is mostly iron. The deposit and the inclosing limestone are cut by a jointing or coarse sheeting that dips 25° E.

On the hanging-wall side the surface is covered with débris and the contact can not be definitely located or traced, but from what could be observed of it the rock here seems to be mostly hard silicified material and is locally regarded as the northerly extension of the "quartz dike" that occurs on the adjoining Belmont ground and is described on page 328.

The zone is composed mainly of a hard greenish-brown garnetiferous gangue which contains considerable quartz. Some ore minerals are distributed throughout the zone, but the ore occurs chiefly in irregular, crudely tabular bodies, mostly dipping to the west. The ore bodies are composed of a mixture of the ore minerals, sphalerite, galena, chalcopyrite, pyrite, oxide of iron, manganese, and carbonates of copper, lead, and zinc, in a garnet-quartz gangue, together with tremolite and other metamorphic minerals. The lead ores, which contain most of the silver, occur mainly on the footwall side of the deposit; toward the hanging-wall side the ores contain principally zinc with a little copper. Most of the ore produced came from the footwall side of the zone. On the hanging-wall side there remains almost intact a body of ore about 30 feet wide, said to average 15 per cent in zinc and a small amount of copper.

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The mine originally contained a large body of carbonate ore extending in general from the surface to a depth of about 10 feet, and in places to 25 or 30 feet, below which occur the basic sulphides of lead with silver, copper, iron, and garnet, and some sporadic native silver. Beginning at about 40 feet below the surface the ore grows leaner with increasing depth.

BELMONT MINE.

The Belmont mine is in the southwest corner of the camp, about 2,000 feet south of the Holland mine, on the upper south slope of a low hill of metamorphosed limestone, at an elevation of about 5,500 feet. The deposit was discovered by the Mexicans prior to 1860, and the mine is about the oldest working in the camp, except possibly the San Antonio. The deposit was opened soon after its discovery, but on the whole no great amount of work has been done nor has much ore been produced. The mine was worked mostly for silver and lead, but some high-grade copper ore has also been shipped from it.

Through Thomas Yerkes, a miner, it was acquired by Mr. Bacon, of San Francisco, early in the seventies. The Bacon heirs, after sinking a 90-foot shaft and doing other development work, sold the mine to the Duquesne Co. in 1905. This company soon after acquiring it took out and shipped some ore, but since that time the mine has been idle, though it is regarded as a good property.

The mine is developed principally by an open cut, an inclined drift, a 200-foot shaft, extensive stopes, a 200-foot tunnel, and winzes. The cut is 150 feet long and 50 feet wide, and has a 15-foot face. From the north end of the cut the drift extends to a depth of 45 feet, and from the drift a series of overhead stopes of unknown depth descend down the bedding planes to the northeast. The shaft is at the south end of the cut. It inclines 40° SW. and is timbered. The tunnel, starting 50 feet below the open cut, is driven eastward and contains several winzes.

The deposit occurs in a north-south metamorphosed mineralized zone in the crystalline limestone near its contact with the intrusive diorite on the south. The zone is about 100 feet in width and 800 feet in length. It lies approximately conformable with the limestone, which on the north dips 60° W. but on the south curves to the east. On the west at a point about 50 feet from the open cut the limestones are unaltered. The mineralized zone is composed principally of garnet and silicated limestone with quartz and calcite. It contains much actinolite with other metamorphic minerals and the ore minerals, which are chiefly sphalerite and chalcopyrite. Some of the sulphide ore is well embedded in quartz. In the open cut the ore was largely a mixture of earthy limonite, malachite, azurite, and

sphalerite, contained in an 8-foot bed of a siliceous garnetiferous gangue that overlies the white crystalline limestone. Ore from the dump of the 200-foot shaft is largely chalcopyrite but contains also oxidized copper and iron minerals.

SILVER BELL MINE.

The Silver Bell mine is in the southwestern part of the camp, at an elevation of about 5,220 feet, and almost joins the Belmont mine on the northeast. It is the next claim after the Belmont that was patented prior to 1889. Subsequent to the patenting considerable very rich oxidized lead-silver surface ore was taken out, mostly by "chloriders." The Duquesne Co. purchased the mine from a St. Louis owner about 1901 but has not yet developed it. The deposit occurs in a garnet zone contained in highly metamorphosed crystalline limestone. The limestone dips to the southwest and, as at the Holland mine, is cut transversely by a sheeting that dips to the northeast. The mineralized zone trends N. 40° W. and dips 45 or 50° SW., conformably with the limestone. It is separated from the zone of the Belmont mine by several hundred feet of intervening white crystalline limestone. The Holland mine, however, is in alignment with its trend, and it may connect with the zone near the Holland mine. Garnet is abundant in the zone, which is stained or mottled with various shades of red, green, and brown by iron and copper carbonates.

The deposit is opened by a 60-foot shaft which inclines 50°–60° SW. and shows the ore-bearing portion of the zone to be at least 16 feet in width. The oxidized ores extend to a depth of 30 or 40 feet, but sulphides, especially chalcopyrite, begin to appear very near the surface, and in the lower part of the shaft the ore is unoxidized and contains appreciable quantities of copper sulphide.

EMPIRE MINE.

The Empire mine is in the southwestern part of the camp, about 900 feet north of the Silver Bell mine. It is one of the oldest properties in the camp, having been patented by Capt. O'Connor in 1874. It was worked considerably, mostly by "chloriders," in the middle eighties and produced much high-grade lead-silver ore. The Duquesne Co. acquired it in 1905 and has done some work on it.

The mine is opened to a depth of only 60 feet. It is on a mineralized garnet zone in the crystalline limestone close to the quartz monzonite contact. The zone is locally regarded as the one on which the Silver Bell is located. The croppings southeast of the mine are prominent and in the top of a small hill they are craggy. They are composed chiefly of a mixture of garnet and quartz. The deposits

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carry mainly lead-silver ore with some copper. The ore minerals—galena, chalcopyrite, and pyrite—are contained in a gangue composed of green garnet and silicated limestone with much associated quartz, pyroxene, tremolite, and iron oxide. The garnet whose analysis is given on page 328 is from this mine.

POOLE GROUP.

The Poole group comprises seven claims, most of them in the northeastern part of the camp. The claims are the Kansas, the Texas (formerly the St. Louis), the New York (formerly the Ohio), the Maine (formerly the Ella), the Cincinnati, the Georgia (formerly the Columbia), and the California (formerly the Grasshopper). The deposits were discovered and located about 1878 by the Allen brothers and others. At one time, it is said, the property was bonded for $24,000.

New York mine.—The New York mine is in the northwestern part of the camp, nearly half a mile west-northwest of Washington, on the north side of Washington Gulch, at an elevation of about 5,500 feet. The claim extends from the gulch northeastward across the ridge and the Nogales road. The history of the New York is about the same as that of the Kansas mine, next described, except that the original owners in the early days took out and shipped from it a considerable quantity of good-grade lead-silver ore. The workings extend to a depth of more than 200 feet but are about all caved. A large stope is outlined on the surface by sunken ground back from the head frame of a shaft.

The ore contains principally chalcopyrite with sphalerite, in garnetiferous crystalline limestone. The zone of mineralization extends northeastward. The garnet zone is not developed here as at the Empire and most of the other mines. The claim and most of the hill it crosses to the northeast of the mine seemingly contain a large body of ore.

Kansas mine.—The Kansas mine, in the northwest corner of the camp, adjoins the New York claim on the northwest and parallels it, extending from Washington Gulch northeastward across the ridge and the Nogales road. It is opened on the road about a mile northwest of Washington, at an elevation of about 5,700 feet.

As copper was not in demand, but little development work was done on it immediately after discovery. The mine was later bonded to the Pride of the West Co., which in 1905 took out several thousand tons of ore. In 1906 it was acquired by the present owner, the Duquesne Co., which has done little else on it than to take out a few carloads of ore. It is opened by a 200-foot inclined shaft and several hundred feet of drifts and stopes.

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The deposit is contained in a 10-foot garnetiferous zone in crystalline limestone. It lies 700 feet from the contact of the limestones with the intrusive quartz monzonite on the northwest, the intervening sediments being mostly unaltered, and it is about 200 feet from the limestone and quartzite contact. According to Crosby[1]—

> The main ore body is veinlike in form but without walls, and clearly a replacement in the limestone, with many isolated bunches or pockets of ore from 3 inches to 3 feet or more in diameter and usually parallel to the main ore body and the bedding of the limestone. The garnet ledge is not developed here, but a feature of special mineralogical interest is found in the pseudomorphic cavities due to the oxidation of the pyrite.

Above the water level the ore was about all oxidized and consisted of limonite, cerusite, malachite, and azurite in the earthy form, with much greenish-yellow lead-copper sulphate. Below the water line the ore contains pyrite, galena, chalcopyrite, and sphalerite, with some silver in a gangue that is mainly quartz.

The ore is of low grade, but there seems to be a very large body of it, and it is not so basic as the ore in most of the other mines.

Maine mine.—The Maine mine is about a quarter of a mile southwest of the New York mine, on a southern tributary of Washington Gulch, at an elevation of about 5,800 feet. The claim was relocated by M. W. Thompson and others in the eighties and subsequently deeded to Chalmer B. Coughlin, who in 1907 worked it with fair results. It was later worked successively by lessees, whose ore shipments, besides containing lead and silver, were credited with 9 per cent in copper by the El Paso smelter, the copper being reported to occur free in the ore.

In 1901 the mine was sold to a New Jersey company, the present owner. This company has driven a 150-foot tunnel, mostly in the quartz monzonite and vein material, but has not yet reached the limestone contact.

POCAHONTAS MINE.

The Pocahontas mine is in the northeastern part of the camp just northeast of Washington. It was located about 1880 by David Harshaw, W. C. Davis, and others and produced in the eighties a very large amount of ore, which was treated in a smelter built for the purpose on the San Rafael ranch, on Santa Cruz River, 6 miles to the east. It is among the properties first purchased by the Duquesne Co. in 1889. The mine is on the limestone and granite porphyry contact. It contained a large body of silver-bearing lead carbonate ore that extended from the surface to a depth of 50 feet, where it gave way to a soft decomposed conglomerate or breccia-like formation in which no ore to speak of has yet been found.

[1] Crosby, W. O., Am. Inst. Min. Eng. Trans., vol. 36, p. 643, 1906.

TIBBETTS MINE.

The Tibbetts mine is about one-eighth of a mile east of Washington, and the claim adjoins that of the Pocahontas on the north. It is on the granite porphyry and limestone contact, but except for local silicification of the limestone and the occurrence of specularite there is no indication that the deposits are contact metamorphic.

The mine is owned by M. M. Trickey and partners, of Washington, and has been worked since 1884. A shipment of 12 tons of ore from it made in 1902 or 1903 is said to have assayed 30 per cent in lead, 31 ounces to the ton in silver, and a little gold and copper. In June, 1909, there was on the dump 50 tons of cerusite ore that was said to average 8 per cent in lead and 10 ounces to the ton in silver. This ore was obtained from the tunnel level 60 feet below the surface. There was also about 100 tons of galena ore that was said to average 18 per cent in lead and 20 ounces to the ton in silver; this ore, however, contains from 18 to 20 per cent of zinc, for which it is penalized by the smelter.

The mine is developed to a depth of 200 feet by tunnels and drifts, stopes, winzes, and upraises, aggregating about 1,600 feet of work, most of which is shown in figure 46. The tunnel runs S. 26° E. into the hill a distance of 144 feet. A 60-foot upraise to the surface is 129 feet from the mouth, and 8 feet in front of it drifts are turned both east and west. The west drift runs S. 75° W. for 120 feet to a 15-foot inclined winze which descends to the north. The east drift is 63 feet long and bears N. 60° E. At its end a hoist station is located, from which an irregular winze inclining eastward is sunk to a depth of 136 feet on a vein that dips 80° N. At 78 feet below the collar of the winze a drift 36 feet long extends to the west. At 116 feet below the tunnel level a platform covers the winze, which continues 20 feet below it. A short drift to the west, one 25 feet to the north, and another 15 feet to the east are run from this level.

The tunnel and most of the other workings lie in the granite porphyry, which in the upper part of the oxidized zone is altered and micaceous, but at the face of the tunnel the porphyry is in fault contact with the Paleozoic sedimentary rocks on the south, here represented by siliceous altered limestone and quartzite. The contact is marked by a red clay breccia. At about 70 feet and 114 feet in from the mouth of the tunnel are two faults that dip 70° and 87° SSW. The zone of the second fault is composed of flinty quartz fragments in a red clay matrix. The upraise is in reddish altered granite porphyry.

The face of the west drift, which is in limestone, also contains a fault that dips 80° NW., with granite porphyry on the hanging-wall side of the winze below the drift. Along this fault contact occurs from 3 to 6 inches of reddish iron-stained gouge containing galena, a little malachite, and some specularite. The east drift lies in a sheet of soft reddish gouge and breccia in which some pockets of galena and cerusite were found. The drift at about 90 feet in from the mouth followed a siliceous iron-stained streak in the clay in which was found some ore that assayed 67 per cent in lead and 93 ounces to the ton in silver, but the streak became lost about 20 feet from the winze. The winze is sunk on a limestone footwall in soft red clay that contains quartz and some bowlder-like masses of galena.

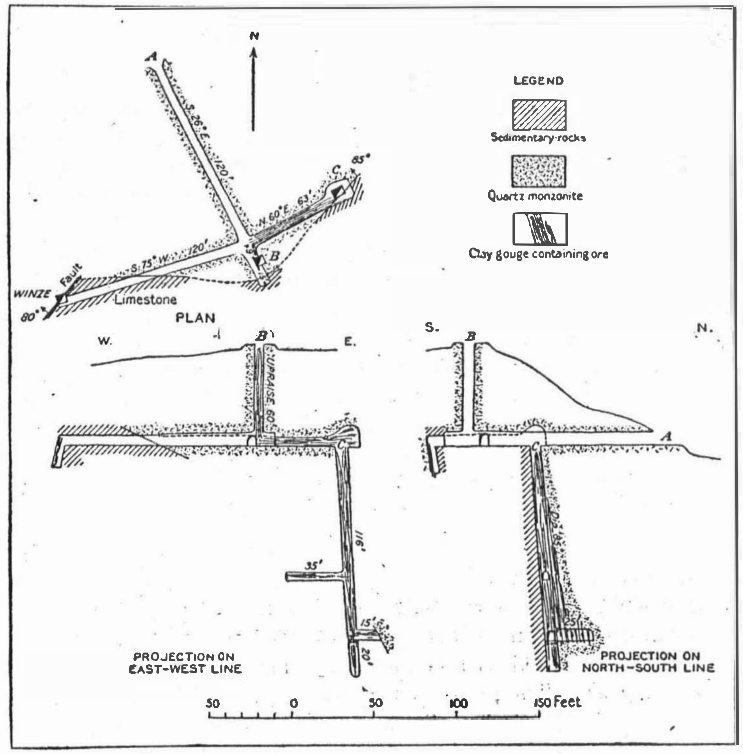

FIGURE 46.—Plan and projections of Tibbetts mine.

On the 116-foot level the footwall dips north-northeast, and granite porphyry was cut 15 feet east of the winze, which dips to the northeast at low angles. A 25-foot drift driven to the north is all in soft red material, apparently ground-up granite porphyry along a fault zone. Most of the galena ore was found as bowlders in this zone, largely following short disconnected ferruginous streaks. Mixed with the galena was more or less pyrite and chalcopyrite. Some ore occurs also in a very miarolitic and partly spherulitic phase of the granite porphyry.

COUGHLIN LEDGE.

The prospect known as the Coughlin Ledge lies southwest of the Pride of the West mine, principally between that mine and the Duquesne Gulch. It is on a 30-foot zone of dense flinty, cherty mineral-bearing quartzite or silicated garnetiferous limestone. It dips steeply to the northwest, and a quartz monzonite dike forms the footwall and limestone the hanging wall, the conditions being just the reverse of those in the Pride of the West mine. The dike seems to be the Pride of the West dike, or at least to be connected with it.

At Duquesne Gulch the zone and dike seemingly pass into the quartz monzonite area and are largely covered with wash material and débris. Croppings which occur at intervals, however, on its trend indicate that the zone continues southwestward in the quartz monzonite to the vicinity of the O'Connor camp or to the northwest of it, half a mile distant. This is the only observed instance of a zone of mineralization extending from the limestone into the quartz monzonite or igneous rock.

O'CONNOR PROSPECT.

Capt. O'Connor owns a group of claims a quarter of a mile west of the Belmont mine, just west of the limestone area, in the quartz monzonite, which is cut by masses of granite porphyry. The rocks have been much disturbed and fractured. They contain a large amount of mineral-bearing drusy quartz in veins and stringers that trend in all directions. The more prominent strike about east.

BROOKS PROSPECT.

The Brooks prospect is a mile west of the Belmont mine, on a vertical shear plane that trends N. 55° W. in the quartz monzonite. The rock along the plane is impregnated with chalcopyrite and pyrite, some of which is coated with chalcocite. The minerals also fill small seams in the rock. The prospect is opened by a shaft and tunnel.

GOLD LEDGE PROSPECT.

About 1¼ miles southeast of Duquesne, in a gulch just south of bench mark 5021, is an 8-foot dike of red rhyolite in quartzite and quartzite conglomerate. The rhyolite is cut by northeast vertical fissures, some of which contain a little iron-stained drusy quartz that is said to carry gold. No work has been done on the deposit.

BENTON MINE.

The Benton mine is 2¼ miles south of Duquesne and about three-fourths of a mile north-northeast of post 113 of the international boundary. It belongs to Dennis Coughlin and partners, of Duquesne. A party of four men was working on it in 1909. The property was known in the early eighties but was not located or worked until January, 1908. It comprises five claims lying in a north-south direction.

The country rock is quartz monzonite, which is cut by granite porphyry, diorite, and aplitic granite, the two last-named rocks cropping out on the hill above the tunnel. The granite porphyry occurs mainly in a 60-foot north-south dike. It is impregnated with pyrite, chalcopyrite, and a little molybdenite, and its contact with quartz monzonite is marked by a sericitic zone a few feet in width.

The developments consist principally of a 165-foot tunnel that trends N. 20° W. and is mainly in the quartz monzonite but toward the face passes through the granite porphyry, which at this point is 50 feet wide and is so highly and uniformly impregnated with pyrite and chalcopyrite that it forms a body of low-grade ore. The rock in the east side of the dike, in which the minerals are a little more concentrated than elsewhere, is said to average 2 per cent in copper. The croppings of the dike are iron stained and contain, in small fissures, little bodies or lenses of limonite, azurite, and malachite that are said to average about 14 per cent in copper and from $6 to $8 to the ton in gold.

ALFONSO VILLY PROSPECT.

The Alfonso Villy prospect, named for the owner, is a quarter of a mile east-northeast of international-boundary post 114. It is on a vertical quartz vein in the quartz monzonite. The vein is 6 feet wide, strikes N. 70° W., and contains seams of pyrite and chalcopyrite coated with chalcocite and covellite. These minerals also occur in small fissures in the adjoining quartz monzonite. The vein is opened by several shallow shafts.

LINE BOY MINE.

The Line Boy mine, owned by Capt. O'Connor, is just north of post 113 of the international boundary. The country rock is the gray quartz monzonite which is intruded by a small stocklike mass of granite porphyry that trends north and is about 300 feet wide. The locality of the mine is seemingly a focal point for several leads. From the mass of granite porphyry near the middle of the claim a 10-foot dike extends to the west-northwest and dips steeply to the north. Much white mica is developed in the quartz monzonite near the contact.

The metallic minerals pyrite, chalcopyrite, and molybdenite,[1] with a little bornite and films of chalcocite, are particularly abundant

[1] The occurrence of the molybdenite is described more fully in U. S. Geol. Survey Bull. 430, pp. 161–162.

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along the contact of the two rocks and are concentrated in joint planes and fissures, locally with a little associated quartz in small stringers and veins, and the adjoining quartz monzonite is partly impregnated with them. Along the hanging-wall side of the dike occurs a sheet of specularite 3 feet wide, shown in the tunnel drift.

The prospect is opened by three shafts and a tunnel, two of the shafts, each 50 feet deep, being at the top of the hill and the third, 80 feet deep, at the north base of the hill. The tunnel is 65 feet long and follows the north or hanging-wall side of the dike.

In August, 1910,[1] development work is reported to have encountered, in a 120-foot tunnel, a 6-foot vein of ore carrying from 11 to 24 per cent in copper. The ore contains principally chalcopyrite, with 15 to 20 per cent of bornite.

PLACER DEPOSITS.

Placer gold occurs in the Patagonia district in the Quaternary stream gravels in the piedmont portion of Mowry Wash and its tributaries, being present on the main wash at the east border of Guajolote Flat about 1½ miles southwest of Mowry, on a south-side tributary gulch about 1¼ miles south-southwest of Mowry, and on two north-side parallel tributary gulches about 1½ miles southeast of Mowry.

The production is small, as the deposits are worked only by Mexicans when in need of money. The average earnings are about 75 cents a day for each man. The placers at the Guajolote locality were being worked by dry washing at the time of visit. The deposits at this place seem to be about 5 feet thick. The known production in 1908 was 2 ounces of gold. In 1906, when, after the closing of the Mowry mine, many unemployed men were in the country, the production was about $200.

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Appendix 9

exerpts from

History of Mining in Arizona

by James Brand Tenney

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1929

CHAPTER 12

COCHISE COUNTY

The detailed histories of the two major districts in this county, Bisbee and Tombstone, have already been given. In this chapter the histories of the smaller districts centered at Gleeson-Courtland, the Dragoon and Little Dragoon Mountains, the Chiricahua Mountains, the Dos Cabezas Mountains, Pearce, the Swishelm Mountains, and the Huachuca Mountains will be given.

Cochise County, originally a part of Pima County, was created as a separate entity in 1881 soon after the discovery of Tombstone and Bisbee. In the pre-Civil War days little was known of this corner of Arizona. A few Spanish and Mexican settlers had penetrated a short distance down the San Pedro river valley, but these settlements had been practically abandoned at the time of the Gadsden Purchase due to Apache raids. The first settlements by Americans were in the San Pedro, Sulphur Springs, and San Simon valleys during the pre-Civil War period, but they were so exposed to Apaches and outlaws that they were not permanent. Northern Cochise County was partly explored during this time near the route of the Butterfield stage, but as this part of Arizona was the center of the Apache mountain fortresses, almost no attempts were made at prospecting.

It was not until it had become assured that the Southern Pacific railroad was to be completed that real prospecting started, which resulted in the discoveries of the Tombstone silver deposits, the Bisbee copper deposits, the Teviston (Dos Cabezas) gold placers, and the Peabody (Little Dragoon) copper deposits, all within a few years of each other in the late seventies. These discoveries were followed very shortly by the discovery of the silver and copper deposits of the Gleeson-Courtland region at the southeast end of the Dragoon Mountains, and the lead-silver deposits of the northern Chiricahua mountains.

Little work was done at any of the smaller districts until the revival of copper mining in the late nineties. This revival of mining was heralded in Cochise county by the discovery in 1895 of the bonanza Commonwealth silver-gold lode in a small hill near the center of the Sulphur Spring Valley.

Most of the smaller districts reached their zenith during the high metal prices during and immediately following the War, during which time they were exhausted of better grade ore. On the collapse of the metal markets in 1921, almost all activity ceased. A revival of mining took place in 1927, but it was short-lived. The smaller districts of Cochise county, like those of eastern Pima county, have been virtually exhausted. Short historical sketches of the most important centers are given in the following pages.

Gleeson-Courtland District

The silver-lead deposits of Turquoise, now known as Gleeson, were discovered in the late seventies after the first real truce in Apache warfare preceeding the completion of the Southern Pacific railroad. Little other than location and assessment work was done until the boom period of the early eighties. The principal claims were the Defiance, Hidden Treasure and Last Chance, now a part of the Costello holdings. From 1883 to 1893 when silver commanded a price of about 1.00 an ounce, considerable high-grade hand-sorted lead-silver ore was mined, hauled to the nearest railroad point at Cochise and shipped to various reduction works at Benson, El Paso, Silver City, Socorro and Pinos Altos. The most extensive work was on the Silver Bell and Tom Scott claims. The Silver Bell shaft was sunk 270 feet on the incline, and the largest tonnage came from stopes off this shaft. Production records are lacking, but from the size of the stopes and the grade of ore left on the dumps it is probable that there was shipped about $100,000 of ore chiefly valuable for its silver content.

After the demonetization of silver in 1893 and its consequent drop in price, nearly all work ceased. The ownership of the claims passed into the hands of Martin Costello and McKittrick, and for many years bitter and protracted litigation still further hindered work in the district.

The first copper ore of any importance was found in 1896 by John Gleeson on the Charleston claim, located in the late eighties by Kit Charleston. The ore was discovered underlying a large outcrop of gossan. Gleeson purchased the Charleston claim from Charleston, and added to his holdings adjoining claims purchased from Alexander Casey and Silas Bryant. After several years of development work the Copper Belle Mining Company was organized by Gleeson in 1898, and in 1899 and 1900 shipments of high grade oxidized copper ore were made to Silver City and El Paso. Due to the high cost of the thirty-mile haul to Cochise, smelting of the ore was decided on in 1900, and by May 1901 a 60-ton water-jacket blast furnace had been belown in. By the end of the year, the oxidized ore had been nearly exhausted, but a large tonnage of massic sulphide ore was encountered on the 200-foot level. Part of this ore was smelted to matte and part was shipped to El Paso, Globe, and Clifton as sulphide flux. Operations continued until late in 1902. The company had been heavily mortgaged to finance the building of the smelter, and was finally forced into bankruptcy. Alt. Emmanuel was appointed receiver in January 1903, and in 1904 the company was reorganized as the Copper Belle Mining

Company under the management of William Kemp. The mine was reopened and shipments of massic sulphide ore were made to the Old Dominion Smelter at Globe. The smelter was again blown in in 1905 and both matte and ore were shipped to Globe. Intermittent production continued to the end of 1906 when the mine was leased to the Shannon Copper Company. In July 1908 the property was purchased at sheriff's sale by Nathan L. Amster of the Shannon Copper Company, and a large tonnage of low grade sulphide ore was shipped to the Shannon Smelter until its close late in 1918. Shipments to other reduction works continued until 1923 when an attempt was made to roast and leach the remaining ore in place. The mine was sealed, the shaft timbers were fired, and fuel oil and miscellaneous old timber was dumped down the shafts. It was hoped that the ore itself would be ignited and would be partially roasted in place, but after a few months it was found that after the timbers were burned the fire extinguished itself. The mine was then flooded, but the leaching of the ore was not effective, and the mine was again pumped out and the main shaft was retimbered, but no further production was made.

On the Courtland side of the district, northeast of Gleeson, little early work was done except on the relatively small outcrops of turquoise. The principal outcrops were of oxidized copper ore containing very little precious metal. The first locations other than for turquoise were made in the nineties, but no work was done until 1901, when the Humbot claim was developed, and a large tonnage of the high-grade oxidized ore outcropping was shipped, stimulated by the high copper market of that year. This claim was one of a group purchased in 1900 by the Young Brothers of Iowa who in that year entered the district, purchased the Mary, Mame, Humbot and other claims from McCormack, Hardy and Warnekross and organized the Great Western Copper Company.

After the drop in the price of copper in 1902, the Great Western developed the Humbot and Mary mines, but made no production until 1900. The property was equipped with a power plant in 1908, which was erected jointly by Phelps Dodge and Company and the Great Western Copper Company. Production started in 1909 at the Mary mine. On the exhaustion of the Mary mine, the Mame was developed and exploited followed by the Highland. Production on company account was continued without interruption until the drop of metal prices at the end of 1920, when the mine was closed. On the reopening of the smelters in Douglas in 1922, various sets of leases working on the property commenced production, which was continued until the drop of metal prices in 1930.

The Leadville group of claims, adjoining the Great Western group was purchased by William Holmes in 1903, who organized the Leadville Mining Company to exploit them. Most of the work on the various mines of the group was done by several companies who had the ground under option at various times, more notably the Calumet and Arizona Mining Company from 1907 to 1909, the Fuller and Near in 1912, and the United States Smelting and Refining Company in 1916. Some production was made by all these companies, and in 1923 the Maid of Sunshine mine was purchased by the Calumet and Arizona. During the high metal prices of the War years from 1917 to 1920, parts of the ground were leased and high grade ore was shipped, chiefly from the operations of the Muso Lease. Since 1921 a small intermittent production has been made by various leases.

The Calumet and Arizona Mining Company and the Phelps Dodge and Company entered the district in 1908, secured options on ground adjoining the Leadville and Great Western and started active development. The Calumet and Arizona secured the Germania and April Fool mines and took an option on the Leadville group. Production was started on the Maid of Sunshine and Germania in 1908 and was continued until 1910. The district was greatly stimulated at this time by the construction of spur railroad lines by the El Paso and Southwestern and Arizona Eastern Railroads into the district. The Phelps Dodge Company discontinued development work and gave up its option in 1909, after the expenditure of considerable sums in equipment. The Calumet and Arizona company closed the Germania at the end of 1910, reopened the mine in 1912, and continued production partly on lease account until 1920. Production was again started by leases after the purchase in 1923 of the Maid of Sunshine mine, adjoining the Germania, from Leadville Mining Company, and continued intermittently until the depression in metal prices in 1930.

On the Gleeson side of the district no work other than at the Copper Belle was done after 1893 until 1912 when work was started on the Tejon claim by the Tejon Mining Company in the endeavor to find copper ore similar to that of the Copper Belle. A small production was made from development work until the end of 1919.

During the years of the World War the Tom Scott mine, one of the early producers in the district, was reopened by Marchello on lease account from owner Mrs. Mary McKittrick, and considerable lead-silver-copper ore was shipped during the high silver prices enjoyed under the Pitman act. The Tom Scott and Tejon mines were reopened in 1925 by the Tejon Leasing Company, and shipments were made for a year to the smelter at El Paso, after which the mines were again closed. They were again reopened by the Tejon Mining Company in 1927 under the superintendence of Frank W. Giroux. Most of the work was centered at the Tejon mine. Development work was pushed energetically and some stoping of copper ore was done until 1930, when work was again discontinued.

The old Silver Bell and Defiance mines remained idle after 1893 until 1922 when they were leased to various parties who both mined ore and sorted the old dumps until the end of 1929, when the low price of both lead and silver prevented further profits.

The reopening of the Silver Bell mine and the development of ore to the sideline of the property stimulated the development of the neighboring group of claims. This group owned by Mr. P. Warnekrose, was sold in 1923 to the Mystery Mining Company, promoted by John Gleeson. The property was developed by a long tunnel, and high-grade lead-silver ore was shipped to the end of 1929 when known ore was exhausted.

The production of the Courtland-Gleeson district, sometimes known as the Turquoise district, from 1883 to the end of 1929 has been approximately 57,500,000 pounds of copper, 4,200,000 pounds of lead, 360,000 pounds of zinc, 540,000 ounces of silver, and 24,000 ounces of gold with a gross worth of $10,400,000. Details are shown in the Appendix.

Commonwealth Mine*

The value of the Commonwealth vein, outcropping in a small hill near the center of the Sulphur Spring Valley, was discovered in 1895 by John Pearce, a cowboy of the valley. His own story is that while driving cattle over the hill he picked up a rock to throw at a recalcitrant cow, but noting its unusual weight, pocketed it instead, and had an assay made of it. On receiving the returns of 2100 ounces of silver a ton, he and his brother returned to the hill and located six claims. They gathered up a carload of rich float ore, hauled it to Cochise, the nearest railroad point and shipped it to El Paso. This first car returned 100 ounces of silver and $20 in gold a ton. They then sank what was later known as No. 1 shaft at the western end of the outcrop to a depth of fifty feet,

*Smith, Lewis A.: "The Geology of the Commonwealth Mine". Thesis (M.S.)-University of Arizona, 1927 and shipped a second car of ore which gave about the same returns. The fame of the rich find spread quickly and in November of that year John Brockman of Silver City visited the prospect and secured an option on the mine for $275,000, payable in installments over a ten-year period. He then enlisted the aid of D. M. Barringer and R. A. F. Penrose, Jr., and the Commonwealth Mining and Milling Company, capitalized at $1,000,000, was organized to take over the option. A $250,000 bond issue was then floated, and the option was closed with the Pearce brothers for $250,000 in cash in lieu of $275,000 over ten years. A large block of stock was then sold to furnish working capital - sold in Germany and England as well as in the United States. John Brockman remained as manager. The original shaft sunk by Pearce was enlarged and a second shaft was started to the east. Both were sunk 267 feet to water level, and the ore cut was hoisted by whims, hauled to Cochise and shipped to the smelter at El Paso. The returns from the first three months of work enabled the retirement of the bonds and in addition $100,000 in dividends a month were paid for six months. The costs on this first work were almost as follows:

Mining	$2.50 a ton
Haul to Cochise	2.50 a ton
Freight to El Paso	3.50 a ton
Treatment charges	7.50 a ton
Total	$16.00

Operations were continued on this basis until 1898 when the first mill was erected, in which the ore was crushed in Blake crushers, ground in Chillean mill, and treated by pan amalgamation. The original capacity of the mill was 30 tons a day which was later increased to 200 tons a day by the addition of sixty 1000-pound stamps followed by rolls. This mill continued in operation until June 1900 when it was destroyed by fire.

A new mill was started immediately after the fire and, while building it, a new extraction shaft was sunk in the footwall of the vein. The mill was completed in January 1901. The higher grade ore had by that time been largely exhausted, and for the succeeding four years the mill was run on a 240-tons a day basis on lower grade ore. The policy followed in mining the ore body, leaving very small supporting pillars, finally ended in 1905 with the collapse of the hanging wall and the loss of the stopes. The mill was closed and the mine abandoned.

A lease was then obtained on the large mill tailing-pile by O. T. Swatling, the mill superintendent, and A. Y. Smith, the mine superintendent, who built a 230-ton cyanide plant for this purpose. The lease was extended in 1906 to include the mine. During the five years life of this operation 288,000 tons of tailing and 107,000 tons of caved ore were treated, averaging about $3 in silver and gold.

The mine was purchased in 1910 by the Montana Tonopah Mining and Milling Company, an organization promoted by Charles Knox and A. Y. Smith. Edward A. Collins acted as manager of the company. A new mill was erected at a cost of $283,000 and a new extraction shaft known as the D shaft was sunk to the 8th level. While the mill was building and the mine was being developed, the old tailing treatment was continued by leases. The mill was completed early in 1913 and was run on low grade ore stoped chiefly from the footwall side of the two veins until May 1917, when operations on company account were discontinued. 375,000 tons were treated at a profit of about a dollar a ton.

After the close of the mill, A. Y. Smith obtained a lease on the property, and organized the Commonwealth Development Company. The mine was subleased to various small leasees, and the ore was shipped to the Copper Queen smelter at Douglas as silicious flux. About 120,000 tons of ore averaging 12.3 ounces of silver and $2.00 in gold was shipped to the end of 1929. Included in this was a small tonnage of old tailing.

The total production of the property through 1926 was approximately 940,000 tons with an average value of $11.71, a gross production of $10,40' which yielded about $5,000,000 in profits and dividends. By the end of 1929 the mine had been virtually exhausted of profitable ore, although under a normal silver market a small production of low grade ore may yet be made.

Dragoon and Little Dragoon Mountains

The main range of the Dragoon mountains in which is located Cochise's stronghold, one of the principal mountain forts of the Apaches, was little prospected until after the death of Cochise in 1879 and the subsequent removal of the Indians to the San Carlos reservation. Prospecting in the Little Dragoon, north of Dragoon Pass, had started at an earlier date, and the first locations were made in the early seventies on the copper outcrops at what is now Johnson, seven miles north of the pass. Little work was done until after the completion of the Southern Pacific Railroad in 1881 when what are now known as the Republic and Mammouth mines, on which rich oxidized copper ore outcropped, were acquired by a Philadelph. company known as the Russel Gold Silver and Copper Mining Company. This company erected a small furnace at what is now known as Russelville, about two miles west of the mine, where the nearest permanent water supply was obtainable. Production started in 1882, and according to the Tucson Star's estimate 266,636 pounds of block copper were produced during the year. The following year the Cochise Copper Company was organized to work the Peabody mine. A pipe line was laid from Russelville to the mine, the smelter of the Russelville Company was moved and rebuilt at the mine, and the town of Johnson sprang up in the mesa surrounding the mine. The smelter started in 1883 and 607,632 pounds of block copper were produced.

In the Little Dragoon mountains north of Dragoon Pass, little work was done after the close of the Peabody mine in 1884 until the high copper market years at the dawn of the twentieth century. The Peabody mine was purchased by the Dragoon Dummit Copper Mines Company organized by Jacobs in 1899. No production was made until 1902 when the company was reorganized as the Dragoon Mining Company. Shipments were started of oxide ore to the smelter at El Paso at the rate of three cars a month. Intermittent work was done through 1903 when the property was closed. The company was reorganized four years later during the high market preceding the 1907 panic as the Bonanza Belt Copper Company and about $500,00 worth of ore was shipped during the year, after which the mine was again closed. It has been reopened at various times since by lessees who sorted the dumps and mined what was left of the high-grade ore of the mine. The production since 1907 has been negligible. The mine has produced since 1881 about 1,2000,000 pounds of copper with a gross value of about $191,000.

The largest producing mines of the Dragoon and Little Dragoon mountains have been those mines now owned by the Arizona United Development Company or Mason Copper Company.

This group consists of the Republic, Mammoth, and Copper Chief mines, near the Peabody mine at Johnson in the Little Dragoon mountains, about seven miles north of Dragoon Pass.

The first work was done in 1904 when the Republic and Mammoth mines and other contiguous groups of claims were purchased by the Arizona Consolidated Mining Company, financed in Pennsylvania. The principal work was centered at the Republic mine and, after equipping and developing the mine, production started in 1905, the ore being hauled to Dragoon station and shipped to the Copper Queen smelter at Douglas. Oxidized ore was shipped from both the Mammoth and Republic until 1909 when the company was reorganized as the Arizona United Mining Company, under the laws of Delaware, and a 125-ton smelter was built near the Republic shaft. A railroad to serve the camp was built in the same year by the Arizona and Michigan Development Company, operating the Copper Chief Mine. Production continued at a larger rate in 1909, and a part of the ore was smelted. The smelter was run for a short time only, and was then abandoned. All shipments ceased in 1910 to await better copper market.

The company was again reorganized in 1910 as the Arizona United Mining Company, under the laws of Arizona, but production did not start until the better copper market of 1912. The company continued to ship ore to the smelters at Douglas at an increasing rate until January 1915. A large body of sulphide ore was developed in 1913 and production was greatly increased in 1914.

The property was leased for a period of ten years in the beginning of 1915 to the Cobriza Mines Development Company of which Halstead Lindsley was ground manager, and David M. Goodrich was president. This company started production in July 1915, and continued shipments until July 1918 when the lease was surrendered to the company on the payment of $75,000 to the leasing company. During the period of the lease, ore of about $4,000,000 gross value was shipped, with a net return to the leasing company after royalties were paid of over a million dollars.

After the surrender of the lease, the Arizona United Company continued to mine until the end of 1920 when the drop in the price of copper forced suspension. No work was done after the close of the property until 1923 when the Copper Chief mine owned by the Dragoon Mountain Mining Company and the Republic-Mammoth mines of the Arizona

United Mining Company were consolidated as the Arizona United Development Company under the management of George F. Wilson. Small intermittent shipments were made in 1924 and 1925, and in 1926 the combined properties passed into the hands of the Mason Copper Company. A start was made at reconditioning the mine and a large flotation concentrator was contemplated, but all work ceased at the end of the year.

The Copper Chief Mine, one of the group now owned by the Mason Copper Company, lies between the Republic and Mammoth mines. This group was acquired by the Arizona and Michigan Development Company in 1904. The property was developed and equipped, and in 1909 a broad-gage railroad was built from Dragoon to the mine, a distance of about six and a half miles. Little production was made until 1914 when small shipments started which were continued into 1915. In 1916 the property was bought by the Dragoon Mountain Mining Company, and eleven cars of ore are reported as having been shipped in 1918, since which time no production has been made. The railroad was taken over in 1921 by the Southern Pacific Railroad Company and the line was abandoned and the tracks raised. The Dragoon Mountain Mining Company was absorbed together with the Arizona United Mining Company, by the Arizona United Development Company in 1923.

Other mines that have been considerably developed but have had only small productions have been the Keystone, financed in Kansas, for which a 200 ton flotation concentrator has been built, the Black Prince, the Centurion and the Johnson Copper Development Company.

The total production of the Dragoon and Little Dragoon mountains exclusive of the Courtland-Gleeson area at its southeast extremity has been approximately 28,500,000 pounds of copper, 1,000,000 pounds of lead, 67,000 pounds of zinc, 350,000 ounces of silver and 9900 ounces of gold with a gross value of about $6,500,000. Details are show in the appen-

CHAPTER 13

EASTERN PIMA COUNTY

EARLY MINING

The first mining in what is now Arizona was done in Eastern Pima and Santa Cruz Counties. The two settlements of Tucson and Tubac in the Santa Cruz River Valley were the northern frontier towns of that part of Mexico west of the Sierra Madres for at least two centuries before the Mexican War. However, mining was never a major industry in Arizona in Spanish and Mexican time, due to the control of the mountains by the warlike Apache tribes against whom no headway was ever made. A little placering was done, and a little silver mining of a very crude kind in the Santa Rita, Patagonia, Catalina, and Sierrita Mountains. "Antigua" workings were found at the Cerro Colorado, Patagonia, San Xavier, and in the Cañada del Oro of the Catalina Mountains. At the time of the American occupation no mining was being done by the Mexicans, and only legends remained of what had been done in the past. One of the legends dealt with the finding in the eighteenth century of a rich silver placer known as the "Planchas de la Plata" somewhere near the present international line west of Nogales. Shortly after its discovery the Spanish government forbad its exploitation on the grounds that it was a "Creadoro" or source of the mineral wealth of the country.

Mining on a comparatively large scale did not commence until after the occupation of Tucson by the Americans in 1854 following the estab-

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lishment of the international boundary by the Boundary Commission. Forts were established in the Patagonia Mountains, San Pedro Valley, and at Tucson as a protection against Apaches, and several large exploring companies were organized in New York, Providence, Cincinnati, San Francisco, and Texas to exploit the territory embraced in the Gadsden Purchase. These early ventures were promoted largely by Army officers and members of the Boundary Commission. The most influential of these early promoters were C. D. Poston, Lieutenant Sylvester Mowry, Major Heintzelman, Colonel Samuel Colt Othe inventor of the Colt pistol), and Captain R. S. Ewell (later a brigadier general in the Confederate Army.) They were ably assisted by two German mining engineers, Herman Ehrenberg and Frederick Brucknow.

The country was then extremely inaccessible, and over-run by Apaches and Mexican outlaws. Tucson and the various forts were the only permanent settlements prior to the establishment of the ranches and mining camps. The most accessible entrance into the country was by boat to Guaymas and by road and trail from Guaymas to Tucson through northern Mexico. After the establishment of the mining camps and ranch haciendas, roads were built from El Paso to Tucson and from Tucson to Fort Yuma, and in 1857* the first stage line was established, known as the San Diego and San Antonio line. This first venture was promoted by James E. Birch and Isiah C. Woods of California. No roads existed and the company occupied itself chiefly in road building. Regular stage service was never achieved. The following year the San Diego and San Antonio line was taken over by the Butterfield line, organized to run from Marshall, Texas, to San Siego, California. Its eastern termines were St. Louis and Memphis and its

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*Farrish, Thomas Edwin, History of Arizona, 1915, Vol. 2.

western termines was San Francisco. Its president was John Butterfield of Utica, New York. The company was subsidized by the U. S. Government for $600,000 a year to carry the mails. The route through Arizona led west-bound through Apache Pass in the Dos Cabezas Mountains, Dragoon Pass at the northern end of the Dragoon Mountains, Benson on the San Pedro River, and down the river to the mouth of Aravaipa Creek. From there there were two routes followed, one to Tucson by way of the present town of Oracle and thence in part following the course of the Cañada del Oro, and the second, down the San Pedro to the Gila at the present town of Winkelman and thence west following the Gila River to Fort Yuma by way of the Pima villages near the site of Maricopa. A route also was established from Tucson down the Santa Cruz River to the Pima villages, and thence west to Fort Yuma. The first stage left St. Louis September 15th, 1858, and reached San Francisco October 10th. From then on regular tri-weekly service was maintained for eighteen months. The through passage cost $150 exclusive of meals, which cost, such as they were, from 40 cents to a dollar. In March 1860 the route was discontinued and moved north through Denver and Salt Lake City. The inauguration of the stage line was a great stimulus to mining in Southern Arizona. Some high grade ore was shipped to mid-western reduction works and most of the machinery for local reduction works was shipped into Arizona by the stage company. A vivid account of a trip into Arizona from St. Louis to Tucson at this time has been given by Pumpelly* who was employed as metallurgist for one of the early ventures in the Snata Rita Mountains. For sheer traveling

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*Pumpelly, Raphael, *My Reminiscences*, H. Holt and Company, 1918, vol. 1.

discomfort and danger, it has had few peers in the history of transportation. The regular maintenance of the line through two thousand miles, half of which was through Apache and bandit-infested country for even the short eighteen months of its existence demonstrated the metal of the men who were attempting to open up the territory. They were a hardy and fearless lot. Short sketches of the lives of the two chief promoters of the period, Poston and Mowry* serve as examples of the type.

Charles D. Poston was born in Hardin County, Kentucky, April 20th, 1825. His mother died when he was twelve years old, and soon after he served three years in the office of the Supreme Court of Tennessee at Nashville. During this time he studied law and was admitted to the bar. Shortly after the '49 gold rush he went to San Francisco and served there in the customhouse. After the Gadsden Purchase in 1854 he accompanied an exploring party into Arizona, and was so much impressed with the country that he spent the following year in a trip to San Francisco, New York, Kentucky, and Washington, D. C., to interest capitalists in Arizona and New Mexico. In 1856 he returned to Arizona with funds for prospecting and acquiring mining properties. He was an active promoter of three of the early ventures which were financed from New York and San Francisco. On the outbreak of the Civil War, he was transferred to the New York office of one of the companies. On the organization of the Territory of Arizona in 1863 he was appointed by President Lincoln as Superintendent of Indian Affairs. After serving one year he was elected first Delegate to Congress from Arizona, and upon the conclusion of his term he made a

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*The two biographies are taken from Farrish's History of Arizona, Vol. 2, 1915.

tour of Europe, practiced law at Washington, D. C., and later accompanied J. Ross Browne, newly-appointed Minister to China, as Commissioner of Immigration and Irrigation. On his return to the United States, he was appointed as Register of the United States Land Office of Arizona by President Grant, and served afterwards as Consul at Nogales and military agent at El Paso. For five years after the conclusion of this work he was very active in Washington, promoting the interest of the government in irrigation, after which he retired to Phoenix, where he died in 1902.

Sylvester Mowry entered West Point in 1848 and graduated with the class of 1852. Among his classmates were General Crook, General Kautz, Colonel Mendel, Jerome Bonaparte, Jr., Major-General Evans, Captain Mullin, and Lieutenant Ives. In the summer of 1853 he was engaged with George B. McClellan on the Columbia surveying for a railroad route. In 1855 he was commissioned to conduct some recruits and animals from Salt Lake to California, and was then transferred to Fort Yuma. While there he made an expedition into southeastern Arizona, and was so inspired with the mineral possibilities that, in 1857, he resigned his commission to engage in mining. In 1860 he purchased the Patagonia Mine in the Sierra Santa Cruz (the Patagonia Mountains) 55 miles south of Tucson, and together with his brother, Charles Mowry, spent the succeeding two years in developing and equipping the property. On the outbreak of the Civil War in 1861 he fortified the mine against Apache attacks and continued working after all troops were withdrawn and the territory was in a terrible state of confusion. He remained in possession of the mine until 1862 when General Carleton of the California Column arrived and took possession of Arizona. Mowry was suspected of southern sympathies, was arrested and sent to Fort Yuma, and the mine was confiscated. He was liberated after six months, without trial, and the mine was afterwards restored to him. After the Civil War he spent the rest of his life in writing about conditions in the Southwest and in unsuccessful attempts to refinance the mine. He died in London, England, in 1871. By his writings and enthusiasm he probably did more to interest the country in Arizonaand its possibilities than any one man of the period.

The principal mining and cattle ventures of southeastern Arizona before the Civil War were the following, as described by F. Biertu*, Metallurgist for the Mowry Mine in 1860: "My first visit to the Patagonia Mine, nowcalled the Mowry Silver Mines, has lasted four days - the time necessary to give it a full examination in all its parts, and to make a careful assay of its ores. But why is it called the Patagonia Mine? Is it because it is situated in a desert inhabited only by Indians? Such were the questions I put to myself while traveling, and which I thought might be answered affirmatively. Great was my surprise, however, when instead of finding as I expected, barren mountains as at Washoe and Mono, I gazed on beautiful landscapes, and a country covered with trees of different kinds, with fertile lands perfectly watered. True it is that the nearest neighbors, the Apaches, are far from being equal to the Patagonians, but this, it seemed to me, could not be the reason for giving to such a beautiful spot, which in spring must be covered with flowers, so savage a name. Mr. Mowry was perfectly right to alter it. ...

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*Mowry, Sylvester, Arizona and Sonora, Harper and Brothers, N. Y., Third Edition, 1864.

"The discovery of the Patagonia Mine dates only from the fall of 1858, but it would appear that its existence was suspected long ago, for the first parcels of ore gathered by the Mexicans were taken, at the time of the late discovery, from shafts which had been sunk many years ago, and which had been abandoned.

"The Owners: - The first owners were Colonel J. W. Douglass, Captain R. S. Ewell, Lieutenant J. N. Moore, Mr. Randal, Mr. Lord, and Mr. Doss, all belonging to the United States Army, excepting the last named individual and Colorel Douglass. Those parties started some preliminary works - sunk shafts, extracted a certain quantity of ore and built up several furnaces for smelting. But being short of capital ... two of the principal shareholders, Messrs. Lord and Doss ... sold their interest during the year 1858-9 to Mr. Brevoort. ....

"The administration of Mr. Brevoort was not a happy one. The mine ... fared much worse. A certain quantity of ore was extracted, but ... the proceeds ... were not sufficient to cover the costs incurred. These failures gave rise to disagreements between the owners, which could not be stilled except by the sale of their whole interest, which Captain Ewell and his partners made to Mr. Brevoort, this last named gentleman turning the interest immediately over to Mr. H. T. Titus. ... Consequently, the sale of the whole was resolved upon, and the conveyance took place in the Spring of 1860 in favor of Lieutenant Mowry, all the interested parties joining in the deed. The price of the mine, including the lands surrounding it, all the works and establishment standing at the time, fixed at $25,000, was paid in cash by the new owner. ...

"The Management of the Mine: The old furnaces having been badly constructed, and being out of use, they will be replaced by others containing all the later improvements, either for smelting or refining. ... The expenses to be incurred this year to put in operation the different projects in view will exceed the sum of $60,000.

"The Eagle Mine: This mine is situated to the east of the Mowry Mine, and its vein composed of argentiferous galera, exactly similar to the Mowry Mine, is, it is stated, its continuation.

"The San Pedro Mine*: This mine is situated on the east side of the San Pedro River, about twenty five miles from the Overland Mail Road, and half a mile from the river.

"Empire or Montezuma Mine[1]: I have mentioned above this mine as forming a part of the Santa Cruz Sierra. It is half-way between the Mowry Mine and the town of Santa Cruz. The ores are composed of lead and silver. The first owners were Th. Gardner and Hopkins, who it seems, sold their interest out to New York companies.

"Santa Rita Mining Company: The Sierra de la Santa Rita, as that of the Santa Cruz, incloses rich deposits of precious ores. The Cazada, Florida and Salero Mines are united in one company, under the above title. The last one was known a long while ago, and was worked by the Jesuits. In that one also the argentiferous galera dominates. Shortly, furnaces will be put up for smelting and reducing; they will be erected on the very mountains of Santa Rita, which are to the east of Tubac, at the distance of about ten miles. The superintendent of the mine is Mr. H. C. Grosvenor, and Mr. Pumpelly is the engineer.

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*Known also as the Brucknow Mine, about six miles from the site of Tombstone. (J. B. Tenney)

[1]One of the Washington Camp properties. (JBT)

The capital is $1,000,000. These mines were opened in 1856.

"Mariposa Mining Company*: This company is working a copper mine, situated forty miles from Fort Breckenridge at the junction of the San Pedro and Arivaca** Rivers and from three to four miles south of the Gila. ... It is under the direction of Mr. A. B. Gray, ex-surveyor of the United States attached to the commission of the Mexican Frontiers, and engineer-in-chief of the Pacific Railroad. Mr. Hopkins is the engineer of the mines; the house of Soulter, of New York, is the principal owner.

"Sonora Exploring and Mining Company: This mine, situated at about thirty miles from Tubac, in the Cerro Colorado, is one of the principal mines, if not the richest in the Territory. The company is working the vein known as the Heintzelman Mine, rich in argentiferous coppers, and also other veins on the Rancho Arivaca. ... One of the principal shareholders, Mr. Charles D. Poston, is the director, and at the same time lessee of the mine for the term of ten years. This company was incorporated in Cincinnati, Ohio, with a capital of $2,000,000 divided into 20,000 shares. The sum already expended for the working of this mine is estimated at $230,000, either in ready cash or from the proceeds of the mine.

"Cahuabi Mining Company***: The mine going by that name is near meridian 112 and 32 north latitude, in a region inhabited by the Papago Indians. The argentiferous copper ores are treated according to the

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*This mine was probably the Collins Mine adjoining the Mammoth. Ancient work was reported as existing at the time of relocation in 1884. JBT

**The Arivaca River is the present Aravaipa Creek. JBT

***The Cahuabi Mine is probably what J. Ross Browne refers to in 1864 as the Picacho Mine. JBT

Mexican amalgamation process known as the patio. I have seen specimens from this mine in the hands of Herman Ehrenberg, president of the company, of extreme richness. The mine was opened since 1859. ...

"Arizona Land and Mining Company: This mine is situated north of the Rancho of Sopori.* This company owns a large tract of land of thirty-two leagues square, on which is situated the old silver mine of San Xavier, which was worked during the time of the Jesuits, and which appears exceedingly rich; other veins, equally rich, are to be found in the center of the property, on the Sierra Tinaja.** The company was incorporated in Procidence, R. I., with a capital of $2,000,000. The Honorable S. G. Arnold is the president. The treasurer is Mr. Alfred Anthony, President of the Jackson Bank of Providence. Colonel Colt, Lieutenant Mowry, and other rich capitalists of the East are the actual owners. Mr. Mowry is the holder of more than one-half of the stock of the company. N. Richmond Jones, Jr., is the engineer-in-chief of the mine, as also of the Sopori Mine.*** ...

"The particulars I have just given you, although already quite lengthy, are far from containing all that might be stated in regard to mineral wealth of the Territory; but I must stop here, as I only intend to give you statements entirely correct."

The Sonora Exploring and Mining Company and the Arizona Land and Mining Company were closely affiliated in stock ownership. The old town of Tubac, abandoned by the Mexicans at the time of the American occupation, was rebuilt and fortified by these two companies, and

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*The original location of the Sopori Ranch was north of Tubac in the Santa Cruz Valley somewhere near the present Canoa Ranch. JBT

**The Sierra Tinaja is the present Sierrita Mountains. JBT

***The location of the Sopori Mine is in doubt. It is probable that it is synonymous with the Cerro Colorado or Heintzelman Mine. JBT served as headquarters. A large fortified hacienda was established at the Cerro Colorado, and a second large ranch and hacienda was built at Arivaca where the reduction works for the Cerro Colorado were erected in 1859 under the direction of Guido Küstel, a noted metallurgist of the times. A large part of the machinery for the works was designed and purchased in New York by Colonel Samuel Colt, one of the principal stockholders.

The headquarters of the Santa Rita Mining Company was the old Tumacacori Mission Ranch, which also had been abandoned by the Mexicans and was partly rebuilt and fortified by the company. All these companies found it necessary to enter the cattle and farming business as necessary accompaniments of mining.

Large sums of money were spent in all these early ventures, but the returns were extremely small. As an example, Colonel Tolcott reported in July 1860 to the owners of the Sonora Exploring and Mining Company that the total yield in bullion from the start of operations to that date (from 614 tons hoisted, of which 327 tons had been treated or shipped and 287 tons were on hand) was $45,010.28, and he estimated the yield from the ore on hand should be $25,794.00. The yield of the Mowry Mine was probably a little larger, but as no real production was made until the fall of 1861, and as the mine was badly managed after its seizure in 1862, the gross yield was not very large. Some of the ore was shipped east, but most of it was treated at the mine, and the lead-silver pigs were shipped to Europe. Some of the lead was refined at the mine and the silver was cast into bars of $2 to $300 value and used as currency. It is to be noted in this connection that the capacity of the Arivaca works of the Cerro Colorado Mine was about 1 and a half tons a day. The capacity of the Arivaca works of the Cerro Colorado at Mowry was larger but the silver yield per tone of ore treated was comparatively small. Only one smelter run was made by Pumpelly at the Salero Mine, and this was disappointing.*

The Cahuabi or Picacho Mine was worked from 1862 to 1864 by Mexican lessees who realized a net profit, according to Browne, of about $50,000. The total yield of all mines from 1858 to 1864, including the Mowry which is outside of the area under consideration, was not over $300,000, including ore stolen by Mexican "gambucinos" from 1861 to 1863. Excluding the Mowry, the yield from the present Eastern Pima County from 1858 to 1864 was not over $200,000.

Early in 1861, when it became certain that the Civil War could not be averted, all the American troops were withdrawn. Absolute chaos and panic resulted. The Apaches immediately descended in force on the haciendas, and most of the Americans either precipitately fled to Yuma, accompanied the troops to El Paso and Santa Fe, N. M. or took up their residence behind the walls of Tucson. Lieutenant Mowry was the only one to stick to his guns. Mowry** describes the desolation as follows:

"Many lives were lost; property of all description was abandoned; crops to an enormous amount were left standing in the fields; never to be gathered. In my late journey from Tucson to Guaymas, I passed over one hundred and fifty miles of beautiful country, studded with ranches and farms, where at every step were found comfortable houses, outbuildings, fences and tilled fields, utterly abandoned and

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*Pumpelly, Raphael. op. cit.
**Mowry, Sylvester. op. cit.

tenantless. The mining interest suffered at the same time. Partly through the cowardice of agents and superintendents, partly through the fault of Eastern directors, the various silver mines in Central Arizona were temporarily abandoned, and I was left with a handful of men who were willing to share my fortunes, and, if fate so willed it, be the last Americans in the Territory to fall by the lance or arrow of the Apache."

After the arrival of the California Column in 1862 attempts again were made to bring the Apaches under control and to reopen the mines, but the destruction of the works and buildings was so complete that no real mining was done in Southern Arizona for about ten years. Chaos again resulted on the withdrawal of the California troops at the close of the Civil War.

It is interesting to analyze the conditions which influenced the type of the preCivil War mining venture in Southern Arizona. The most important factor was the excessive cost of transportation caused by the extreme isolation of the country. Only those ores could be worked which could be easily reduced or were so rich that they could bear transportation charges to outside reduction works. A second important factor was the peonage system in vogue in Mexico at that time. Labor was extremely cheap. By the establishment of company stores at the various haciendas, the peon laborers were kept continuously in debt, so that the actual cost to the companies was their food and clothing. Under these conditions, it paid to sort all ore to the extreme limit, and to treat only the richest at the imported expensive reduction works. Mines that could be worked at a profit under these conditions could not be worked under modern conditions of high labor. Of all the properties worked at this period, only five were later reopened and worked to any extent, and of these five, only one, the Ajo Mine, was profitable in later years. The other four, the Mowry, Empire, San Xavier, and Collins had checquered careers, but were on the whole, financial failures.

After the withdrawal of the California Column in 1864 Southeast Arizona again lapsed into the condition of utter isolation and lawlessness prevalent in 1854, with the additional handicap of extremely bitter Apache warfare. The Butterfield line was never reestablished. Transportation of passengers, goods, and the mail was by private conveyance. The most accessible entrance from the outside was by boat to Yuma (then known as Arizona City) and by road from Yuma to Tucson. Freight from San Francisco cost about thirty cents a pound, which absolutely prevented mining of anything but the richest gold and silver ores. The relations of the Apaches and Americans were strained to the limit. A state of war without quarter on either side existed, largely brought about by the unwise policy of the small force of American troops. All sense of honorable dealing between the troops and settlers and the Indians was abandoned. The worst kind of attrocities were perpetrated by American and Mexican renegades, which were retaliated with interest by the Apaches. At first the advantage lay with the Indians, as the trails to their strongholds in the mountains were not known by the Americans. To add to the confusion, the suspected Confederate sympathies of a large proportion of the settlers, encouraged carpet-bag rule by the early Territorial Government established at Prescott. In the first two Territorial legislatures Pima County was poorly represented, and it was not until the third assembly in 1866 that it was adequately represented. In 1867 the fourth legislature through the political ambitions of Governor Richard C. McCormick, voted to move the capitol from Prescott to Tucson, in exchange for the Pima County vote for McCormick as delegate to Congress. The first census of the Territory in 1866 showed a total population, exclusive of Indians, of 5,526, distributed as follows: Pima County 2,115, Yavapai County 1612, Yuma County 810, Mohave County 448, and Pah-Ute County, (most of which was later transferred to Nevada) 541.

In the years 1866 and 1867 the first surveys were made through the Territory for possible transcontinental railroad routes, and the two routes, one following the 35th and the second following the 32nd parallels of latitude, were found to be the most feasible. Legislation was introduced in Congress in 1867 authorizing the construction of the Atlantic and Pacific Railroad, following the northern route land grants were made, and public subscription of stock in the company was offered. The road was not completed, however, until 1882. After the removal of the capitol to Tucson, McCormick used all his influence in Congress to speed the construction of the second or southern route.

At this time the only commercial activity in Southeastern Arizona was in supplying contracts to the Military. The excessive costs of transportation encouraged agriculture and cattle raising to supply these contracts. This part of the Territory literally lived off the pay roll of the Army and federal employees. The moving of the capitol was therefore a big stimulus to Tucson and the surrounding country. No mining activity started at this time due to the Apaches against whom the feeling of bitterness constantly increased. By the year 1871 the trails to their mountain fortresses had nearly all been discovered. The advantage in the warfare from then on lay with the settlers and troops. In that year, 1871, Congress authorized a Peace Commission to negotiate terms with the Apaches in New Mexico and Arizona, headed by Vincent Colyer as Commissioner. Ample powers were given him to establish reservations, and to enlist the full support of the army in the enforcement of whatever terms were made. The local feeling in the two territories was extremely bitter. The majority of the population approved of nothing short of the utter extermination of the Indians and had little faith in the feasibility of keeping them within the bounds of reservations. Colyer in 1871 and 1872 made a thorough and impartial survey of the situation, established reservations and induced over half of the Apaches to enter them and to agree to remain there. Unfortunately two of the most able of the Apache chiefs, Cochise and Geronimo, refused to make peace, and they were able to keep their followers almost half of the tribes, on the war-path. The federal government also wisely chose a splendid type of man to head the Arizona division of the Army in General Crook, who replaced General Stoneman in 1871. A policy of diplomatic treaties with the different Indian chiefs was inaugurated by him, coupled with stern and rapid punishment of those breaking the pacts which were kept by the Americans for the first time since the trouble. A beginning of law and order was made in 1872, resulting in the first renewal of prospecting in Southeastern Arizona since 1860. The old silver properties in the Santa Rita, Patagonia, and Cerro Colorado Mountains were relocated, but little work was done. The first new discovery of note in South Central Arizona was that of the Silver King

Mine, near the present town of Superior, in 1872. This was followed in 1873 by the discovery of the rich gold placers of Greaterville south of Tucson in the Santa Rita Mountains.

Late History

The result of the discovery of these two new deposits and the reports of high grade copper ore ar various points greatly speeded the interest of the Southern Pacific Company of California in its projected construction of a railroad to connect Los Angeles with El Paso. By 1873 the line was completed into Arizona City (Yuma) and by 1876 it had been extended to Casa Grande. Right-of-way difficulties prevented further building and for four years Casa Grande was the eastern terminus of the road. Prospecting was still further increased, and in the next three years rich copper deposits were located at Bisbee, Silver Bell, Helvetia, Twin Buttes and Globe, the bonanza silver deposits of Tombstone, Hermosa and Total Wreck were discovered and the old Olive Camp deposits were relocated. In 1877 the surrender of Geronimo and the death of Cochise marked the end of serious Indian warfare, although complete peace was not established until about 1884.

The Southern Pacific completed construction into Tucson in 1880, and by the end of 1881 the line was completed into El Paso. For the next four years a mining boom took place in Southern Arizona chiefly in the start of exploitation of the copper deposits of Silver Bell, Helvetia, Rosemont and Twin Buttes in what is now Pima County, in the development of the deposits at Bisbee in what is now Cochise County, and at Globe in what is now Gila County. During the boom the silver deposits of Quijotoa were discovered and the Total Wreck and San Savier Mines were equipped and actively worked. Copper was then commanding a price of from 16 1/2 to 21 1/2 cents a pound, and silver was worth $1.13 an ounce. A good start was made in all the camps, smelters and mills were erected, and a bright future was apparently in store. The end came in 1884 in the financial depression of that year. Copper started to drop, and by the end of the year had reached a low of 10 cents. The average price in 1885 was 10.8 cents, and all the copper mines in Pima County closed down. The old silver deposits did not prove economical under modern high labor conditions, and the new bonanzas at Quijotoa and Total Wreck were rapidly bottomed. By 1886 mining in Pima County was again nearly at a standstill. The lead-silver deposits of the Sierrita Mountains at Olive Camp were worked in a small way by lessees, and the Greaterville placers were active on a much reduced scale. The demonetization of silver in 1893 still further depressed the situation, and almost all mining ceased in Pima County.

It was not until 1894 that the rapidly expanding use of electric lighting, telephone, telegraph and electric power lines began to be felt in an increased demand for copper. Due to the depression of 1893 prices did not immediately respond, but a feeling of confidence in the future of copper resulted in a general speeding up of the older mines and in an active search for new ores. The first camps to respond in Pima County were Helvetia and Rosemont in the Santa Rita Mountains south of Tucson, and the Silverbell deposits northwest. These were followed soon after by the exploitation of the Sierrita deposits at Azurita (Mineral Hill) and Twin Buttes, and the Camp Apache deposits in the Catalinas.

All of these deposits had reached the production stage by the beginning of the twentieth century except the Catalina Mountain deposits, which were never able to overcome their handicap of high transportation costs. They all furnished their quotas of copper during the World War but were practically exhausted by the end of the War.

Eastern Pima County, by the end of 1929, found itself without ore deposits of any size except, those in the Catalina Mountains possibly, and these will have to remain in reserve until such a time as the price of copper will justify their exploitation. The eastern end of the county - that is, all of the county with the exception of Ajo and Gunsight - has produced up to the end of 1929 approximately 157,000,000 pounds of copper, 26,400,000 pounds of lead, 3,000,000 pounds of zinc, 3,500,000 ounces of silver and 48,000 ounces of gold with a gross value of approximately $30,900,000.

In the following paragraphs historical sketches of the individual camps are given:

Helvetia-Rosemont

It is probable that the copper outcrops of these two districts, on either side of the main ridge of the Santa Rita Mountains at their northern end, were discovered at a very early date. No mention, however, is made of them by the early explorers before the Civil War. It is highly probable that, if found, they would not have been deemed of sufficient importance to note, as only those copper ores high in precious metal value were possible to exploit under the conditions then extant.

The first locations in the district were made in the late seventies after it had become certain that the Southern Pacific Railroad was to be completed. Locations were made on the principal outcrops at both Helvetia and Rosemont.

opened. A townsite was established, and considerable work was done. A small portable concentrating plant was installed in 1919, and a small production was made.

The Ramsdell Lead-Silver Mine, south of the Banner, was acquired in 1926 by Tucson interests. The mine was developed by open cut and shaft during the next three years, and a small gravity concentration plant was installed in 1929, and a few shipments of lead concentrates were made. The district labors under transportation difficulties, as ore has to be hauled around the range to Tucson, a distance of about forty miles.

The silver-lead area of the camp, centered at Olive Camp, remained dormant in the years following the World War until 1926, when the Helmet Peak Mining Company was organized to develop a deposit of low grade complex ore at Olive Camp. This company did considerable development work for three years, but never reached the production stage.

The Sierrita Mountains deposits have made a noteworthy contribution to the wealth of Eastern Pima County. The total has been approximately 36,000,000 pounds of copper, at least 18,000,000 pounds of lead, 2,300,000 pounds of zinc, and at least 1,400,000 ounces of silver with a gross value of at least $9,000,000.

Empire Mountains.

The lead-silver deposits of this range of hills northeast of the Santa Rita Mountains were not discovered until after the Civil War. The first location was made in 1879 by John Dillon on the Richmond lode. The following year, during the construction of the railroad from Tucson into Benson, the claim was relocated by Vail and Harvey as the Total Wreck.

The surface ore was very rich and extensive activity was reported throughout 1880. Operations were delayed in the following year by a lawsuit to determine the title to the claim. After the settlement of the suit in favor of N. R. Vail, the Empire Mining and Smelting Company was organized to develop and equip the mine. By February 1883 the plant was completed. The mine had been opened up by a 360-foot inclined shaft with levels at 50-foot intervals. A large hoist was installed, and a 20-stamp mill was built, six hundred feet from the mine, and connected to it by an aerial tramway. An ample water supply was issued by pumping from Cienega Creek through a six-inch pipe line 14,000 feet long against a head of 560 feet. The ore averaged $65 a ton in silver. Operations were extensive for the times as evidenced by the townsite which was described in the Tucson Weekly Star as being composed of five saloons, three general stores, a butcher shop, and a shoemaker's shop, and from eight to ten Chinese laundries. The mine was operated to the end of 1884 under the supervision of John O. Daugherty with a production of about a half a million dollars in silver bullion. After its close, it was bought by the original owners, Vail and Harvey, at a delinquent tax sale.

For twenty years after the close of the Total Wreck, the camp remained virtually dormant other than for intermittent small shipments from the Total Wreck and other mines from assessment work. In the early years of the World War, the Arizona Rare Metals Company was organized in Tucson to mine wulfenite lead molybdate for delivery to Eastern steel manufacturers. The Total Wreck Mine was leased by this company in 1917 and a mill was built to make wulfenite concentrates. Production continued to the end of 1918, when the lease was surrendered.

The last large operation at the mine was in 1926 when the old mill tailing pile was leased and over 1000 tons of low grade material was shipped as flux.

In the first years of the district's development in the late seventies, lead-silver deposits were discovered in the mountains fifteen miles southwest of the Total Wreck. As these deposits were comparatively low in silver content, little work was done on them at that time. Production did not start until the high metal prices of the War years. Small shipments were made in 1915 and 1916 from the Andrade, Copper Point, Verde Queen, Jerome no. 2, and State of Maine, and in 1917 the Forty Nine Mine was quite extensively developed, and ore was shipped by the owner steadily to El Paso until June 1924. It was then bonded to the St. Louis Smelting and Refining Company. This company continued shipments to the end of the year, and surrendered the option.

The Lone Mountain Mine adjoining the Forty Nine Mine was opened up by Hilton, the owner, 1924 and he shipped high grade lead carbonate ore for three years when in 1927 it was optioned to the Calumet and Arizona Mining Company of Bisbee. This company established a camp at the mine and in the next two years did a considerable amount of development work on the Lone Mountain and adjoining claims, but surrendered the option at the end of the campaign.

The camp continued to ship ore to various reduction works until the depression of 1931 when all work ceased.

The production from the Empire Mountains from the start of operations in 1880 to the end of 1929 has been approximately $1,000,000, chiefly in silver and lead. Details are shown in the Appendix.

gold was discovered at the north end of the mountains. The richest deposit was found in Horseshoe basin. The production from this field is un-recorded but was probably not very great as all the gold was recovered by dry methods from gravels, most of which were consolidated and required breaking to free the gold. Blake reported to the Governor of the Territory in 1899 that the field was then being worked by Papagoes who realized between $6,000 and $7,000 a year. There was reported as produced from the Quijotoa placers a total of about $29,000 from 1903 to 1912, but no production has been reported since. The best ground in Horseshoe Basin is now held by a company who keep a caretaker on the property. The total production from 1883 to 1912 probably has been not over $180,000.

Except for intermittent placer production by the Indians in various dry arroyos, little work was done in the Papago country until 1922, when a vein carrying copper and silver values in the Cababi Hills northwest of Sells was located as the Little Mary. The Como Pima Mining Company was organized by Carl Erichson to exploit the deposit. A few small shipments were made from 1923 to 1929, but the values proved superficial and the work was discontinued.

The production from the Papago country from 1860 to 1929 inclusive has been approximately $468,000 mostly in gold and silver. Details are shown in the Appendix.

Greaterville

The history of this district in the north central part of the Santa Rita Mountains is almost wholly that of the gold placers. Some lode mining has been done but comparatively little production has resulted.

The placers were discovered in 1873 by David Burroughs and Arden. They were known at first as the "Smith diggings." Some large nuggets were found, and the field held the center of attraction for several years after its discovery. For three years the field was worked by several hundred men, but by 1876 the best ground had been exhausted. P. J. Coyne reported to Burchard, Director of the Mint in 1883, that about $250,000 was the approximate yield from 1873 to 1875, but that in 1883 the yearly yield had dropped from 18,000 to $12,000. Coyne's estimate of the total produced through 1884 was $500,000. Small scale work by individuals continued until 1900 when a company was organized by Stetson of San Jose, California, to work the ground of Kentucky Gulch on a large scale by hydraulic methods. Wells were sunk but insufficient water was developed. Stetson continued his investigations of the field, and in 1904 he and McAvery of San Jose reorganized the company as the Santa Rita Water and Mining Company to work the same ground. Impounding dams were built in Gardner and South Canyons, and several miles of pipe line were laid looking towards hydraulic operations. The work was never consummated due to the death of both Stetson and McAvery in 1905.

Since 1905 several companies have attempted to work different parts of the field by various methods. One company tried a steam shovel, two companies used drag-lines, and one company installed a dredge. All were failures due to the development of insufficient water and to poor sampling, of the ground.

A small production of from several hundred dollars up to over a thousand dollars a year continues to be made by Mexican and American miners who sink shallow pits, gopher the pay gravels, and save the gold in rockers.

After the discovery of the placers, a search was made for lodes. Several were located in the early years, more notably the Anderson or Conglomerate, Enzenberg or Mountain King, and the St. Louis. Very little production was made from them. Some rich pockets were mined, but principal work was done at the Conglomerate Mine two miles southwest of Greaterville. This mine is to the south of the placer area, and the ore occurs as pockets of lead, silver-gold ore in limestone and adjacent granite. The property was acquired in 1923 by Reese of Bisbee, who developed the mine for a year and in 1925 shipped over $8,000 of rich lead-silver ore. The mine was bonded to the Midland Copper Company of Twin Buttes in 1926, who deepened the shaft, drove several hundred feet of drifts, and relinquished the bond at the end of the work. A small tonnage was shipped by Reese in 1927, and at the end of the year the mine was bonded to the Phelps Dodge Corporation. This company shipped a small tonnage of ore in 1928, and relinquished the bond. The mine was then turned over to lessees who continued to ship ore in the succeeding two years.

During the high metal prices of 1929, the St. Louis Mine, which had been slowly developed for years, was reopened and a small tonnage of copper-lead ore was shipped to the Phelps Dodge Lead Smelter at Douglas. The Greaterville district has produced approximately $710,000 from the discovery of the placers in 1873 through 1929. Of this total, approximately $680,000 has been derived from the placers. Details are shown in the Appendix.

Tucson Mountains

This range to the west of Tucson contains numerous small deposits of various metals, which were worked in a crude way by the Spaniards

CHAPTER 14

SANTA CRUZ COUNTY

Chapter 13 which dealt with the history of mining in Eastern Pima County, covered the subject in that county prior to the Civil War, and included, in the account, the activities in that part of the original county separated from Pima County in 1899 as Santa Cruz County. The later history of Pima County, in the same chapter, covered only that part of the county included within the present boundary of Pima County. In this chapter, a general review of the late history of Santa Cruz County is given, followed by detailed accounts of the more important centers.

After the withdrawal of the garrisons from Arizona at the start of the Civil War, only one camp, that of Mowry, was able successfully to withstand the pressure from the Apaches and Mexican renegades. The situation of the camp was ideal for defence, and it had been well fortified and equipped prior to the outbreak of the War. The owner of the property, Sylvester Mowry, remained at the mine. Enough silver bullion was produced to pay for the labor and local supplies necessary. The scale of operations was large for the day, but small as compared with modern standards. Mowry continued to work the mine until the arrival of the California Column under the command of General Carleton in 1862. For a short period before Carleton's arrival, Southern Arizona had been partly occupied by Texas Confederates, and Mowry was suspected as a Southern sympathizer, and was accused of having furnished lead from the mine for Confederate bullets. He was arrested in 1862 and the mine was confiscated. Mowry was sent to Fort Yuma, where he remained six months but was then liberated without trial. The mine was operated by agents of Carleton until the withdrawal of the California Column in 1864. It was then returned to Mowry, but it had been so badly managed that it had become unprofitable without considerable further expenditures for reequipment. It was not reopened, and after a fruitless campaign by Mowry to interest capital in the venture, he died in London in 1871.

During the lawless years following the withdrawal of the California Column and up to the dawn of peace with the Apaches inaugurated by Vincent Colyer in 1872, the mines in what is now Santa Cruz County were completely abandoned.

The year following the work of the Peace Commission, early in 1873, Raymond* reported that the Mowry Mine was relocated by jumpers and that some work was done. Capital was supplied by merchants and army officers of Tucson. In the same year he reported that the Oro Blanco gold mine west of Nogales was located by Leatherwood, Hopkins, Hewitt and Marsh of Tucson, and that the mine was worked by lessees. By 1875, the Trench and Salero Mines had been relocated in the Santa Rita and Patagonia Mountains, and the Ostrich and Yellow Jacket Gold Mines north of the Oro Blanco Mine.

Little real work was done however at any of the mines until the completion of the Southern Pacific Railroad into Casa Grande in 1876. The following year the bonanza Hermosa Silver Mine was discovered in the Patagonia Mountains. This mine was purchased the

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*U. S. Treasury Dept. Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains. v. 7, 1874.

year after location by a New York company known as the Hermosa Mining Company. A large stamp mill was built and in less than two years about a million dollars in silver bullion was produced. The railroad had by then been completed to Tucson and in 1881 connections were made into El Paso.

The erection in 1882 of the Benson smelter very much stimulated the development of lead-silver mines in the Patagonia Mountains. During its short life from 1882 to 1886, the Flux, Hardshell, Mowry, Pride of the West or Washington, New York, Kansas, Blue Nose, and other smaller properties shipped considerable ore. On its close in 1886 nearly all production ceased.

In the Oro Blanco Mountains west of Nogales, several new discoveries were made in 1880, more notably the Montana Ledge. Several mills were built and were run when water was available. By 1887 the better ore from the oxidized zone had been largely exhausted, and nearly all activity ceased. The gold output from the discovery in 1873 to the end of 1886 is incompletely recorded. It was probably not over $700,000.

A spectacular venture in the Patagonia Mountains created considerable stir in 1880. The Holland Mine and adjacent claims were purchased by the Hon. H. J. Luttrell for sixty thousand dollars, and the Holland Smelting and Mining Company was organized. A smelter was built, but little production was made. The finances of the company were grossly mismanaged, and by July 1881 all work ceased.

The Patagonia and Santa Rita Mountain districts were much stimulated on the completion of the Mexico and Arizona Railroad from Guaymas, Mexico to Fairbank in 1884, which allowed the lead-silver mines to ship their ore, at first to the Benson smelter and after its close, to various reduction works in Texas and New Mexico.

Several small smelters were built at or near Patagonia at various periods. The first was built by the Nogales and Sonora Mining and Smelting Company near Nogales in 1886 to treat ore from Mexico. This venture lasted about two years. The second was built at Crittenden four miles north of Patagonia in 1888. Its life was less than a year. A third attempt was made in 1897 at Patagonia, but it also was not a financial success, and was short-lived.

The demonetization of silver in 1893 had a profound effect on the silver mines of Santa Cruz County as it did throughout the world. Its depressing effect was partly offset in the Patagonia and Santa Rita Mountains by the improved base-metal metallurgy and the consequent lowering of smelter rates, and concentration costs. The lead-silver mines have been worked intermittently since 1893 with varying success, more notably the Flux, Hardshell, Mowry, Holland, Belmont and World's Fair.

The largest operations in the area did not start however until the revival of copper prices in the late nineties allowed for the marketing of copper as an important bi-product or principal constituent of some of the mines. The first of these ventures was the Washington or Pride of the West Mine. This mine in the Patagonia Mountains was purchased early in 1899 by A. R. Wilfley, the inventor of the Wilfley concentrating table, and his associates in Denver. The ore, a complex mixture of the sulphides of copper, zinc, lead and iron in a heavy gangue of garnet, quartz and calcite, had been worked in the early years for the silver associated with the lead. Wilfley erected a concentration plant to separate the three valuable base-metal sulphides and shipped the three concentrates separately to suitable reduction plants. The attempt was a success metallurgically and the mine and plant were operated a little over three years until a change in the character of the ore in depth forced suspension. The plant was purchased two years later by the Duquesne Mining and Reduction Company. This company, financed by the Westinghouse Electrical Company, had been gradually acquiring ground in the district since the eighties. Considerable development work had been done on several of the mines acquired, and some testing of the complex ores had been done, but little real production had been made. After the purchase of the reduction plant of the Pride of the West, the plant was used at first as a test plant and later as the main reduction plant for the ores from the Bonanza and Pride of the West Mines. Large-scale work commenced in 1913 and continued to the end of 1918 when the mines and plant were closed and the plant was dismantled and sold.

Santa Cruz County has produced only one major copper mine. This mine, the Three R Mine in the Patagonia Mountains was discovered in 1897 by R. R. Richardson, a pioneer operator of the district. Little work was done on the property until the organization of the Three R syndicate in 1909 by Richardson and his associates. In the succeeding three years the mine was extensively developed by tunnels and connecting raises and a large body of high grade chalcocite ore was blocked out. The mine was then bonded to N. L. Amster of Boston. In the succeeding two years over 30,000 tons of ore were shipped after which the bond was relinquished. The property was idle during the first year of the World War in 1915.

It was bonded the following year to the Harrison Brothers of Texas. A concentrator was erected at the mine, the water supply for which was furnished by a pumping plant on the Sonoita River. After two years of operation during which both concentrates and first-class ore were shipped, the bond was relinquished. The mine was sold at the end of 1919 to the Magma Copper Company. This company further developed the mine for a year, then closed it down and offered it for sale. The mine remained idle until the end of 1928 when it sold to the Three R Mines Company. This company, in 1929, reopened the property and shipped a small tonnage of ore from old pillars. Considerable development work was also done and a small flotation concentrator was built. After its completion in 1930 a small output of concentrates was made after which operations ceased due to the rapid fall in the price of copper.

A third copper venture, the Santo Nino, was not developed to any extent until 1926. It has produced a fair tonnage of copper sulphides and a small tonnage of high grade associated molybdenite.

In the Oro Blanco Mountains the gold mines, after the early period of activity, remained dormant until 1893 when the close of the silver mines of the state turned the attention of miners again to gold. Several of the old mines were reopened and new mills using the cyanide process were built. The most successful of these ventures were the Montana, Austerlitz, Yellow Jacket and Old Glory Mines. The boom in copper mining in 1902 finally attracted capital from these low grade gold properties, and the camp again lapsed into idleness.

At several of the larger veins in the Oro Blanco Mountains, the gold ore changes at shallow depth to zinc-lead-silver sulphides.

The largest of the deposits of this type is the Montana. The first attempt to treat the base ore was made in 1917 during the high zinc market of that year. Little work was done however until the mine was purchased in 1927 by the Eagle Picher Lead Company of Missouri. After assuring an ample supply of ore by development work, a large concentrator was constructed, and production of lead and zinc concentrates commenced and continued until the slump in metal prices in 1930.

The total production of the mines in what is now Santa Cruz County has been about 33,600,000 pounds of copper, 51,400,000 pounds of lead, 13,900,000 pounds of zinc, 5,000,000 ounces of silver, 60,000 ounces of gold, and 500,000 pounds of molybdenum sulphide with a gross value of about $16,000,000.

In the following paragraphs short sketches are given of the separate mining centers.

Patagonia Mountains. This range, the northern extension of the Sierra Santo Cruz of Mexico, is separated from the Santa Rita Mountains to the north by the valley of the Sonoita River.

Prior to the occupation of southern Arizona after the Gadsden Purchase by the United States in 1853, the principal silver deposits of this range of mountains had been found by Spanish and Mexican prospectors, chiefly the former. A start had been made during the Spanish regime at exploitation, but on the withdrawal of effective garrisons after the Mexican War of Independence in 1828, the Apaches soon dominated the mountains to such an extent that all mining ceased. The American prospector in 1853 found evidence of this early work in numerous shallow partly-caved shafts, tunnels and stopes, whose production and histories had been nearly forgotten since their abandonment for over a generation.

Mowry Mine. The first important deposit to be rediscovered and located by Americans was the Patagonia Mine, on the eastern slopes of the range, five miles north of the international boundary. The mine was first located, or purchased from Mexican owners in the fall of 1858 by Colonel J. W. Douglass, Captain R. S. Ewell, Lieutenant J. N. Moore, Mr. Randal, Mr. Lord and Mr. Doss, most of whom were connected with the United States Army.

The old workings were reopened and conditioned and several crude furnaces were built for smelting the ore. Due to lack of capital, little real work was done, and in 1858 and 1859 two of the owners, Messrs. Lord and Doss, sold their interest to Mr. Brevoort, who assumed the management. He was also handicapped by lack of funds, and the venture under his management was a financial failure. After a year of disheartening work, the other owners sold their interest to Colonel H. T. Titus. In the spring of 1860 these two sold the mine to Lieutenant Sylvester Mowry, a wealthy retired officer of the United States Army who had entered the new territory three years before with the intent of investing his capital in mining. The price paid for the property was $25,000 including all equipment standing. Lieutenant Mowry changed the name of the mine to the Mowry and immediately sent for F. Biertu, a noted mining engineer and metallurgist of the period to design suitable smelting works for the property. He advised the expenditure of about $60,000 in new plant. The outbreak of the Civil War in the year following and the consequent withdrawal of all the troops may have prevented the complete consummation of the plans, as it became necessary to fortify the camp against Apaches and Mexican outlaws. Work, however, did not

not cease as at all other mines in the Territory, and Mowry himself remained at the property. Production on what was then considered a large scale was started. The ore consisted of silver-bearing galena in a basic gangue. The lead bars produced were at first shipped abroad for refining, only a certain number being refined at the plant, for the purpose of supplying silver to be used as currency to meet the payroll and local expenses. After the start of the Civil War more refining was done locally. Texas Confederate troops penetrated in their drive for California as far as Tucson in 1861, but withdrew early in 1862 on the advance of the California Column under General Carleton. On Carleton's arrival, he suspected Mowry of Southern sympathy, accused him of having supplied lead from the mine to the Confederates, arrested him, and in June confiscated the mine. Mowry was sent to Fort Yuma, but was never brought to trial and, after six months incarceration, was released. The mine, however, was not restored and was operated by Carleton's agent during the remainder of the War, and was not returned until after the withdrawal of the California troops in 1864. The administration of the mine during this time was bad. All blocked ore was mined, supplies were stolen and the reduction works were worn out. On return of the mine to Mowry, successful operation necessitated the expenditure of large sums in further development equipment and remodeled works. Mowry's resources were gone, and in the succeeding seven years he attempted unsuccessfully to raise the necessary capital, and died in London, a disappointed man in 1871. The mine in the meanwhile was completely abandoned. The production of the property in silver in the first period of operation from 1860 to 1864 is unrecorded. Mowry*

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*Mowry, Sylvester, Arizona and Sonora, Harper Brothers, N. Y., Third Edition, 1864.

claimed that with the twelve crude blast furnaces installed in 1860, followed by cupelling, he was able to make about $4,500 in silver a week or 3,3360 ounces at the prevailing price of $1.34. If it is assumed that the property was worked at half capacity from 1860 to 1862 and quarter capacity from 1862 to 1864, the total production was about 250,000 ounces of silver. As the ore treated was carefully sorted galena, even with the crude methods used, about twelve pounds of lead were obtained in the form of litharge for each ounce of silver, making a total production of about 3,000,000 pounds of lead. With silver at $1.34 an ounce and lead at five cents a pound, the gross production was probably about $335,000 in silver and $150,000 in lead, a total of about $485,000. Prior to the confiscation of the mine, the port of entry for supplies was Guaymas, Mexico, to which connections were made through Magdalena by a 280-mile wagonroad. Freight to San Francisco for incoming goods was five cents a pound in 1860 and had been reduced in 1862 to less than four cents. Outgoing ore or bullion shipments from the mine took a rate of two cents a pound. Peon labor at the mine cost about fifty cents a day, and was paid chiefly in goods supplied by the large company store. About seventy men were employed, and the camp was the trading center for most of the surrounding territory on both sides of the border. After the withdrawal of Carleton's troops in 1864, and up to the first partial truce with the Apaches in 1872, practically no mining was done in the Patagonia Mountains. On the dawn of peace with the Apaches in 1872, prospectors again entered from Tucson, grub-staked by local merchants and army officers. The Mowry was relocated by claim jumpers, and was worked in a small way by Dr. Bennett. Its inaccessibility proved too great, however, and aside from a little ore shipped to the Silver King to help smelt the high silver ore of that bonanza, little production was made.

After the completion of the railroad through Patagonia, in 1883, the accessibility of most of the mines was greatly increased. The Mowry Mine, however, was still fourteen miles from rail connections. Little was done until it passed into the hands of Silverberg and Steinfeld of Tucson who reopened it in 1890 with the object of developing the property for slae. Several hundred tons of ore were shipped in the course of development work over a period of three years, after which the mine was again closed, and remained idle until 1900 when Steinfeld reopened the mine and erected a 100-ton concentrator. Daily shipments of ore and concentrates were made for a short period. The mine was again closed in 1901 and remained closed until 1904, when it was sold to a company known as the Mowry Mines Company.

The mine was reopened and extensively developed, and in 1905 a 100-ton steel blast furnace was erected. The company acquired the Alto Mine in the Salero district in the Santa Rita Mountains, and in 1906 a reorganization was effected as the Santa Cruz Mines and Smelter Company to operate both properties. A railroad was planned to the Mowry. The venture did not long survive the business depression at the end of 1907. Both mines were closed at that time, and the Mowry Mine eventually passed into the hands of A. J. Hazeltine of Warren, Pennsylvania. The last work done before closing was to sink the shaft to the 500-foot level. After closing the pumps were pulled and the deeper workings were allowed to flood.

No further work was done for eleven years until, in 1918, the owner reopened the workings above the water level and did several thousand feet of development work. The old stopes were reentered and small shipments were made partly from new ore and partly from sorting old stope fills. The working shaft caved in 1928, since which time no further work has been done. The total production of the mine has been about $600,000, largely estimated.

Washington Camp. Four miles south of Mowry a second large center of mineralization, known now as Washington Camp, was partly exploited by the Spaniards prior to the Mexican War of Independence in 1828. As at the Mowry only superficial work was done, and this camp had been abandoned for twenty-five years when the United States took over the territory in 1853. The principal mine worked by the Spaniaŝds for its silver content was known as the Montezuma. It was relocated or purchased prior to the Civil War by Thomas Gardner and Hopkins about the same time that the Mowry Mine was revived. A second adjoining mine was relocatéd as the Empire. Little was done at the time and the properties were abandoned at the outbreak of the Civil War in 1861, when Hopkins and Gardner fled to Tucson.

The district was completely abandoned after the Civil War until a partial peace with the Apaches was effected in 1872 by the Peace Commission under Vincent Colyer. Gardner and Hopkins returned to their holdings, and a third rich silver-lead mine was located by W. C. Davis near the present camp of Washington. The rich lead-silver outcrop of the deposit was developed by Davis, and by the fall of 1880 over 1,600 feet of work had been done, and 500 tons of ore had been extracted. The property was then under the management of James Finley. A small furnace was built in the San Rafael Valley to the east of the mine in the following year, which was operated intermittently for about a year. The total ore treated is unrecorded

The ore body proved to be superficial and was soon exhausted. The grade reported in the local press was 40 percent lead, 10 percent iron and 40 ounces of silver. It is doubtful if more than the 500 tons reported on the dumps in 1880 was smelted.

A second rich silver-lead deposit was discovered adjoining the old Montezuma and Empire Mine located prior to the Civil War by Gardner and Hopkins. It was located as the Holland. A third mine, the Belmont, was also located and partly developed bv Thomas Yerkes and H. D. Bacon.

In 1879 a promoter styling himself the Hon. H. J. Luttrell entered the district. He bonded the Holland for $60,000 and organized the Holland Smelting and Mining Company. The mine was purchased, and a smelter known as the Holland smelter was erected south of the mine. Capital was to have been raised by sale of stock set aside for the purpose. After about two years of work, the venture collapsed financially.

A second venture was launched by Luttrell in the fall of 1880 involving the Belmont and San Antonio Mines and a large adjoining group of ten claims known as the Washington Pool, owned by Allen Longbottom, Davis, Lowell, Baker, Hensley, Wait and Ayers, all pioneers of the district. This venture never got beyond the promotion stage.

On the collapse of the Holland Company in 1881, the district was almost abandoned for two years until, in January 1884, A. B. Elder purchased the Holland Mine and Smelter. The smelter was reconditioned and enlarged and was blown in April of that year as the La Noria Smelter. After a run of about eight months the plant and mine were again closed. The first month's run was 797 bars of

101 pounds each of 95 percent lead, 210 ounces of silver and 1 1/16 ounces of gold, according to a report of the Tucson Star of May 22nd, 1884. The Mint Report of 1884 described the smelter as a single furnace of fourteen tons capacity which treated ten tons a day, making three tons of bullion yielding 220 ounces of silver and 1 1/16 ounces of gold from Holland ore of 25 percent lead, 36 ounces of silver. At this rate about 150,000 ounces of silver, 750 ounces of gold and 1,300,000 pounds of lead were produced during the year.

On the completion of the New Mexico and Arizona Railroad through Patagonia in 1883, considerable ore was shipped from various properties to the Benson Smelter, and, after its close, to other reduction works. The district however did not realize in full the benefits of the railroad as the haul was still about seventeen miles to the nearest rail point at Crittenden. The Tucson Star reported that in 1885, 1353 1/2 tons of ore were shipped from Crittenden, part of which came from the Washington district and a part from Harshaw.

With the exception of the Holland and Davis Mines, the other deposits, at shallow depths, changed into massive copper-lead-zinc sulphides associated with garnet and silico. The most valuable of the base sulphides in the ore is chalcoprite. The possibilities of the mines as copper deposits were first realized in the late eighties by George Westinghouse of the Westinghouse Electrical Company. The first properties purchased by him in 1889 were the W. C. Davis Mine known as the Pocahontas, the Bonanza, the Pluto, and the Illinois. The oxidized ore to a depth of about seventy feet was developed by Westinghouse for two years, and a little ore was shipped. Base sulphides were encountered below the oxidized ore.

Very little work was done in the camp until the revival of the copper market in the late nineties. The Westinghouse Company in 1896 leased a small furnace at El Paso and shipped about 2,000 tons of lead-zinc ore for treatment. In the same year the Washington Mine, the oxidized ore from which had been worked by the Benson Smelter during its life from 1882 to 1886, was optioned to Senator W. A. Clark of Montana. The Giroux shaft was sunk to a depth of about 150 feet and a considerable tonnage of complex ore was developed, after which the option was surrendered.

In the same year the Holland Mine was purchased for $15,000 by F. L. Bartlett of Denver. A concentrator was built to treat the lower-level complex ore. Huntington Mills followed by Wilfley tables recovered lead and zinc concentrates, both of which were shipped, the latter to Canon City, Colorado for manufacture of zinc oxide. Work ceased after a run of about a year.

In the following year the Pride of the West, formerly known as the Washington Mine, was leased by N. H. Chapin, one of the owners, and about 8000 tons of sorted copper sulphide and oxide ore was shipped and the work of Senator Clark was continued from the Giroux shaft. This work blocked out 200,000 tons of complex sulphide ore. The mine was then sold in April 1899 to C. R. Wilfley of Denver, the inventor of the Wilfley Concentrating Table. Wilfley and his associates organized the Pride of the West Mining and Smelting Company and continued to ship high grade copper ore for a period of about three months, until the exhaustion of the shoot. The company then started the construction of a 100-ton concentrator which was completed towards the end of the year. Many experiments were made and by June 1900 the mill consisted of crusher, stamps and Wilfley tables making a 50 percent lead concentrate. A roaster was installed to roast the tailing from the Wilfleys and a Weatherill Magnetic Concentrator was installed to separate the copper-iron from the zinc roasted product. Zinc concentrates of 56 percent zinc and copper concentrates of 24 percent copper were produced. The zinc was shipped to Europe and the copper to the Copper Queen Smelter in Bisbee. By April 1901 the prices had been changed. All the crushed ore was roasted and passed over the magnetic concentrators which produced a copper-iron product and a zinc-lead-copper product. The latter was then treated on Wilfleys and a lead-silver concentrate was made, the blends - a garnet-quartz-calcite product, - being rejected as tailing. A reverberatory furnace was installed to smelt the copper concentrate to a 50 percent matte. Eight tons of matte and five tons of lead concentrates were produced daily. The crude ore treated contained 17.33 percent chalcopyrite, 8.80 percent pyrite, 19.53 percent zinc blende, 4.83 percent galena, 34.68 percent garnet, 18.30 percent quartz and 3.53 percent calcite. The plant was built fourteen hundred feet from the mine and was connected to it by a switch-back, three-rail gravity tram laid on a 15 percent grade. The reverberatory furnace was operated only for a short time, after which the copper concentrates were shipped to Silver City and other reduction works. In 1902 the plant was remodeled and enlarged, after which the mine was closed at the end of the year, due to the change of the higher grade copper ore in depth to an ore with high zinc content.

The camp remained nearly deserted for three years when, in 1906, the Pride of the West plant was purchased by the Westinghouse Company. Further mining property was purchased, the principal mines being the

Holland, Belmont and Washington Pool group of ten claims. The mill was run intermittently to experiment with the treatment of the company's Bonanza Mine base ore.

Operations in the district were much facilitated in 1913 by the construction by the Southern Pacific Railroad of the connecting line from Nogales to Naco. The haul to the nearest rail point on this line at Zorilla, Mexico, from Washington is about eight miles, as against a seventeen-mile adverse grade haul to Patagonia.

After four years of intermittent experimentation, the Westinghouse interests, organized as the Duquesne Mining and Reduction Company, started to equip the property for large-scale production. The principal mine, the Bonanza, was developed to a depth of 650 feet and connected with the mill at Washington by a 3000-foot aerial rope tramway. A large Diesel power plant was erected and comfortable camp buildings were constructed at Washington and at the Bonanza Mine, known as Duquesne Camp. Production started in August 1912. Three products were made: copper, lead, and zinc concentrates, hauled at first to Patagonia and later to Zorilla and from there shipped in bond through Mexico to the port of Naco. The greater part of the ore mineral was handtreated at the plant. Most of the ore came from the Bonanza. The Pride of the West was optioned from the owners and reopened, and some ore was also mined from the Belmont, Holland, Kansas, New York and other mines owned by the company. The plant was run until early in 1919, when it was closed, and the mines were turned over to lessees. In the succeeding three years there was shipped a considerable tonnage of sorted lead and copper ore on lease account until the depression in metal prices at the end of 1920. Since then small intermittent work has been done at various mines.

The plant was dismantled and sold, and the property was offered for sale, and in 1926 was purchased by Bracy Curtis and Associates of Nogales.

The total gross production of the Duquesne Mining and Reduction Company from August 1912 to the end of 1920 was approximately $6,500,000 in copper, lead, zinc, silver and gold.

The only other large producing mine in the vicinity is the Santo Niño, 2 1/4 miles south of Duquesne. This deposit is geologically quite different from the mines of the Washington Camp. It is entirely within the large monzonite mass forming the back-bone of the range. The ore is a mixture of massive copper and iron sulphide associated with smaller amounts of molybdenite. It did not outcrop as carbonate or oxide ore, and for that reason was not discovered until recent years.

The mine was located in 1908 as the Benton by Dennis Coughlin of Duquesne. In the following year a tunnel was driven to crosscut the ledge at depth, and a zone fifty feet wide was cut of low grade disseminated purite-chalcopyrite ore together with some molybdenite. Little further work was done until the high copper market of 1917 when it was relocated as the Santo Niño Mine and was sold in 1919 to the Southern Copper Company, a subsidiary of the General Development Company. The company further developed the zone to the end of 1920, and again in 1922 and 1923. A small tonnage of ore was shipped, and in 1926 the mine was leased to Smith and Fulton of Nogales. The zone was further developed at greater depth and high grade lens of chalcopyrite ore was encountered. This ore was mined by the leasing company until the first of January 1929, when the owners took possession and continued to mine and further develop the property until June 1930. The leasing company found several small associated lenses of high grade molybdenite ore, the best of which were mined and shipped separately in 1927 and 1928. Lower grade molybdenite-pyrite-chalcopyrite ore was mined in 1929 and 1930 and was shipped to Nogales for treatment in a small flotation plant. The mine produced about 1,700,000 pounds of copper, 9000 ounces of associated silver and 200 tons of high grade molybdenite ore and concentrates, from 1926 to the end of 1929.

Morning Glory Mine. About two miles north-west of Mowry is the Morning Glory Mine. The mine was first located in the eighties as a silver mine by David Neal who is said to have mined and treated, together with A. S. Henderson, considerable ore from the outcrop.*

Sulphides were reached at shallow depth, carrying much lower silver values. The property was abandoned until the better copper market of the late nineties, when it was relocated by Richard Farrell and wife.

Little work was done until 1907 when it was purchased by C. B. Wilson, then residing in Helvetia. Under the stimulus of the abnormally high copper market of that year, the main shaft was deepened and about 1000 tons of low-grade ore were shipped. On the collapse of the market at the end of the year the mine was closed. It was not reopened until four years later when the copper ore was further developed and about 5000 tons were shipped. The mine was again closed in 1913, and was not reopened until 1918 when it was developed at further depth by a crosscut tunnel. A large pipe of mineralized groung was cut in the tunnel and connections were made with the

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*Schrader, Frank, C., "Mineral Deposits of the Santa Rita and Patagonia Mountains, Arizona." U. S. Geological Survey. Bulletin 582, 1915, p. 306.

shaft. A little ore was shipped.

The mine passed to new owners three years later when J. B. Schriever of Scranton, Pa., organized the Morning Glory Mining Company to take over the mine. The crosscut tunnel work was continued to the end of 1923 when the mine was again closed. Schriever reorganized the company in 1927 as the Morning Glory Mining and Smelting Company. The reorganized company with much new capital reopened the mine and equipped it to treat by flotation the low-grade ore from the mineralized pipe cut in the cross-cut tunnel. A 100-ton concentrator was completed in 1929 together with a Diesel-run electric power plant and camp buildings. The concentrator was operated a few months, after which the property was again closed.

The total production of the mine from 1907 to 1929 inclusive has been approximately 374,000 pounds of copper and 20,000 ounces of silver, chiefly mined during the high copper market periods. The production in silver from the surface ore is not known, but was not great as the tonnage shipped was small.

World's Fair Mine. The history of this well-known silver producer is intimately associated with two picturesque pioneers of the Patagonia Mountains, Frank and Josephine Powers. The mine was entirely developed by Mr. and Mrs. Powers with almost no initial capital. It was one of that rare species of which prospectors dream, one that paid its way from the "grass-roots."

The early history of the property is not known. It is supposed to have been worked in a small way by Spanish miners previous to the American occupation in 1853. It was not located by Americans until 1879* when McNamee worked the surface ores two years and then abandoned the location.

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*Ibid. p. 248.

It was relocated two years later by William Moran who sold it in 1884, a year after location, to Frank Powers for the succeeding twenty years. Frank and his wife Josephine slowly developed the property, occasionally making small rich shipments sufficient to make them a comfortable living. In the middle nineties, after the oxidized ores had been replaced by enriched sulphides, a 10-stamp gravity concentrator was installed, but was not operated long. A rich pocket of ore was encountered at about this time from which a single 20-ton car load returned $14,200, mostly in silver. The property began to attract attention. The Powers set the purchase price at $1,000,000 and continued to ship ore at intermittent periods until 1909 when the property was bonded for $500,000 for a short time to a company known as the World's Fair Mining Company. On the relinquishment of the bond, the Powers continued to make rich shipments of cupriferous silver ore, with occasional bonanza car loads until 1912 when the mine was bonded to Phelps Dodge and Company. On the relinquishment of the bond after six months examination, the property again reverted to the Powers. Shipments were resumed in 1914 and were continued irregularly to the end of 1917 when the mine was bonded to the Commonwealth Development Company of Pearce. A concentrator was installed in 1918 and was operated for about a year when the bond was surrendered and the machinery was removed.

The mine was then leased to the Bachman-Merritt Metals Company, owners of the Tres de Mayo Mine, but little was done by this company, and the mine remained virtually closed until it was leased in 1823 to Louis L. Perry, Carl Scheler and Michael Hogan. Shipments were resumed and were continued to the end of 1926. During the duration of the lease the property became involved in litigation, resulting in its being placed in the hands of a receiver in 1927. It was then bonded to a company known as the Zero Mining Company. The old concentrator was remodeled into a flotation plant which was started in the fall of 1928. The company was insufficiently financed, and in the succeeding year its assets were acquired by the Trench Mining Company financed by the machinery house which had erected the concentrator. This company acquired the neighboring Trench and Josephine Mines, and operated the concentrator on ore from the three properties.

The Powers interests in the property became badly clouded after the start of litigation in 1925, although they continued to maintain their residence at the mine throughout.

The rpoduction of the mine prior to 1900 is not of exact record. It was probably about $50,000 chiefly in silver with some copper and lead. The production since 1900 to the end of 1929 has been about $550,000 in silver cěpper and lead, making the total production about $600,000.

Hermosa Mine. The Hardshell, Hermosa, Alta, January, Trench, Josephine, World's Fair, Flux, and Three R Mines have been the principal producing properties in the northern end of the Patagonia Mountains. These deposits are closely associated with a large intrusive mass of rhyolite and granite porphyry, the most prominent outcrop of which is in Red Mountain south of Patagonia. The Hardshell and Hermosa Mines are at the Eastern extremity of this zone followed to succession to the west by the January, Trench, Josephine, World's Fair, Flux and Three R Mines. The total width of the zone from the Hermosa to the Three R is about four miles.

The Hermosa silver mine was not worked, as far as is known, by the Spaniards, and was not discovered by American prospectors until after the revival of prospection initiated the Colyer Peace Commission in 1873. It was first located, according to Schrader,* in 1877 and was sold within two years of location to a New York Company known as the Hermosa Mining Company. The mine was energetically developed and by September 1880 over 4000 feet of work had been done, 824 feet of which was tunnels, and 4000 tons of ore were reported on the dump. A 100-ton stamp amalgamation mill had been constructed and started operating August 20th. It was then crushing 75 tons a day. The company headquarters and mill were established about a half a mile from the mine, and became the nucleus for the town of Harshaw, which for many years was the metropolis of this part of the mountains. The mill while in operation was the largest in Arizona. The ore consisted of altered rhyolite carrying values in silver chloride. The production for the year 1880 according to the U. S. Mint Report was $365,654.49. The company continued to operate the mine until the latter part of the next year, when the better ore was exhausted. The total production in bullion for the run of a little more than a year was, according to the Tucson <u>Star</u> of January 5th, 1882, $1,155,154.49

After the close of the mine and mill, the town of Harshaw was almost deserted. The mill was sold two years later to the operators of the Peerless Mine at Quijota and was moved there. The mine was sold in 1887, six years after its close, to James Finley of Tucson. It was not reopened by Finley until 1890 when he installed a small Huntington Mill at Harshaw, and is reputed to have produced $150,000 worth of bullion. During this time the mine was bonded for a short time to Senator McGoverney of Canon City Colorado. On the drop in the price of silver in 1893 little further work was done. The last

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*Ibid. p. 272.

operation was in the late nineties by a company known as the Hermosa Mining Company, financed from Guthrie, Oklahoma. This company enlarged the mill and drove 900 feet to work below the old stopes, with negative results. The total production after the original operation was comparatively small, and the deepest commercial ore found was 825 feet below the outcrop.

The net profit made by the original company was over $500,000, and this was used as the basis for the formation of the Prietus Mines Company, which made a spectacular success in the exploitation of the La Colorado Mine of Sonora, Mexico.

Hardshell Mine. The original claims on ore of which the mine was later discovered were located on both sides of Hardshell Gulch about a mile south of Harshaw, as a base for the search for the source of boulders of rich ore found in the Gulch. The locations were made about the same time as those on the Hermosa by David Harshaw and Jose Andrade, who shortly sold the locations to R. R. Richardson. For ten years Richardson, one of the most active pioneers of the district, searched unsuccessfully for the ledge and abandoned the locations. Several years later he relocated the ground and after further search finally found the ledge in 1895. The following year he bonded the mine to the Empire Mining and Milling Company. This company sank an inclined shaft 400 feet on the ledge, took out 4000 tons of ore and shipped 3000 tons to El Paso. The company then erected a 100-ton blast furnace at what was then known as Rollin, two and a half miles south of Crittenden, which was blown in in August 1897. The Flux Mine was also bonded by the company and the smelter was operated chiefly on ore from the two mines. The settlement of Rollin became the nucleus of the town of Patagonia, now the mining center of the Patagonia and Southern Santa Rita Mountains. The smelter was operated for three months, after which the Hardshell reverted to the original owner, R. R. Richardson.

Two years later in the fall of 1899 the Patagonia Mining Company was organized by Richardson, and a fifty-ton concentrator was built which was operated throughout the year of 1900 and until May 1901 and is said to have treated about 15,000 tons of ore. The mine was again closed and was not reopened for four years when, in 1905, the Patagonia Mining Company was reorganized by Benj. Heney of Tucson. The shaft was deepened and considerable development work was done in 1906 and 1907, after which the mine was again closed and was not reopened until 1913, when the Patagonia Mining Company reorganized as the Hardshell Flux Mining and Development Company, mined and shipped a small tonnage of ore and then closed down the mine, after which the property reverted to Richardson.

No further work was done until 1917 when it was bonded to H. W. Welch of Tucson. The concentrator was remodeled to make a high manganese concentrate and a new vertical shaft was sunk 400 feet to develop the ledge at greater depth. Work in the shaft was discontinued after a large flow of water more than taxed the capacity of the pumps installed. The property again reverted to Richardson, in 1921, and has been held by his estate since his death. A small production is made, as market conditions warrant, from the operations of lessees.

Trench Mine. The mine is said to have been located for the first time, prior to the Civil War, by Colonel H. T. Titus, one of the early owners of the Mowry Mine. Not much work was done at this time, and the mine was abandoned on the outbreak of the Civil War in 1861. It was not relocated until about 1872 during the general revival of prospecting of that year, and is said to have been developed in the next eight years by Senor Padrez.*

It was sold in May 1880 by Samuel Hughes of Tucson, trustee for the owner, to W. G. Galigher, acting for Haggin and Hearst of San Francisco. Development started in December and a 400-foot shaft was sunk on the vein which was completed in the following July, when the work was discontinued due to the low-grade of the ore encountered.

After the completion of the Benson smelter in 1882 the mine was leased by Hagan and Tevis and considerable ore was mined and hauled to the smelter. After its close other lessees shipped reduction works in Texas and New Mexico until the demonetization of silver in 1893. The subsequent drop in the silver market made further operations unprofitable, and all work ceased in 1894. During the operations of the lessees, a small gravity concentration plant was erected and was operated intermittently.

The mine remained closed until 1905 when it was developed for about two years, but little ore was shipped. The mine was again closed and remained down for about eight years when, late in 1912, it was bonded to Senator Clark of Montana. After three years of development work from the old shaft, a new 600-foot shaft was started in 1915 and shipments of ore were commenced in 1918 and were continued on a small scale to the end of 1925. The mine was operated under the name of Trench Consolidated Mines Company. It was operated on lease account in the last three years by John Hoy of Patagonia. It was again closed for two years until late in 1928 when it was leased by

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*Hinton, R. J., Handbook to Arizona. San Francisco and New York, 1878, p.126.

Frank Ahlberg, who also leased the World's Fair Mine, and both mines were reopened and the ore was treated at the World's Fair flotation plant erected by the Zero Mining Company in 1927.

The new company organized as the Trench Mining Company operated the two properties together to the end of 1929.

The total production of the Trench is not known. Since 1905 to the end of 1929 it has been about $20,000 in lead, and silver. The production by lessees prior to 1894 was intermittent. Two carloads shipped to the Crittenden smelter in 1899 by Powers were said to have run 40 percent lead and 60 ounces in silver.*

If 200 tons is assumed as shipped of this grade the gross yield would have been about 1,500,000 pounds of lead, and 120,000 ounces of silver worth about $170,000. It is probable that including the lower grade ore milled, the yield was not over $250,000, which with the recorded yield since 1905 would make a probable total production of about $190,000.

Josephine Mine. The vein, worked at this mine is a continuation to the northwest of the Trench vein. It was located at the same time as the Trench but was not opened until five years later.** It is said to have been most extensively worked from 1893 to 1897 by Farrel, William, Powers, and Morrison who developed the mine to a depth of 500 feet and are said to have shipped at an average rate of three cars a month (60 to 90 tons). The grade was about the same as that of the Trench. Little has been done since 1899, when it was relocated by Farrel, Powers, and Morrison.

The production is not recorded. If, during its productive life

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*Schrader. op. cit. p. 253.
**Schrader, op. cit. p. 254.

of five years, an average of 60 tons a month of 40 percent lead and 60 ounces of silver is assumed as shipped, this would have yielded a gross production of about 2,000,000 pounds of lead and 200,000 ounces of silver worth about $200,000.

Flux Mine. This mine, about a mile and a half northwest of the World's Fair in Flux Gulch, a tributary of Alum Gulch, was said to have been worked by the Spaniards and Mexicans prior to the Gadsden Purchase in 1853. Although not mentioned by Mowry,* it is supposed to have been located prior to the Civil War and to have had the richer surface ore smelter in an adobe furnace near the mouth of Alum Gulch.

It was not relocated until 1882 when Salisbury, owner of the Benson Smelter, opened up the mine, built a road from Sonoita Creek to the mine at a cost of $5000, and in 1884 shipped at a rate of about a car a day (20tons). No exact figures are recorded. At the 1884 rate several thousand tons were probably shipped of ore carrying about 60 percent lead and about 15 ounces of silver.

No further work was done until 1897 when it was relocated by R. R. Richardson, and the mine was reopened and bonded, together with the Hardshell to the Empire Smelting Company whose history has since been given under the Hardshell Mine. About 2000 tons were smelted from both properties during the three months run of the smelter after which the company relinquished the mines to Richardson, early in 1898. Richardson then organized the Patagonia Mining Company to operate both the Flux and Hardshell Mines. The principal operations were conducted at the Hardshell where a concentrator was built, a few shipments of high-grade lead-silver ore were made to El Paso from the Flux, but not much work was done until the reopganization in 1905 of the company by Benj. Heney. The mine was opened by a series of tunnels and connecting shaft and raises. A little ore was shipped after which the mine was closed in 1909.

No further work was done until 1914 when it was bonded to a California company. This company built a dry concentrator at the junction of Flux and Alum gulches, and connected the mine and mill with a 5000-foot aerial tramway of unusual design. A small tonnage was mined but the mill was unable to save the values and the property was abandoned and reverted to Richardson in 1917, who operated it himself for a year. It was then bonded for $150,000 for five years to a syndicate from Bisbee organized as the Flux Mining Company, managed by Fred H. Kohlberg. A 250-ton flotation concentrator was built at the site of the older dry concentrator to treat the low-grade oxidized lead-silver ore of the upper workings by sulphidizing followed by flotation. A pumping plant was installed on Sonoita Creek. A considerable tonnage of ore was treated and concentrates were shipped in 1918 and 1919. The oxidized ore proved refractory to flotation and the milling was discontinued early in 1919 to await further developments in the lower level sulphide zone. The mill was reopened in 1920 to treat a small tonnage of complex sulphide ore. The company went into the hands of a receiver in 1921. The mine was closed and the equipment was sold. The mine again reverted to Richardson who reopened it in 1923 and there has been shipped intermittently a small tonnage each year to the end of 1929.

The total production of the mine from 1897 to the end of 1929 has been about $70,000 in lead and silver. The production previous to 1897 is not recorded but probably was about 4,000,000 pounds of lead and 60,000 ounces of silver with a gross value of about $230,000, making the probable total yield to the end of 1929 about $300,000.

Appendix 10

Kentucky Camp
U.S. Forest Service Stabilization Project

Kentucky Camp

U.S. Forest Service Stabilization Project

Once the scene of a grandiose engineering scheme and optimistic activity, a small gold mining camp in southeast Arizona had fallen into lonely abandonment for decades. But recently, Kentucky Camp, on the Coronado National Forest, has come alive once more as several partners have joined with the Forest to preserve the site for the future.

Over a century ago, the Greaterville gold placers on the east slope of the Santa Rita Mountains were alive with activity. Gold had been discovered in 1874 in the Greaterville mining district, which proved to be the largest and richest placer deposit in southern Arizona. In 1875, an Arizona Citizen article reported that one "Horace Arden, not noted for working imprudently hard" was recovering an ounce of gold a day, even though he had to pack the pay dirt to water for washing. Such success stories brought over 200 miners to the Greaterville mining district in the 1870s. But by the end of the 1880s the Greaterville placers were "worked out"; all the easily obtainable gold had been recovered, and the population began to decline. One claim named "Burro Placer" is suggestive of the major difficulty in mining the Greaterville placers: lack of water. Most gulches flowed only intermittently, and water for the placer washing was packed in on mules and burros from wells in the vicinity.

At the turn of the century, a millionaire and an engineer teamed up in an effort to solve the mining area's incessant water shortage. In 1904, a mining engineer from San Jose named James Stetson conceived a grand scheme to channel runoff from the Santa Ritas' spring snowmelt into a reservoir that would hold enough water to last ten months. With that, he could keep a mine operating. Stetson convinced George McAvery, also of San Jose, to invest in the plan, and together they formed the Santa Rita Water and Mining Company to make it work. From 1904 to 1906, the buildings at Kentucky Camp served as the headquarters for dam builders, ditch diggers and miners. They employed 40 men in building Kentucky Camp and in constructing miles of pipeline.

In spite of optimistic reports on their preliminary work, the Santa Rita Water and Mining Company failed. Tragedy struck in 1905, the day before a meeting with stockholders, when Stetson was killed in a fall from a third-story hotel window in Tucson. McAvery died shortly thereafter. Arguments among McAvery's heirs kept the estate tied up and, although other partners tried to keep the operation going, it too soon died. The buildings and land at Kentucky Camp were sold for back taxes at a 1906 sheriff's auction. An attorney bought the property and his family used Kentucky Camp as a base for cattle ranching until the 1960s.

Thanks to the care bestowed on the buildings by the ranchers, the site was in much better condition than most turn-of-the-century mining camps in the area, with standing adobe buildings, pieces of the pipeline, and the hummocky landscape of placering. But decades of abandonment and weathering, vandals, and misguided recyclers had taken their toll on the site by the time it was acquired by the Coronado National Forest, in 1989. One structure had collapsed, and leaky roofs threatened the remaining four buildings. Broken glass, rusty nails, and crumbling walls seemed to invite lawsuits as much as inquisitive visitors.

The buildings that remain at Kentucky Camp were built about 1904. The largest was probably used as an office by the Santa Rita Water and Mining Company. Later, it was the main ranch house. The small building behind it was used to process the gold ore. A large barn lies in ruins opposite a small house where Stetson may have lived, and another small house lies at the far end of the site.

Because many of the old mining ghost towns have been completely obliterated or are inaccessible to the public, Kentucky Camp appears to offer an excellent opportunity for interpretation. As a development engendered and abandoned with the fortunes of a large engineering project, Kentucky Camp illustrates the crucial role water has played in mining this arid region of Arizona. Further, the site is little over an hour from Tucson, with most of the drive along an Arizona scenic highway.

The Forest contracted with Ryden and Associates, of Phoenix, to prepare a historic building analysis. The basis of a site stabilization plan, the historic building analysis describes and ranks the steps needed to preserve the build-ings and to restore them for future use. The Forest will restore the buildings to the way they appeared in the mining era. Until Kentucky Camp is restored, you should keep certain things in mind. The buildings are old and deteriorated, so care should be taken when inside--floorboards may give way, and some ceiling boards hang low. And please - do not remove anything from Kentucky Camp. Although they may appear old, broken and abandoned, all the artifacts will be useful in reconstructing life in the camp.

In the spring of 1991, Passport in Time volunteers helped document architectural and archaeological features and drew room plans. With patience and care, scattered trash and fragments of lumber were transformed into clues about the doors, windows, porches, and other features that once graced the buildings. Their work aided not only in preservation efforts, but also allowed the initial cleanup of safety hazards.

The Nogales Ranger District Fire Crew, with a historic archaeologist who specializes in historic buildings, made adobe bricks to rebuild a collapsed wall, and replaced wooden beams that had been "salvaged" during Kentucky Camp's abandonment. The Fire Crew re-roofed the standing buildings with wooden shingles acquired through a cooperative agreement with the Young Riders film company, which shoots episodes of the television series in the vicinity.

Public interpretation requires public facilities, like toilets and picnic tables, so an interdisciplinary team has begun an Interpretive Plan to guide future design, and to ensure developments to not detract from the historic setting. The Interpretive Plan outlines Forest priorities, identified research needs and possible interfaces with other interpretive opportunities, targets audiences, and develops themes for future booklets, living history, tours, and trails. The gradual phasing of projects will allow some interpretation to begin soon, while options for accomplishing long-term goals can be explored.

Forest-led tours and outreach have generated a pool of other interested volunteers, and the Nogales Ranger District is committed to pursuing the preservation of Kentucky Camp for future generations.

FIELD TRIP

HANDOUTS

MOWRY MINE NOTES, OCT 1992

S.R.Titley

The old workings of this mine may be viewed from the surface as a linear group of caved stopes along the ENE-striking vein. The observer should be extremely careful at this site because of this caving and stay away from any opening - and do not get near the fences that protect these openings. There are plenty of samples in rock piles along the vein trace. At this writing, remnants of some adobe buildings at the old town site of Mowry are still present and the "stone-masoned" powder building still stands near the outcrop of the No. 4 orebody.

The actual date of discovery of the Mowry vein is unknown and it may have occurred some time in the 18th Century by unknown prospectors who left behind a number of shallow pits and trenches. But it was "rediscovered" by a Mexican prospector at about the time of the Gadsden Purchase and sold for virtually nothing to a group of investors headed by Lt. Sylvester Mowry about 1858. The mine evolved from the presence of exposed rich, (enriched) silver-lead ores, the dominant metal production through some 50 years of intermittent mining. Elsing and Heinemann (1936) report a production value from 1858 to 1930 of about $1,000,000 in currency of the time - derived from 10,000,000# of Pb at about $0.05/# average and from about $500,000 worth of Ag. Granger (1960) reports a production of $1,500,000. Through much of its significant mining life, the Mowry is said to have been geared to production of about 100tpd.

The mine has a storied history, some of which is described by Granger (1960) and Schrader (1915). Important points of this history stem from its discovery to the imprisonment of Lt. Mowry for some 6 months after the U.S. Government seized the workings in 1862, for ostensibly selling Pb to the confederacy. (Mowry was unsuccessful in regenerating interest in the mine after the Civil war and is said to have died penniless in London a few years later (Granger, 1960). Raphael Pumpelly, at the time a chemist/metallurgist with the "Santa Rita Mining Co." is said to have known and visited the property during early years of its operation.

Withdrawal of troops from Ft. Crittenden during the Civil War resulted in renewed dangers from Apaches and mining stagnated until the 1870s during and following which mining was carried out intermittently until the early part of the Century. Mining of Mn ores took place for a brief period of time during the mid 1950s under DMEA encouragement, and Ventures Ltd. is said to have had an interest in the property at that time. Schrader states that the property consists of 20 patented mining claims.

Rich silver ores were processed both on site where bullion and local coinage was produced, and in Europe by way of wagon transit of Ag and Pb bars to Yuma. Some specimen quality material is said to have been shipped to London during this early period. Lead ores at Mowry, as well as from other mines in the Patagonia and Santa Rita Mountains were smelted locally during the late decades of the 19th century in Alum Canyon, Patagonia, and Duquesne. The ores at Mowry during the late 1800s are said to have yielded more than $100/ton at prevailing prices, an ore-grade value cut-off that was commonplace in this region at this time.

The mine comprises a group of fault-controlled ore shoots of veins and carbonate replacement ores in a 75m wide shear zone marking the fault boundary between Precambrian granitic rocks (to the south) and the Paleozoic-Mesozoic section to the north. This structure, the Mowry Fault, is known to be mineralized along a strike length of some 350-400m, representing only a small fraction of the composite length of the fault as shown in the accompanying section extracted from Smith (1956), compared with the fault as mapped by Simons (1974). Development, all of which is old, extended to the 500ft (160m) level. Exploration of the early 1980s is said to have attempted to discover mineralization, by geophysics,along the fault trace to the east and to further trace it beneath cover beyond outcrop. Results of this work have not been disclosed to the public.

Ores mined consisted, in the main, of oxidized, argentiferous primary lead-silver mineralization. Principal minerals were cerussite, and anglesite in a dark wad of various manganese (psilomelane and pyrolusite) and iron (hematite) oxides. A secondary Sb mineral "bindheimite" ($Pb_2Sb_2O_6[O,OH]$) and a member of the stibiconite group, is present and possibly derived from stibnite or a Ag-bearing sulfosalt such as miargyrite or andorites. Galena is reported to have been sparingly present and, although accounts differ between authors, oxidation of the ores was present to a depth of between 300 and 400. Primary sulphides are present in the lowest levels at about 500 feet, but Ag grades are reported to have fallen. Where galena was associated with pyrolusite it is said to have been rich (several 1000s of ounces/t) in silver.

The south wall of the vein is Precambrian "granite", the north wall a complex of Paleozoic strata with incorporation of horses of a pyroxene monzonite of likely younger age. Replacement of carbonate rocks has taken place in various strata along the vein with a dominance of mineralization in the Escabrosa limestone (See attached map.). The longitudinal section of the vein by Smith (1956) is attached and shows the structure cutting a deep exposure of "porphyry" interpreted in Schrader as "gabbro". This is possibly the pyroxene monzonite of Cretaceous age mapped by Simons (1974).

Age of the mineralization is unknown and may only be inferred as Laramide owing to the manifestation of a (dated) widespread thermal event of such an age (Simons, 1972,1974) in this region. Laramide trachytic volcanic rocks and intrusions of the Patagonia mountains are widespread, the most significant manifestation of which is Red Mountain flanking the town of Patagonia to the east. However, owing to increasing recognition in some mining districts in southern Arizona of a mid-Tertiary thermal overprint, the age of the event at Mowry remains open. Mineralization is manifestly related to the margins of a significant block fault whose age would set an oldest limit but an age which is presently unconstrained. It could be as old as Triassic and related to widespread volcanic activity of that age (ca. 200Ma), or as young as some time in the Tertiary. No evidence links mineralization with or precludes its development synchronous with faulting.

Tucson, 20th Oct. 1992.

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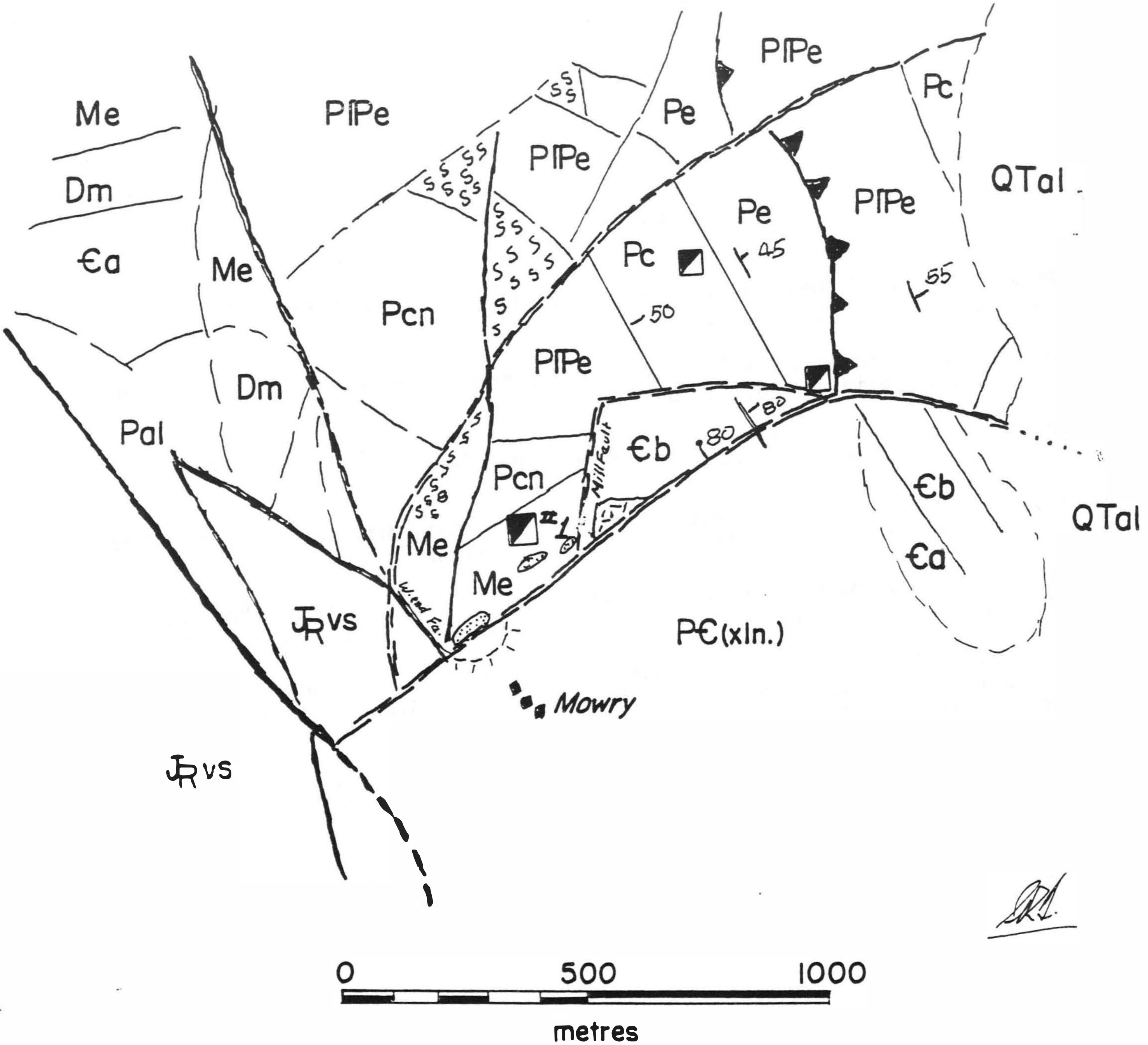


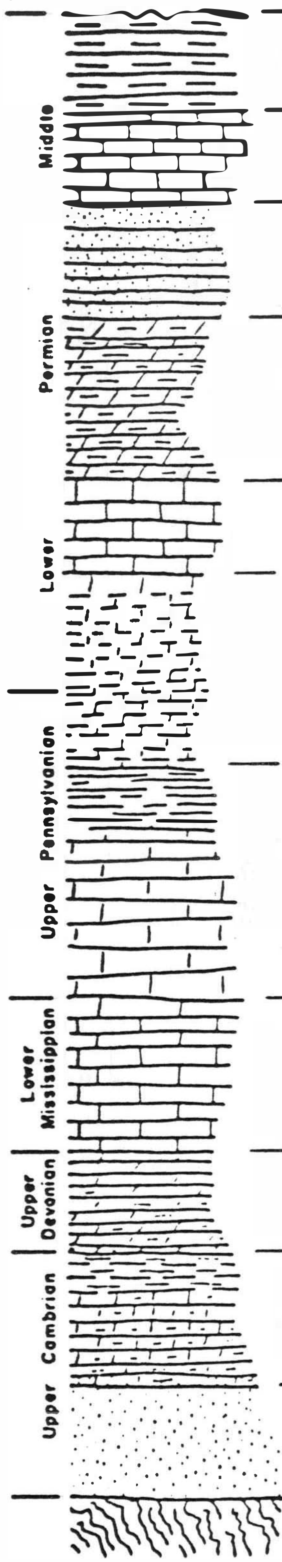
GEOLOGICAL SKETCH MAP – MOWRY MINE AREA

(Adapted from Simons(1974) & Smith(1956))

(Unsurveyed)

Generalized Paleozoic Column for southeastern Arizona. Not included are units of local occurrence such as the El Paso Limestone, Portal Formation, and Black Prince Limestone.

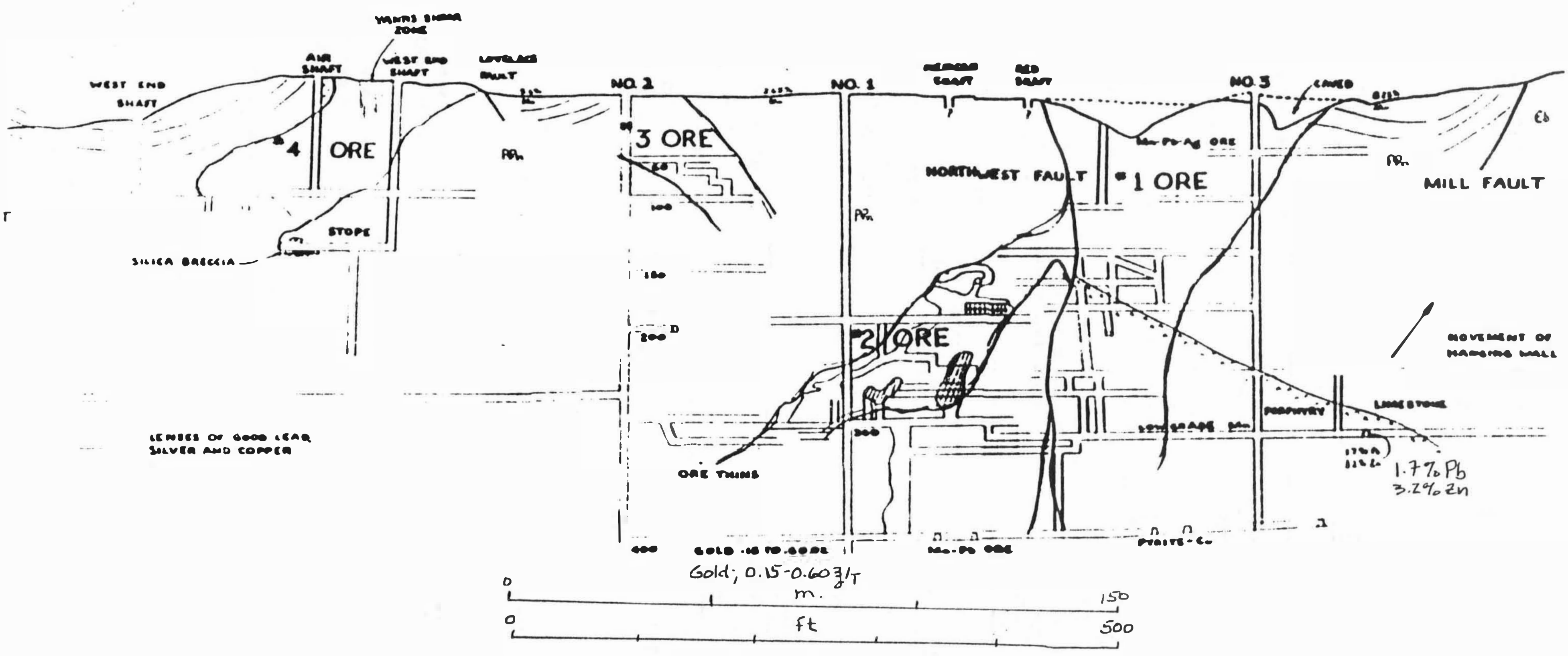
Map not.



Map unit	Age	Formation	Thickness	Description
Prv	Middle Permian	Rainvalley fm.	~ 500'	variable thin to thick-bedded limestone - 80% limestone
Pcn	Middle Permian	Concha fm.	~ 500'	thick-bedded clean limestone ~ 90% carbonate (with some chert)
Ps	Permian	Scherrer fm.	~ 500 - 600' thinning to west	lower and upper silt-sandstone units (~ 200' total) sandwich 300-400' of silty sandstone carbonate ~ 40% carbonate, 60% clastic
Pe	Permian	Epitaph fm.	750' (Tombstone) to 1500' (SW N. Mex.)	extremely variable unit with evaporite facies, in west is 1/3 dolomite and in east is 3/4 dolomite, locally includes gypsum, chiefly to northeast - thin-bedded with chert
Pc	Lower Permian	Colina fm.	200' (Silver Bell) to 600' (Tombstone)	thick-bedded relatively pure $CO_3^=$, low dolomite content but widely variable
Pℙe	Lower Permian – Pennsylvanian	Earp fm.	~ 1000'	ferruginous (pink) silty limestone and dolomite, ~ 65-35 carbonate to siltstone, thin-bedded
ℙh	Upper Pennsylvanian	Horquilla fm.	600' (Silver Bell) to 1600' (Chiricahuas)	formation boundary @ 50-50 carbonate-shale upper 1/2 ~ 40% shale and silt, 60% carbonate lower 1/2 increasing from 40-60 to 5-95% clastic to carbonate
Me	Lower Mississippian	Escabrosa Gp. (Hachita fm., Keating fm.)	600 - 750'	upper massive and lower thin-bedded limestone clean ~ 97% carbonate (< 5% $CaMg(CO_3)_2$)
Dm	Upper Devonian	Martin fm.	300 - 400'	50% carbonate (1/2 dolomite) 50% silty carbonates (shales, thin sands)
Єa	Upper Cambrian	Abrigo l. s.	600 - 800'	50% limestone, 50% shale, thinly laminated micaceous, locally
Єb	Upper Cambrian	Bolsa Quartzite	400 - 700'	37% quartzite 60% arkose 3% shale

(from Norton, et al., 1975, U. of A.

SR [signature]



MOWRY MINE

SANTA CRUZ COUNTY, ARIZONA

LONGITUDINAL SECTION THROUGH ORE BODIES

DATA COPIED FROM MAPS BY BILLINGSLEY, LOCKE, MAYO, LOVELACE

From. George Smith 1956
Thesis, U/A, 44p.