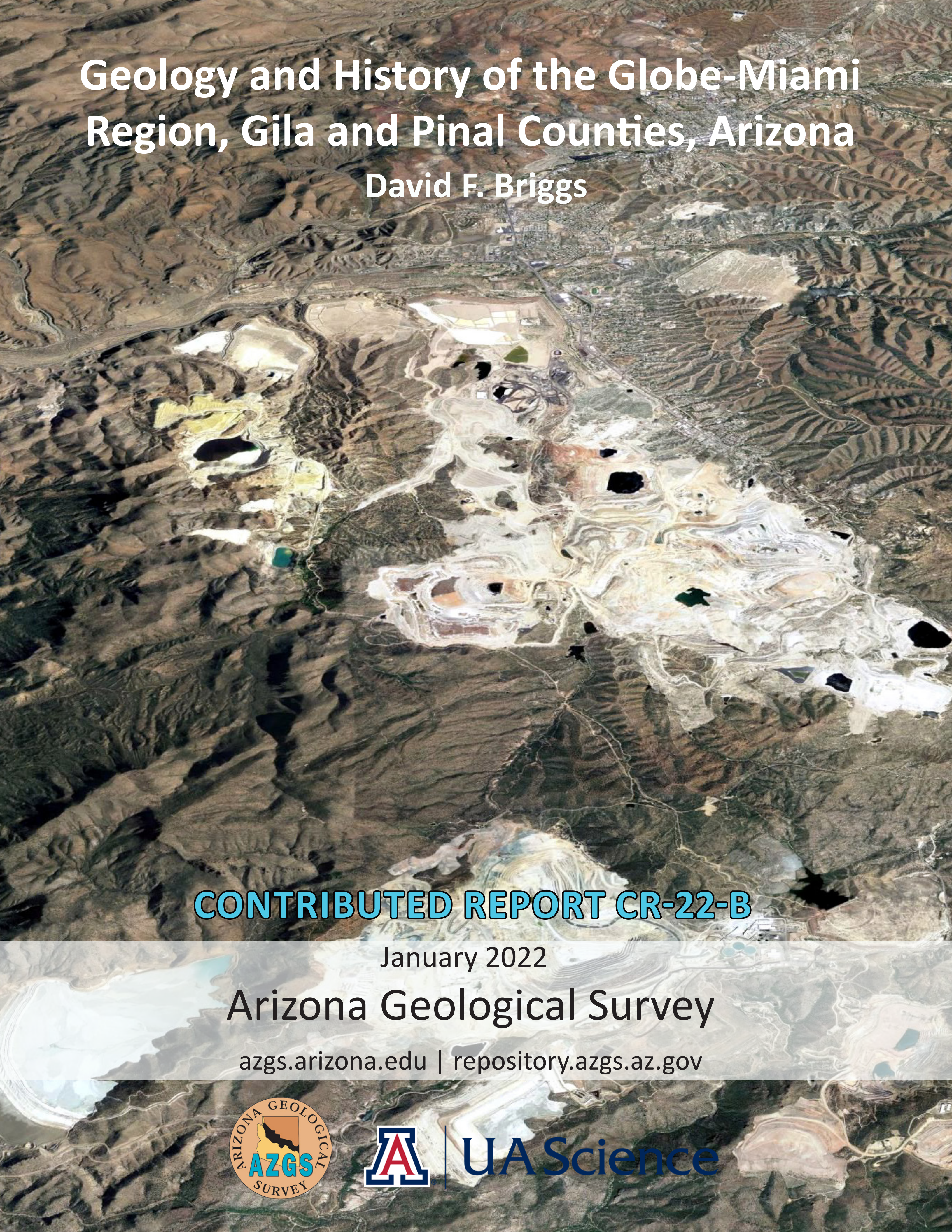

Geology and History of the Globe-Miami Region, Gila and Pinal Counties, Arizona

David F. Briggs

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Cover Photo: Oblique aerial view, looking east, of Globe-Miami mining region, Gila and Pinal Counties, Arizona (courtesy of Google Earth).

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1 INTRODUCTION

The history of the Globe-Miami Mining Region (Figure 1) spans a period of more than 150 years. Including copper deposits located in the Globe Hills and Miami areas, it is a part of Arizona’s Copper Triangle, a region known for its concentration of large copper deposits.

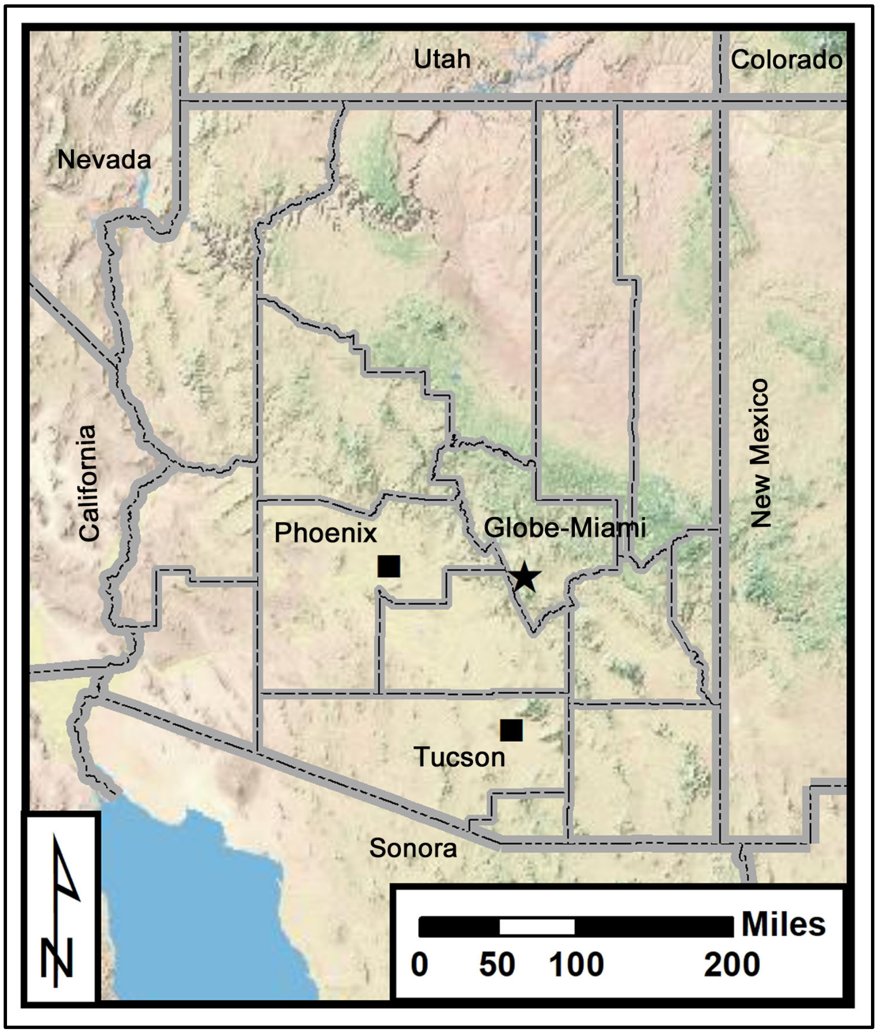


Figure 1. Globe-Miami Mining Region is located approximately 80 miles north of Tucson and 75 miles east of Phoenix

Arizona’s Copper Triangle encompasses a region between Globe, Superior and Hayden (Figure 2). In addition to the large porphyry copper deposits in the Miami-Inspiration, Globe Hills and Summit mineral districts that will be discussed later, it also includes the Pioneer (Magma, Resolution and Superior East), Mineral Creek (Ray), Dripping Springs (Troy Ranch), Banner (Chilito), and Christmas mineral districts. Copper smelters are located at Miami and Hayden.

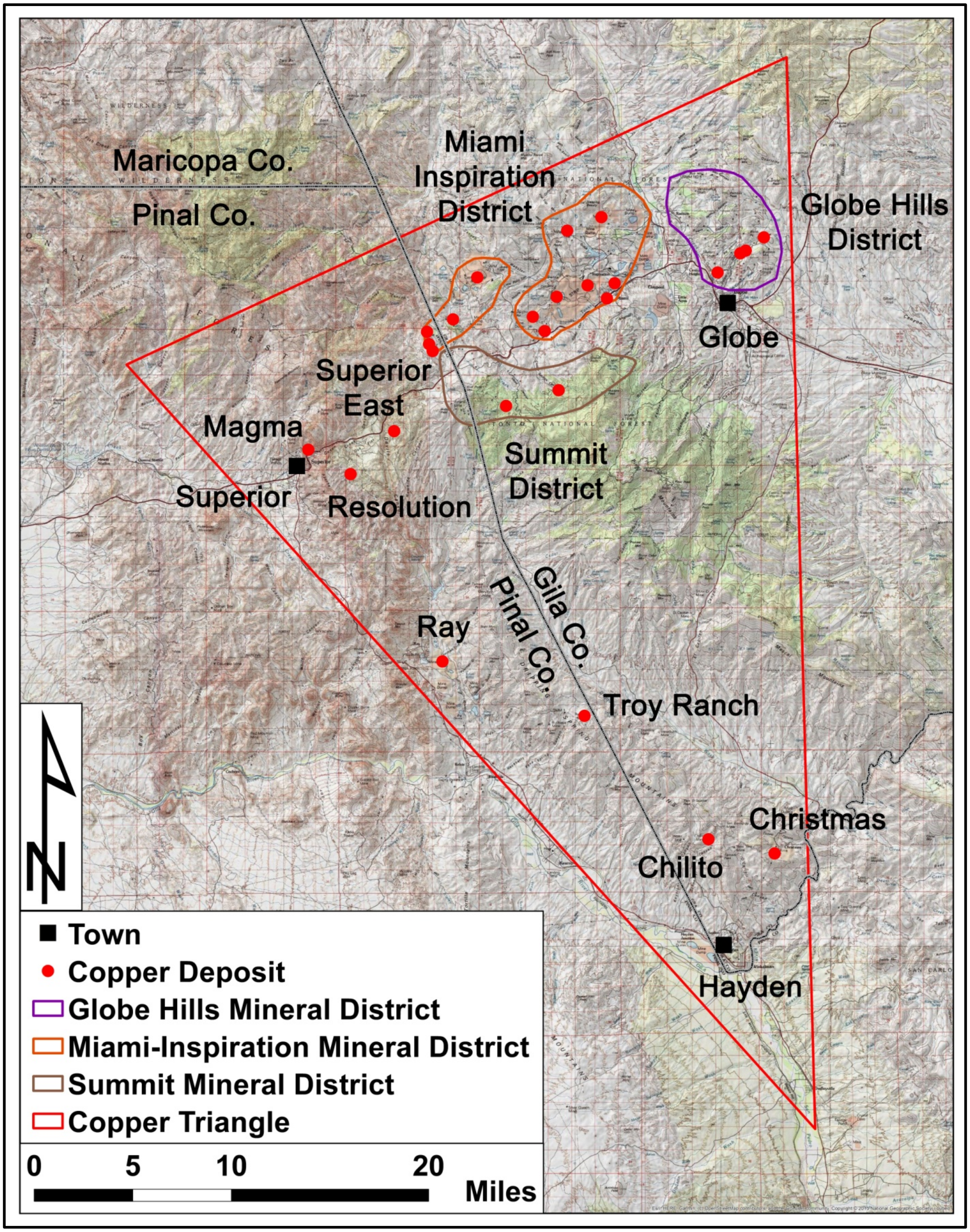


Figure 2. Major copper deposits in Arizona's Copper Triangle, Gila and Pinal counties, Arizona. Operations at ASARCO's Hayden smelter have been temporarily suspended since October 2019.

Cumulative copper production from Arizona's Copper Triangle (as of December 31, 2020) totals about 37.3 billion pounds, which represents approximately 13.6% of the total reported historic U. S. production (Briggs, 2021). Significant proven and probable ore reserves (9.6 billion lbs. of copper) remain at Pinto Valley, Ray, Cactus-Carlota, and South Eder. Additional unmined mineral resources total approximately 85.1 billion pounds of copper (Table 1).

Table 1. Historic copper production as of December 31, 2020 (source from Briggs, 2021), unmined copper reserves, and unmined copper resources in Arizona's Copper Triangle (N/A – no data reported)

Mineral District	Historic Copper Production Lbs.	Deposit(s) containing Reported Unmined Reserves and/or Resources	Unmined Copper Reserves Lbs.	Unmined Copper Resources Lbs.	References
Globe Hills	1,012,283,000	Old Dominion	-	960,000,000	Kinnison, 1977
Miami-Inspiration	18,080,427,000	Pinto Valley, Miami, Miami East, Van Dyke, Cactus-Carlota, Eder North, Eder Middle, Eder South	2,949,000,000	13,724,000,000	Capstone Mining Corp., 2021 Magma Copper Company, 1995 Bird et al., 2020 BHP Billiton PLC, 2004 Wellman et al., 2006
Summit	17,501,000	Copper Springs, Azurite	-	169,000,000	Corn, 1990 Gatchalian, 1975
Pioneer	2,602,933,000	Magma	15,000,000	113,000,000	Magma Copper Company, 1995
		Resolution	-	60,125,000,000	Rio Tinto PLC, 2021
		Superior East	-	3,600,000,000	Sell, 1995
Mineral Creek	15,204,410,000	Ray	6,635,000,000	N/A	Grupo Mexico SAB de CV, 2019
Dripping Springs	356,000	Troy Ranch	-	N/A	Russell, 2006
Banner	10,673,000	Chilito	-	3,784,000,000	Grupo Mexico SAB de CV, 2021
Christmas	362,889,000	Christmas	-	2,656,000,000	Freeport-McMoRan, Inc., 2021
Total	37,291,472,000		9,599,000,000	85,131,000,000	

Despite its long history of copper exploration, development and production, the potential for additional significant discoveries in Arizona's Copper Triangle remains high. In February 1995, the Magma Copper Company discovered the Resolution copper deposit, which is concealed beneath approximately 4,900 feet of post-mineral volcanic cover (Briggs, 2015a). After 26 years of exploration and development, the Resolution copper deposit is now recognized as one of world's largest undeveloped copper deposits (U.S. Forest Service, 2021), containing indicated and inferred resources of 1,970,000,000 short tons of mineralized rock, assaying 1.53% copper and 0.036% molybdenum (i.e., contained copper content is approximately 60.1 billion lbs.) (Rio Tinto PLC, 2021).

1.1 In Search of New Opportunities

Following the discovery of gold at Sutter's mill in January 1848, more than 300,000 fortune seekers from the four corners of the globe converged on California in an effort to secure their financial future. While some prospectors who arrived early found gold most failed to realize their dream of striking it rich. Production peaked in 1852 and by 1860 much of the easily accessible placer gold in streams along the western flank of the Sierra Mountains had been recovered (Clark, 1970). Profitable mining of the remaining ores required substantial financial resources and technical expertise that were well beyond the means of the average prospector.

Undeterred by their lack of success along California's Mother Lode, prospectors trekked throughout the West in search of the next discovery. Over the next decade important mineral discoveries were made at Virginia City, Nevada (1859), Idaho Springs, Colorado (1859), Central City, Colorado (1859), Aurora, Nevada (1860), Austin, Nevada (1862), Bannack, Montana (1862), Alder Gulch, Montana (1863), Helena, Montana (1864), and elsewhere (Koschmann and Bergendahl, 1968).

Prospectors who ventured into the western portion of the New Mexico Territory, which became the Arizona Territory in 1863, found rich placer gold deposits at Gila City (now an abandoned ghost town) near Yuma in 1858, Rich Hill near Congress in 1862, and Lynx Creek near Prescott in 1863 (Koschmann and Bergendahl, 1968).

Prior to the 1870s, prospectors were mainly searching for gold or silver, which could be easily extracted with little effort or expense. Their forays into the vast, remote and often inhospitable regions of the West commonly resulted in many discoveries that were short-lived and are now little more than a memory. However, a few were far more significant and long lasting.

Bingham Canyon (1863) in Utah, Butte (1864) in Montana, and Robinson (1868) in Nevada were initially mined for gold and silver, but later became important producers of copper (Koschmann and Bergendahl, 1968). The transition from precious metals to copper production did not occur immediately. It took time to develop the infrastructure required to profitably mine and extract copper from these ores. This development took place during a period of rapid industrial growth (i.e., 1865-1914), which coincided with the linking of these remote sites via rail with eastern markets, where the meteoric demand for the red metal was spurred by rapidly expanding electric power grids and communication networks (Mohajan, 2020).

In the Arizona Territory, the Globe-Miami Mining Region evolved from a small, insignificant silver camp into one of America's largest copper producers. The first reported copper production in Globe-Miami Mining Region occurred at the Hoosier mine in 1878 only nine years after silver was discovered. Globe-Miami's largest early copper producer, the Old Dominion mine, commenced operations during the spring of 1882.

Prior to 1911, most of the copper production was derived from high-grade copper veins located in the southern portion of the Globe Hills. During these early years, the major challenges to the development of the area's vast copper resources were related to its location in a remote mountainous region that made access to eastern markets difficult. High shipping costs to a distant railhead by wagon limited production to only the highest grade ores, making these early operations marginally profitable and vulnerable to minor fluctuations in the price of copper. These impediments were largely resolved with the arrival of the Gila Valley, Globe and Northern Railroad at Globe in December 1898.

Recognition of widespread porphyry copper mineralization in the hills north and west of present-day Miami, Arizona also occurred very early. However, the low copper content of these deposits made its economic recovery impossible with the technology that was available at the time.

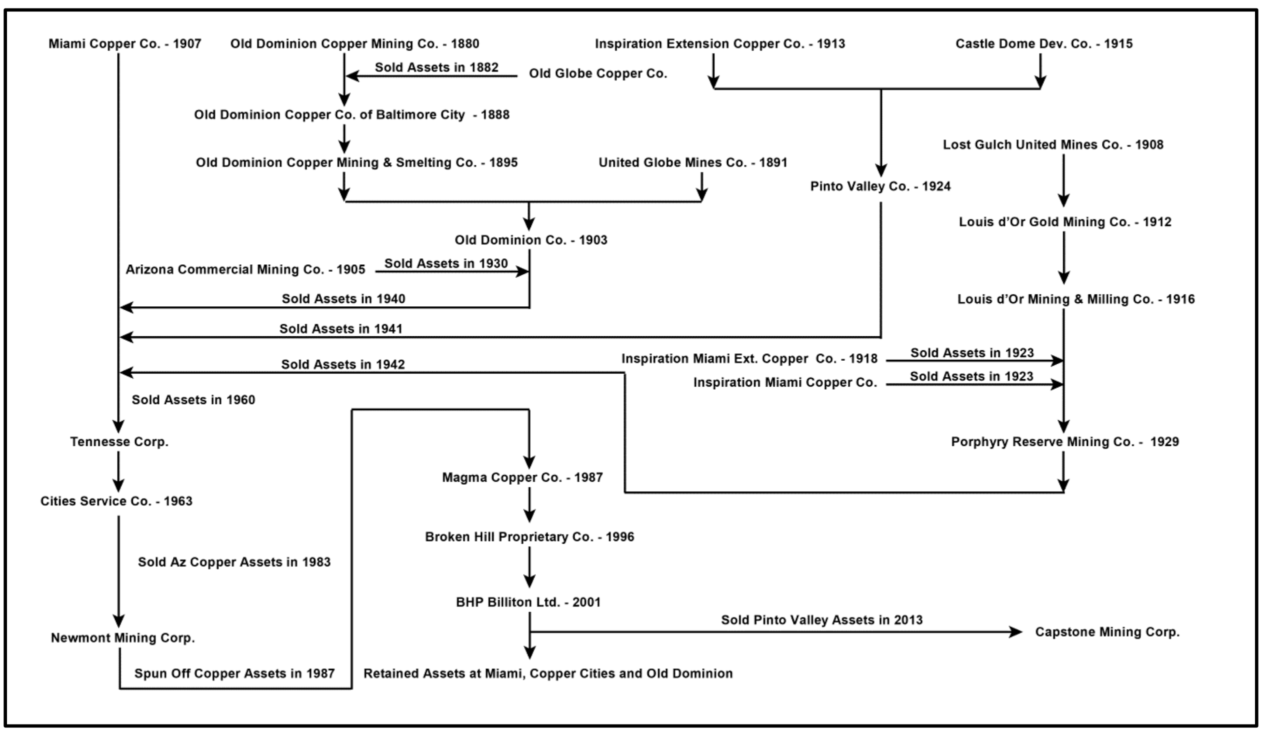


Figure 3. Ownership history of Miami, Castle Dome, Pinto Valley, Copper Cities, and Old Dominion mines

Development of these porphyry copper deposits began during the final decade of the 19th century. Early mining ventures included the Inspiration, Live Oak, Black Warrior, Keystone, and Cordova Copper properties, which were explored and slowly developed with limited success, prior to 1910.

The Miami Copper Company (incorporated in November 1907) and Inspiration Consolidated Copper Company (incorporated in December 1911) played a prominent role in the successful development and production of porphyry copper ores of this region.

The Miami Copper Company and its successors, shown in Figure 3, developed copper ores at Miami, Castle Dome, Copper Cities, and Pinto Valley. BHP Billiton Ltd. currently controls these assets, but sold its Pinto Valley holdings to Capstone Mining Corporation in 2013.

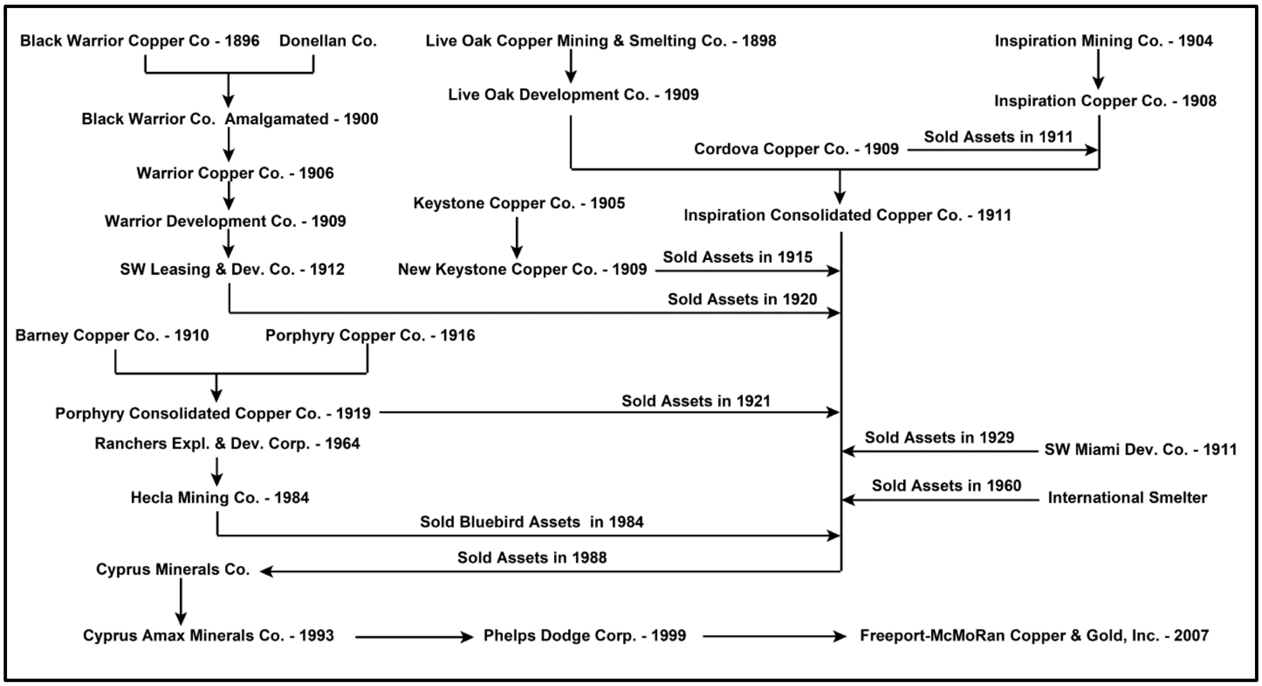


Figure 4. Ownership history of Inspiration, Live Oak, Keystone, Black Warrior, and Bluebird mines

The Inspiration Consolidated Copper Company developed and mined copper ores from Joe Bush, Thornton, Live Oak, Upper Ox Hide, and Lower Ox Hide. They acquired the adjoining Bluebird property from the Hecla Mining Company in 1984 (Figure 4). Freeport-McMoRan Copper and Gold, Inc. (renamed Freeport-McMoRan, Inc in 2014) has controlled these assets since 2007.

1.2 Advances in Technology and Mining Practices

Virtually all of the early copper production in the Globe-Miami Mining Region involved extracting oxidized and enriched ores by underground mining methods. In January 1942, Miami Copper's Castle Dome project became the region's first operation to employ conventional open pit mining technology (i.e., shovel and haul truck) that is currently used by many modern producers. Open pit mining commenced at Inspiration Consolidated Copper's Live Oak operation in January 1948.

The Miami Copper Company began one of America's longest-lived and productive in-place solution mining projects in December 1941, extracting copper from a broken and fragmented zone located above an inactive portion of their underground block-caving operation. Full-scale solution mining operations commenced after conventional underground operations ceased in 1959 and continued to recover copper until commercial leaching activities were suspended in 2013.

Methods of processing copper ores evolved to meet challenges presented by changes in the metallurgical character of the mineralization encountered over the life of these mining projects. During the early days, operations near Globe treated high-grade copper ore in blast furnaces, initially producing a black copper product (also known as copper bullion), containing 94% to 96% copper, and later as an intermediate matte product (~50% copper) that was upgraded to a blister copper product (~99.5% copper). As the copper content of the ores declined during the early 1900s, primitive gravity concentrators employing jigs, vanners and tables were introduced to produce a concentrate product that could be treated by these early smelting facilities.

Inspiration Consolidated Copper's concentrator was revolutionary as it was the first large-scale facility in the United States to employ flotation as the primary method to process copper ores (Parsons, 1933). Flotation was an important innovation and largely replaced gravity circuits at mining operations throughout the world. Over time, Miami Copper and Inspiration Consolidated Copper developed processes that efficiently recovered copper from the abundant mixed oxide/sulfide ores in the district.

The Ranchers Exploration and Development Corporation's Bluebird mine was the world's first mining project to employ solvent extraction-electrowinning (SX-EW) technology to recover copper from commercial dump leaching operations (Cole 1969). Today, approximately 46% of the copper produced in the United States is recovered by this cost-effective SX-EW technology (Flanagan, 2021).

The introduction of oxide/sulfide concentrators during the first decade of 20th century led to additional challenges at the early smelting operations. Smelters in use at the time employed blast furnaces that were ideally suited for direct-smelting ores (i.e., DSO). However, smelting fine material, such as copper concentrates, proved to be more difficult (Rickard, 1987). If care was not taken during the smelting process, much of the metal contained within this fine material was lost through the small smoke stacks that were in use at the time. The Old Dominion smelter resolved this problem through the introduction of dust chambers, where the fine material was allowed to settle out. Briquetting plants were commonly used to agglomerate the fine concentrates prior to smelting (Stevens, 1908). However, this issue was not completely resolved until the widespread introduction of reverberatory furnaces during the early 1900s.

By the time International Smelting and Refining erected its smelter at Miami, management decided to employ the less troublesome reverberatory furnace technology, which was more suitable for the concentrate products produced in the Globe-Miami Mining Region. Commissioned in July 1915, this facility was the third copper smelter in Arizona erected without a blast furnace (Rickard, 1987). Inspiration Consolidated Copper purchased the Miami smelter from Anaconda in 1960. Modernized in the early 1970s and again during the early 1990s, this facility is presently one of only two operating copper smelters in the United States.

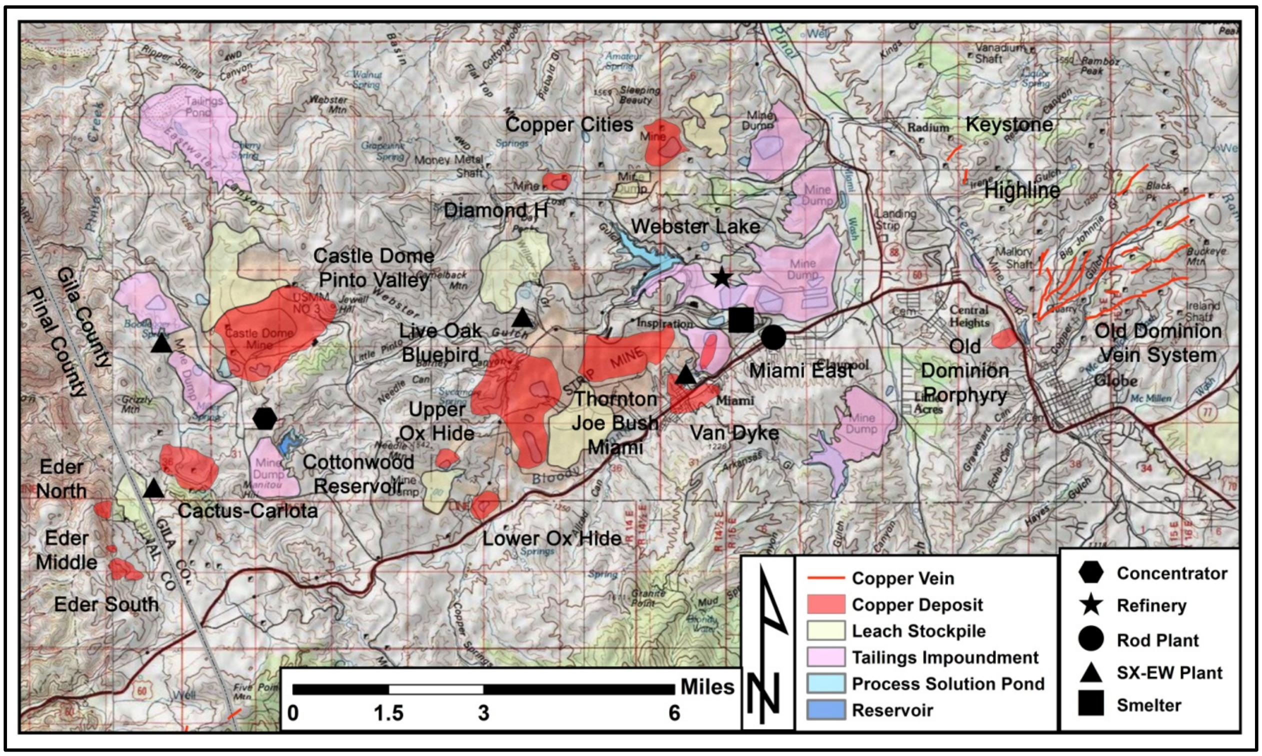


Figure 5. Major copper deposits and processing facilities in the Miami-Inspiration mineral district. The Inspiration refinery was closed in 2005 and Miami Copper SX-EW plant closed in 2013

Today, the Miami-Inspiration mineral district has two operating mines; Eder South and Pinto Valley (Figure 5). After 100 years of production, Freeport-McMoRan's mine at Inspiration ceased mining operations in 2015, but continues to produce copper by leaching ores on existing mine stockpiles. They also operate a copper smelter and rod plant at Miami. In addition to the low-grade primary (i.e., hypogene) resource remaining at Inspiration, Miami and Copper Cities, unmined copper resources are also present at Miami East, Van Dyke, Cactus-Carlota, Eder North, and Eder Middle.

1.3 Scope of Study

Mining district is a legal term used to describe a geographically distinct mining area that is usually designated by a name related to a nearby natural landmark or a recognizable mining camp (Grant et al., 2022). Prior to passage of the General Mining Law of 1872, mining districts were governed by rules and regulations created by the prospectors working within the district (Lacy, 1987).

However, in strongly mineralized regions, such as Arizona, it is not uncommon to find two or more genetically different mineral deposit types within the same mining district (e.g., Laramide San Manuel porphyry copper system overprinted by the Early Miocene Tiger mesothermal vein). The concept of "mineral district" was developed to categorize mineralized areas based on geological criteria such as metals and alteration assemblages, age of mineralization and ore forming processes (Keith et al., 1983).

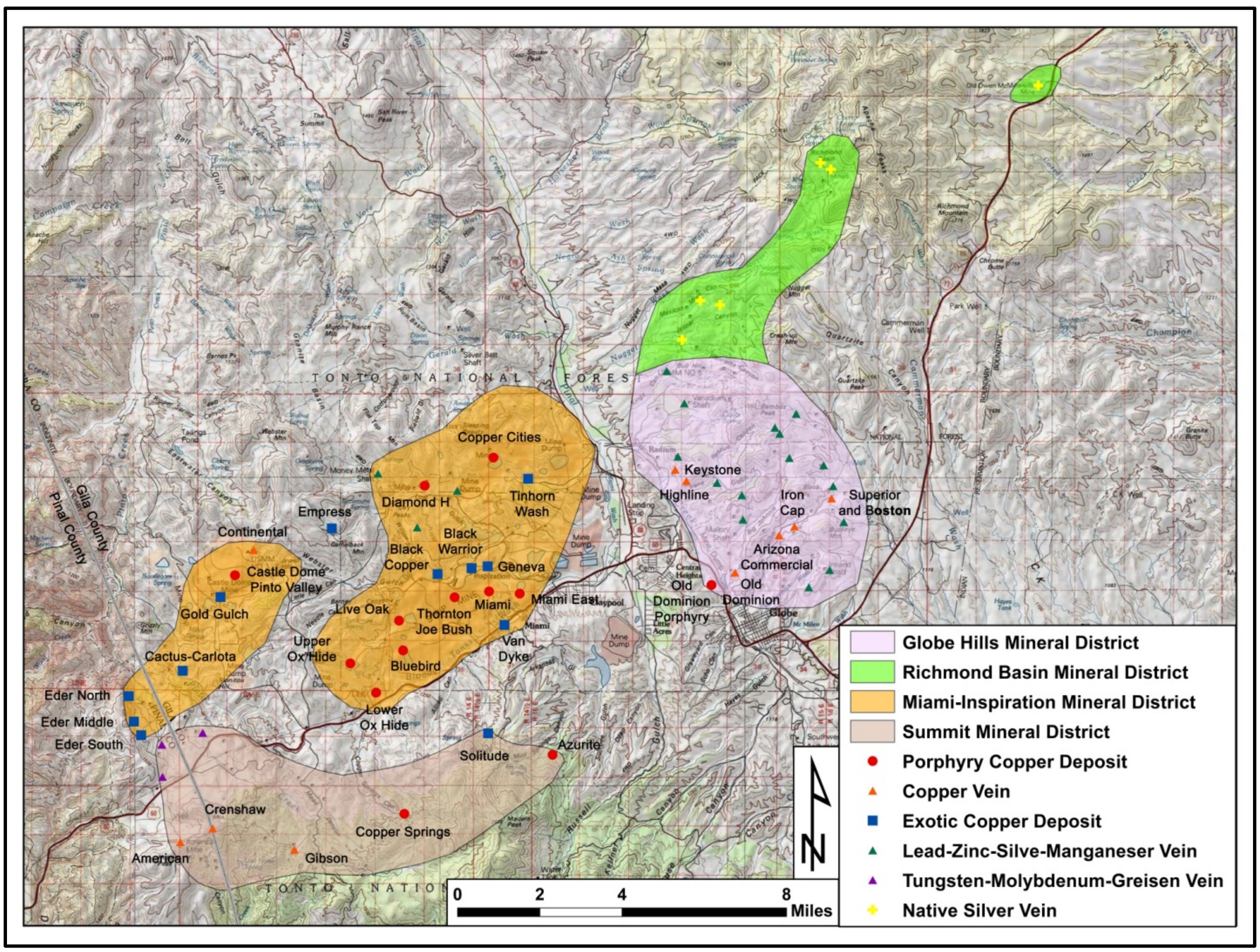


Figure 6. Major copper deposits located in the historical mineral districts of the Globe-Miami Mining Region (modified from Keith et al., 1983)

The Globe-Miami Mining Region, shown in Figure 6, includes four separate mineral districts (modified from Keith et al., 1983). Copper is the principal product recovered in the Globe Hills, Miami-Inspiration and Summit mineral districts. Originally included within the Globe Hills mineral district by Keith et al. (1983), the Richmond Basin mineral district is noted for its high-grade silver veins and placer silver occurrences around Richmond Basin and McMillenville that initially attracted the attention of early prospectors to the region.

The Globe Hills, Miami-Inspiration and Summit mineral districts include three Laramide age (i.e., Late Cretaceous to Paleocene) porphyry copper systems and their associated vein occurrences, which are related to the emplacement of the Schultze Granite. Associated exotic copper occurrences post-date the formation of the primary sulfide deposits and were formed during the oxidation of primary sulfides, when the copper was remobilized by meteoric waters and re-deposited at a distant site.

Unlike the porphyry copper systems in the Globe-Miami Mining Region, the rich silver occurrences of the Richmond Basin mineral district occur along short, narrow veins, where silver is the only payable metal. Long overshadowed by the region's prolific copper production, recent discoveries of large silver nuggets in the area have revived interest in the district's potential for rich silver lodes. While much exploration and research remains to be done to confirm the economic potential and nature of these occurrences, examination to date suggests they pre-date (i.e., probably Mesoproterozoic) the Laramide porphyries and occur in a geological setting that is similar to the silver occurrences at the Cobalt mining camp in Ontario, Canada (Osterman, 2021).

This paper presents a summary of the area's geology, structural setting, copper deposit types, and a description of the major mineral deposits of the region. Geologic models that have been postulated to explain the spatial and genetic relationships between the various mineral deposits of the Globe-Miami Mining Region are also briefly discussed.

This is followed by a comprehensive review of the area's cultural and mining history, including prehistoric indigenous inhabitants of the region and early mining communities of Globe and Miami. It also covers the discovery and development of the major ore deposits, evolution of mining practices and technology employed over the life of the mining operations, recent reclamation activities, and the region's future exploration potential.

1.4 Historical Production Statistics

The Globe-Miami Mining Region is the fifth largest copper producing area in the United States, accounting for 19.1 billion pounds or nearly 7% of the nation's total historic output as of December 31, 2020. Only the West Mountain, Copper Mountain, Pima, and Butte mineral districts have produced greater amounts of the red metal (Table 2).

Table 2. Top twenty copper producing mineral districts in the United States (source from Briggs, 2021)

Rank	Mineral District	Deposit(s)	State	Years	Copper Production Lbs.	Percentage of Total U.S. Copper Production
1	West Mountain	Bingham Canyon, Carr Fork	Utah	1865-2020	44,124,534,000	16.13
2	Copper Mountain	Morenci, Metcalf, Coronado, Garfield	Arizona	1872-2020	41,946,041,000	15.33
3	Pima	Mission, Twin Buttes, Sierrita, Esperanza	Arizona	1880-2020	22,942,176,000	8.39
4	Butte	Berkeley, Continental	Montana	1880-2020	22,594,699,000	8.26
5	Globe-Miami	Inspiration, Pinto Valley, Miami, Old Dominion	Arizona	1875-2020	19,110,211,000	6.99
6	Central	Chino, Continental	New Mexico	1801-2020	16,419,318,000	6.00
7	Mineral Creek	Ray	Arizona	1881-2020	15,204,410,000	5.56
8	Eureka	Bagdad	Arizona	1890-2020	9,429,326,000	3.45
9	San Manuel	San Manuel, Kalamazoo	Arizona	1956-2002	9,394,137,000	3.43
10	Warren (Bisbee)	Lavender, Copper Queen, Calumet & Arizona	Arizona	1880-2013	8,187,951,000	2.99
11	Robinson	Liberty, Ruth, Veteran, Tripp, Kimberly	Nevada	1907-2020	8,021,234,000	2.93
12	Burro Mountains	Tyrone	New Mexico	1904-2020	7,716,064,000	2.82
13	Calumet	Calumet & Hecla, Kearsarge, Osceola	Michigan	1865-1968	7,081,890,000	2.59
14	Ajo	New Cornelia	Arizona	1899-1985	6,180,323,000	2.26
15	White Pine	White Pine	Michigan	1868-1995	3,907,406,000	1.43
16	Verde	United Verde, UV Extension	Arizona	1883-1992	3,753,114,000	1.37
17	Pioneer	Magma	Arizona	1875-1996	2,602,933,000	0.95
18	Silver Bell	El Tiro, Oxide, North Silver Bell	Arizona	1881-2020	2,493,954,000	0.91
19	Safford	Dos Pobres, San Juan, Lone Star	Arizona	1903-2020	2,053,426,000	0.75
20	Yerington	Yerington, MacArthur	Nevada	1905-2020	1,901,942,000	0.70
Total				1801-2020	255,065,089,000	93.24

Much of the Globe-Miami Mining Region's early production was derived from the Globe Hills mineral district, where high-grade copper ores were mined from narrow veins confined to northeast trending fault zones. Four mining operations; the Old Dominion, Arizona Commercial, Iron Cap, and Superior and Boston, accounted for more than 99% of the district's reported copper production (Table 3).

Table 3. Historical production from Globe Hills mineral district, Gila County, Arizona. Includes production from the Richmond Hill and McMillenville areas (modified from U. S. Bureau of Mines data)

Mine Name	Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
Arizona Commercial	1905-1981	2,084,514	106,268,120	0	0	0	18,333	514,743
Iron Cap	1908-1963	679,867	66,717,601	0	0	0	7,179	1,392,584
Old Dominion	1882-1959	9,337,900	806,851,648	199,450	24,400	0	73,858	3,306,024
Superior & Boston	1908-1959	246,896	23,404,095	0	0	0	270	1,380,494
Others (371)	1875-1964	72,339	9,041,577	3,294,047	75,696	0	3,200	1,421,371
Total	1875-1981	12,421,516	1,012,283,041	3,493,497	100,096	0	102,840	8,015,216

Prominent mines of the Miami-Inspiration mineral district include Inspiration (Joe Bush, Thornton, Live Oaks, Upper Ox Hide, and Lower Ox Hide), Porphyry Mountain (Castle Dome and Pinto Valley), Miami, Copper Cities, Bluebird, and Cactus-Carlota. Approximately 18.1 billion pounds of copper were recovered from 2.5 billion tons of ore (Table 4).

Table 4. Historical production from Miami-Inspiration mineral district, Gila and Pinal Counties, Arizona (modified from U. S. Bureau of Mines and other data)

Mine Name	Period	Milled & Direct Smelting Ore Short Tons	Leach Stockpile Short Tons	Cu Lbs.	Pb Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
Black Warrior	1902-1919	348,474	0	44,397,083	0	0	0	29,041
Blue Bird	1950-1983	72	48,215,493	215,066,445	0	0	0	0
Cactus-Carlota	1941-2020	51,998	42,430,000	205,193,978	0	0	0	89
Castle Dome	1907-1973	41,443,387	48,000,000	584,464,283	0	0	9,385	583,069
Continental	1906-1941	34,000	0	2,000,000	0	0	3,600	134,000
Copper Cities	1907-1982	77,375,272	46,197,000	890,897,494	0	1,481,640	19,351	1,315,481
Inspiration	1899-2020	332,825,812	566,081,754	8,236,245,772	813,025	5,741,631	17,319	2,614,474
Keystone	1899-1910	5,209	0	1,033,336	2,994	0	131	617
Lower Ox Hide	1967-1982	0	13,426,493	39,010,202	0	0	0	0
Miami	1910-2013	152,382,123	0	3,093,947,975	0	9,742,831	34,971	2,431,021
Pinto Valley	1974-2020	604,503,111	532,349,000	4,703,101,802	0	22,463,324	125,378	7,211,408
Upper Ox Hide	1968-1974	0	14,077,250	50,894,729	0	0	0	0
Van Dyke	1929-1989	122,187	0	13,243,437	0	0	0	341
Others (19)	1907-1962	13,627	0	930,380	59,201	0	823	9,669
Total	1899-2020	1,209,105,322	1,310,776,990	18,080,426,916	875,220	39,429,426	210,958	14,329,210

The Gibson mine was the only significant producer in the Summit mineral district, accounting for 98.3% of the district's total copper production (Table 5). Although its output was insignificant compared to the Globe Hills and Miami-Inspiration mineral districts, deposits in the Summit mineral district are noteworthy in that they appear to represent the roots of two of the three recognized porphyry copper systems in the Globe-Miami Mining Region (Maher, 2008).

Table 5. Historical production from the Summit mineral district, Gila and Pinal Counties, Arizona (modified from the U. S. Bureau of Mines data)

Mine Name	Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
Gibson	1903-1969	55,750	17,201,360	0	0	0	129	14,775
Others (Gila Co. 12)	1907-1959	682	46,385	0	0	0	0	132
Others (Pinal Co. 4)	1916-1962	1,842	253,046	2,196	0	0	18	7,857
Total	1903-1969	58,274	17,500,791	2,196	0	0	147	22,764

2 REGIONAL GEOLOGY

The Globe-Miami Mining Region straddles the boundary between the Southern Basin and Range Province and Transition Zone, a broad physiographic boundary that separates the Colorado Plateau to the north from the Southern Basin and Range Province to the south (Figure 7).

The Colorado Plateau of northern Arizona is an elevated area (4,900 to 9,200 feet), which is characterized by large valleys and a number of low-relief plateaus that are locally disrupted by monoclinal uplifts and incised by deep canyons of the Colorado River system (Menges and Pearthree, 1989).

Discontinuous northwest to northeast-trending mountain ranges separated by alluvial valleys typify the Southern Basin and Range Province, which varies from broad, mostly undissected valleys and low mountain ranges of southwestern Arizona to regions of greater altitude, local relief and basin dissection in the southeastern and northwestern portions of the state. Most of the drainages in southern Arizona are presently incorporated in the Gila River system (Menges and Pearthree, 1989).

The rugged terrain of Arizona's Transition Zone is characterized variably dissected alluvial basins and large mountain ranges, which are capped by erosional remnants of the Colorado Plateau (Menges and Pearthree, 1989).

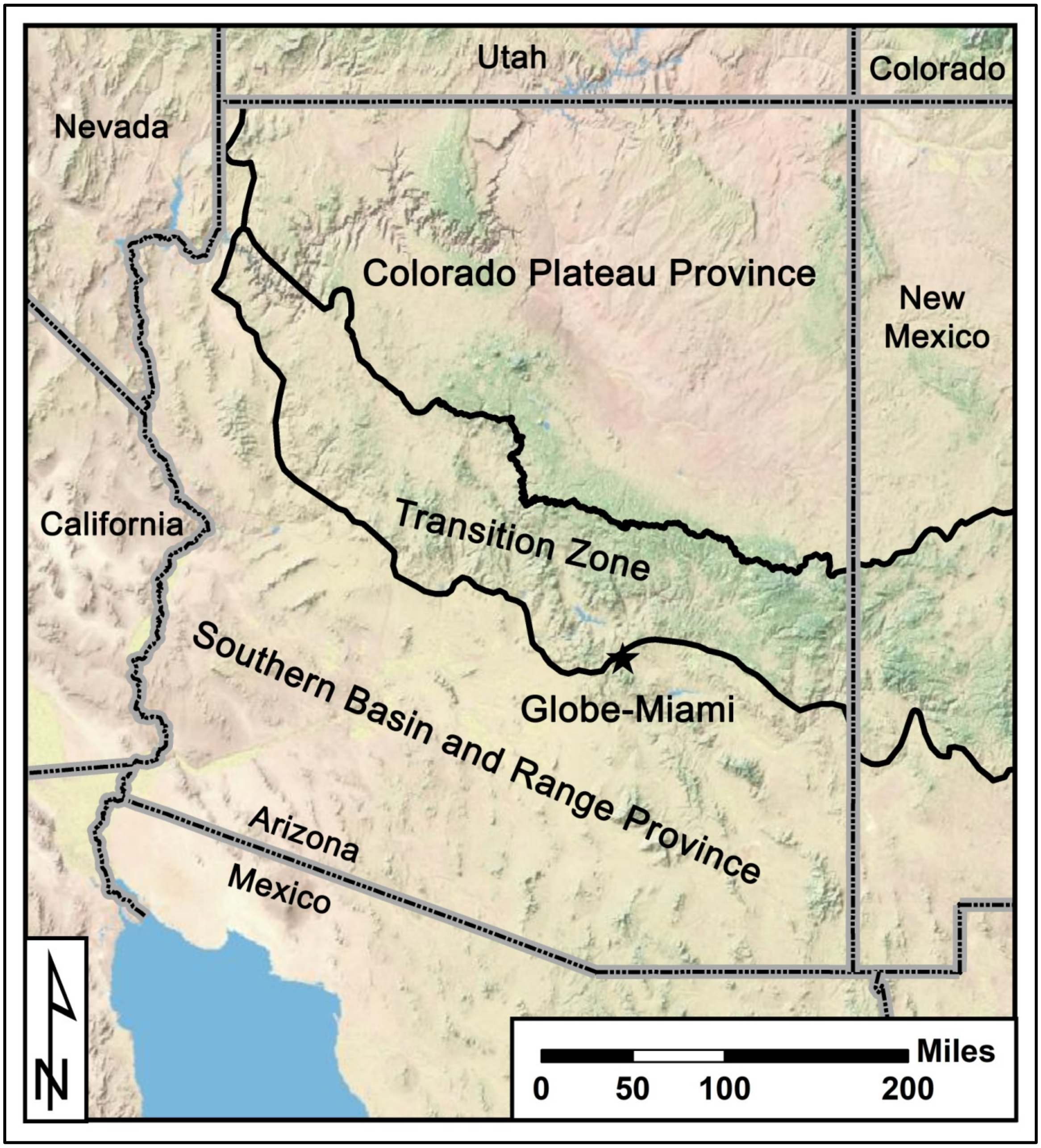


Figure 7. Globe-Miami Mining Region (star) and the physiographic provinces of Arizona and southwest New Mexico (modified from Menzes and Pearthree, 1989)

2.1 Stratigraphic Section

The oldest formation exposed in the Globe-Miami Mining Region is the Paleoproterozoic Pinal Schist (Figure 8). Characterized by a turbiditic sequence of feldspathic sandstone, greywacke, siltstone and shale, these sediments were deposited in the Pinal Basin approximately 1,710 to 1,675 million years ago (Conway and Silver, 1989). Deformed during the Mazatzal Orogeny (1,675 to 1,625 Ma), these strata were subsequently cut by syntectonic and post-tectonic intrusive batholiths and regionally metamorphosed under greenschist facies conditions to produce a metasedimentary sequence composed of fine to coarse-grained quartz-muscovite schist with variable amounts of chlorite (Conway and Silver, 1989).

Age	Formation	Symbol	Lithologic Description
Recent	Alluvium		Gravel, sand and silt occuring along main washes and intermittent streams. (Thickness - less than 50 feet)
	Talus		Locally derived angular fragments of bedrock on steep hillsides and slope wash.
Middle Miocene to Pliocene	Gila Conglomerate		Alluvial fan deposits composed of coarse conglomratic detritus largely derived from local sources with interbedded layers of sand and silt. Outcrops are light gray to light brown, moderately well consolidated to friable and commonly cemented by siica or carbonate. Locally interbedded with basaltic lava flows. (Thickness - locally exceeds 4,000 feeet)
Early to Middle Miocene	Apache Leap Tuff		Light brownish gray, massive dacitic tuff with small feldspar, quartz and biotite phenocrysts in an aphanitic matrix. K-Ar age - 17.2 to 20.4 Ma (Thickness - 1,200 feet)
Late Eocene to Middle Oligocene	Whitetail Conglomerate		Locally derived conglomerate from older units that was deposited in low lying areas and along stream channels prior to deposition of the Apache Leap Tuff. Contains angular to subangular pebbles, cobbles and boulders in a coarse-grained, poorly sorted sand matrix. Generally moderately well consolidated. (Thickness - up to 500 feet)
Paleocene	Schultze Granite		Grayish yellow, medium-grained, porphyritic granodiorite, quartz monzonite and quartz porphyry (U-Pb zircon age - 62.9 to 66.9 Ma). Local marginal phase of the Schultze Granite is represented by a porphyry containing quartz, orthoclase and plagioclase phenocrysts in a microcrystalline groundmass.
Cretaceous	Diorite Porphyry		Thin sills, dikes and small irregular masses of light gray to medium gray diorite prophyry with plagioclase phenocrysts in an aphanitic groundmass.
Pennsylvanian	Naco Limestone		Fine to medium-grained, thin-bedded, light gray, cherty limestone interbedded with thin layers of gray marl or calcareous shale. (Thickness - up to 500 feet)
Mississippian	Escabrosa Limestone		Basal member is a massive cliff-forming to medium-bedded, coarsely crystalline, light to medium gray limestone, which is overlaiin by a thin to medium-bedded, mostly fine-grained, light to medium gray limestone. (Thickness - 260 to 365 feet)
Devonian	Martin Formation		Subdivided into five members. 1) Basal conglomerate overlain by quartz sandstone, 2) interbedded limestone and dolomitic limestone, 3) coarse-grained, gray to brown, cross-bedded quartzite, 4) uniform medium to thick-bedded limestone, and 5) gray calcareous shale and marl. (Thickness - 150 to 300 feet)
Mesoproterozoic	Diabase		Dark gray or dark greenish gray, aphanitic to coarse-grained diabase, occurs as dikes and sills. K-Ar age - 1,050 to 1,068 Ma
	Troy Quartzite		Braided steam deposits represented by a basal conglomerate grading upward into a dark reddish-brown, pebbly sandstone and argillaceous sandstone. (Thickness - 160 to 200 feet)
	Apache Group: Basalt		Gray to brownish black, aphanitic to fine-grained, visicular olivine basaltic lavas, now composed largely of serpentine, calcite and iron oxides. (Thickness - 0 to 220 feet)
	Apache Group: Mescal Limestone		White, light greenish gray to medium gray, thin-bedded, siliceous, stromatolic limestone. White, gray, brown and black chert is common as nodules, layers and irregular masses. (Thickness - 250 to 360 feet)
	Apache Group: Dripping Spring Quartzite		Tidal flat and braided stream deposits represented by a basal quartz pebble conglomerate (10 to 20 feet) known as the Barnes Conglomerate, which is overlain by light-gray to light-brownish gray, medium to coarse-grained, thinnly laminted and cross-bedded quartzite that grades upward into a thin-bedded (1 to 12 inches) quartzite interbedded with soft, fissile, arenaceous shale. (Thickness - 350 to 650 feet)
	Apache Group: Pioneer Formation		Alluvial fan and braided stream deposits represented by interbedded fine to locally coarse-grained arkosic quartzite, siltstone and shale. (Thickness - 200 to 270 feet)
	Apache Group: Scanlan Conglomerate		Conglomerate with well-rounded to sub-angular pebbles and cobbles (0.5 to 6 inches) of white quartz, schist and granite in a coarse-grained, poorly sorted, silica-cemented arkosic matrix. (Thickness - 0 to 12 feet)
	Ruin Granite		Light brown to light gray, coarse-grained, porphyritic quartz monzonite to granite with large pink orthoclase phenocrysts and smaller quartz phenocrysts. K-Ar age - 1,440 Ma
Paleoproterozoic	Willow Spring Granodiorite		Biotite granodiorite to quartz monzonite porphyry with large orthoclase phenocrysts and smaller phenocrysts of quartz, biorite and plagioclase in a fine-grained matrix.
	Madera Diorite		Medium-grained gray granodiorite. K-Ar age - 1,665 ± 40 Ma
	Manitou Hill Granite		Yellowish gray, fine to medium-grained, crudely foliated, muscovite granite.
	Solitude Granite		Equigranular, medium-grained, nearly white, two-mica granite.
	Pinal Schist		Turbidite sequence, now represented by fine to coarse-grained, isoclinally folded, light to dark gray, quartz-muscovite schist with variable amounts of chlorite.

Figure 8. Stratigraphic section for the Globe-Miami Mining Region (modified from Peterson, 1962 and Peterson, 1960)

Paleoproterozoic syntectonic intrusive bodies in the Globe-Miami Mining Region include the Solitude Granite, Manitou Hill Granite, Madera Diorite (K/Ar age – 1,665 Ma), and possibly the Willow Springs Granodiorite. Mesoproterozoic post-tectonic intrusive batholiths are represented by the Ruin Granite (U/Pb age – 1,440 Ma) (Reynolds et al., 1986).

The Paleoproteroic and early Mesoproterozoic rocks are unconformably overlain by a younger unmetamorphosed sedimentary/volcanic sequence consisting of the Scanlan Conglomerate, Pioneer Formation, Dripping Springs Quartzite, Mescal Limestone, and basalt of the Mesoproterozoic Apache Group and the Troy Quartzite, which are preserved along the northern and western fringes of the Miami-Inspiration mineral district and in the Globe Hills (Peterson, 1962). An extensive complex of Mesoproterozoic diabase sills and dikes (K-Ar age – 1,068-1,050 MA) intrude the older units (Reynolds et al., 1986). Erosional remnants of the Paleozoic stratigraphic section, which include the Martin Formation, Escabrosa Limestone and Naco Limestone, are locally preserved above an erosional unconformity, overlying the Proterozoic units (Peterson, 1962).

The Proterozoic basement was intruded by the Laramide-age Schultze Granite, a large irregular stock that ranges in composition from granodiorite to quartz monzonite and quartz porphyry (Creasey, 1980). Restricted to the northeastern and southeastern edges of the Schultze Granite, peripheral porphyritic phases (Figure 9) are spatially and genetically related to copper mineralization in the Globe-Miami Mining Region (Creasey, 1984). Radiometric (U/Pb zircon) dating of this intrusive body yield ages ranging from 66.9 to 62.9 million years (Seedorff et al., 2019). Spatial relationships between the porphyritic phase of the Schultze Granite and the copper deposits are shown in Figure 10.

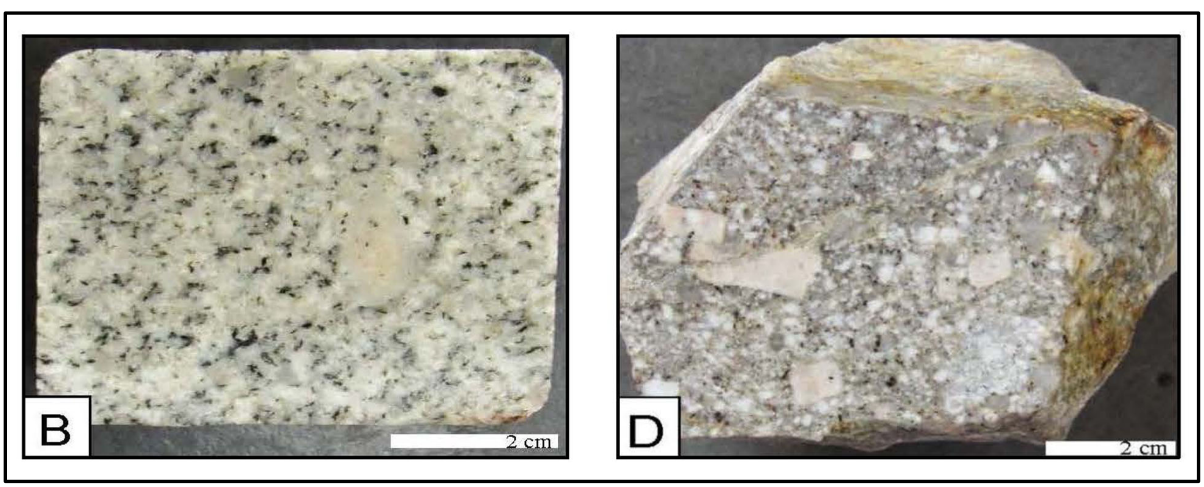


Figure 9. Main phase of the Schultze Granite (B) and Schultze Granite Porphyry (D) (photo from Swaim, 2020)

Following a period of uplift, erosion and oxidization/supergene enrichment of the primary copper ores, Paleocene and older units were locally unconformably overlain by older Late Eocene to Middle Oligocene clastics of the Whitetail Conglomerate, felsic volcanics of the Miocene Apache Leap Tuff (informally known as dacite), and younger basin-fill clastic sediments with locally intercalated basalt lava flows of the Gila Group (informally known as Gila Conglomerate).

2.2 Structural Setting

The Globe-Miami Mining Region, shown in Figure 10, has been subdivided into three major structural blocks: the eastern Globe Hills block, central Upper and Lower Pinal Creek Basin block, and western Inspiration block (Peterson, 1962). They reflect the Basin and Range topography we see today, which was formed between late Miocene (10-8 MA) until early Pleistocene (6-2 MA) time and continued to develop at a much slower rate until present (McKee and Anderson, 1971; Nations et al., 1982; Keith and Wilt, 1985).

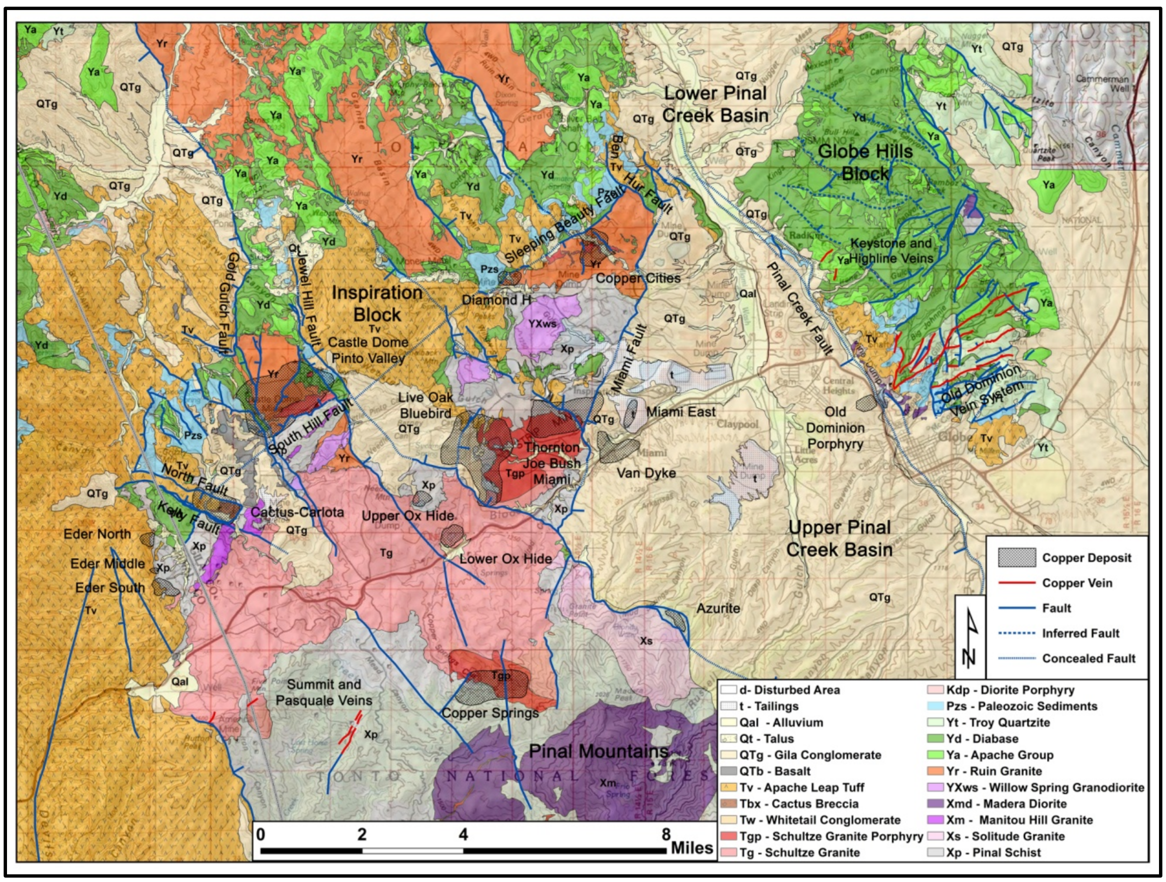


Figure 10. Geologic map of the Globe-Miami Mining Region and the area's copper deposits (modified from Peterson, 1960; Peterson, 1962; Peterson, 1963; Peterson, 1969; Creasey, 1984; Ransome, 1903; Wilson et al., 1959; Wrucke et al., 2004)

Outcrops of the Globe Hills horst block are predominantly diabase, which forms an extensive complex of interlaced dikes and sills that cut the Mesoproterozoic Apache Group and Troy Quartzite. Paleozoic carbonates are locally preserved in the western and southern portions of Globe Hills. In the northern portion of Globe Hills, repetition of the stratigraphic section that dips 15 to 45^{o} to the southwest, suggests that it is cut by several, poorly defined, northwest trending step faults that are downthrown to the northeast (Maher, 2008). Strata in the southern portion of the Globe Hills generally dip 15 to 30^{o} to the south or southeast and are cut by northeast striking faults that converge to the southwest. While most of these structures dip moderately to the southeast; a few are vertical or dip steeply to the northwest (Peterson, 1962).

The Globe Hills structural block is bounded on the southwest by the Pinal Creek fault zone. This broad, poorly exposed zone of sub-parallel, southwest dipping, normal faults extend from near the junction of Pinal Creek and Miami Wash, through underground mine workings of the Old Dominion mine southeastward along the course of Pinal Creek. Downthrown to the southwest, total cumulative displacement along this structural zone is probably less than 600 feet (Peterson, 1962).

The Upper Pinal Creek Basin is a major graben that lies between the Globe Hills structural block to the east and the Inspiration structural block on the west (Neaville and Brown, 1994). Roughly triangular in shape, it is bounded by the Miami fault to the west and the Pinal Creek fault on the east. Its southern boundary is a southeasterly striking normal fault zone exposed along the northern flank of the Pinal Mountains. Outcrops within the Globe Valley block consist entirely of Gila Conglomerate and younger alluvial sediments (Peterson, 1962).

The principal structure in the Globe-Miami Mining Region is the Miami fault. This normal fault strikes N20^{o}E and dips 50 to 60^{o} to the southeast (Peterson, 1962). The eastern hanging wall of the Miami fault has been down-dropped 2,000 to 3,000 feet, juxtaposing Gila Conglomerate against Proterozoic rocks and Laramide intrusions in the footwall (Reed and Simmons, 1962). The Inspiration-Miami copper deposit lies within the western footwall of the Miami fault. Its faulted extension, the Miami East deposit, lies at a depth of 2,500 to 3,700 feet within the hanging wall of this structure.

The Inspiration structural block is divided into two distinct structural domains separated by a boundary that is represented by the northeast striking, steeply dipping South Hill-Sleeping Beauty fault (Figure 10), which locally coincides with the physiographic boundary separating the Transition Zone to the northwest and Southern Basin and Range Province to the southeast. The last movement along this reverse fault post-dates Laramide porphyry mineralization (67-63 MA), but pre-dates late Miocene to early

Pleistocene Basin and Range extensional tectonism (10-2 MA) (Breitrick and Lenzi, 1987).

The Apache Group, diabase, Troy Quartzite, and Paleozoic sediments outcrop north of the South Hill-Sleeping Beauty fault zone. Basement exposures consist of the Ruin Granite. South of this structural zone, outcrops are mainly Pinal Schist and intrusive bodies that cut the schist. Units outcropping in the southern domain are structurally higher than the stratigraphic section exposed in the northern domain, suggesting at least 1,200 feet of vertical displacement along the South Hill-Sleeping Beauty structural boundary. Outcrops of younger units, including the Whitetail Conglomerate, Apache Leap Tuff and Gila Conglomerate are present in both structural domains (Peterson, 1962).

North of the South Hill-Sleeping Beauty fault zone, the complexly tilted, strata has been broken into a series of upright, northwest trending horsts, grabens and half-grabens that expose only several thousand feet of the stratigraphic section. Normal faulting has disrupted local anticlines and synclines developed within the Apache Group and Paleozoic sediments (Peterson, 1962). In the Gerald Hills area, similar attitudes within the Gila Conglomerate, Apache Leap Tuff and underlying sediments of the Apache Group suggest extensional deformation in this region is related to Late Miocene to Early Pleistocene Basin and Range tectonism (Skotnicki, 1995).

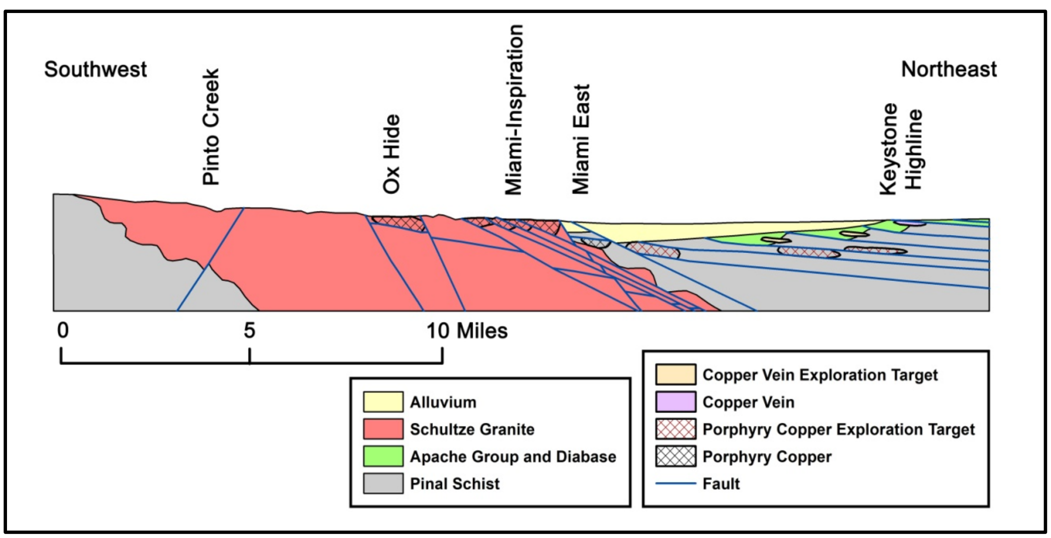


Figure 11. Schematic geologic cross-section of Globe-Miami Mining Region, showing dismembered copper deposits of the Miami-Inspiration porphyry copper system and possible exploration targets (modified from Maher, 2008)

The structural domain located south of the South Hill-Sleeping Beauty fault zone experienced significant southwest-northeast directed extensional deformation from Late Oligocene to Middle Miocene (i.e., 25 to 15 million years ago) time. This involved multiple, superimposed sets of predominately down-to-the-east normal faults that dismembered the porphyry copper systems and tilted the structural blocks up to 40 to 70^{o} to the west-southwest, resulting in an aggregate extension of about 200% (Figure 11). Like the northern structural domain, it was also deformed by a series of northwest trending horsts and grabens during the Late Miocene to Early Pleistocene further complicating its structural setting. The net product of this complex extensional history was the vertical telescoping of the earth's crust, which exposed numerous structural levels ranging from the Laramide paleo-surface to a paleo-depth of approximately 30,000 to 33,000 feet at the present erosional surface (Maher, 2008; Stavast, 2006).

3 ECONOMIC GEOLOGY

According to Maher (2008), much of the mineralization in the Globe-Miami Mining Region is related to three Laramide-age porphyry copper systems (i.e., Pinto Valley, Miami-Inspiration and Copper Springs systems) which occur within three northeast-trending linear belts. Deeper levels of each porphyry system are located at the southwest end of each belt, while the shallower levels are exposed at the northeast end (Figure 12).

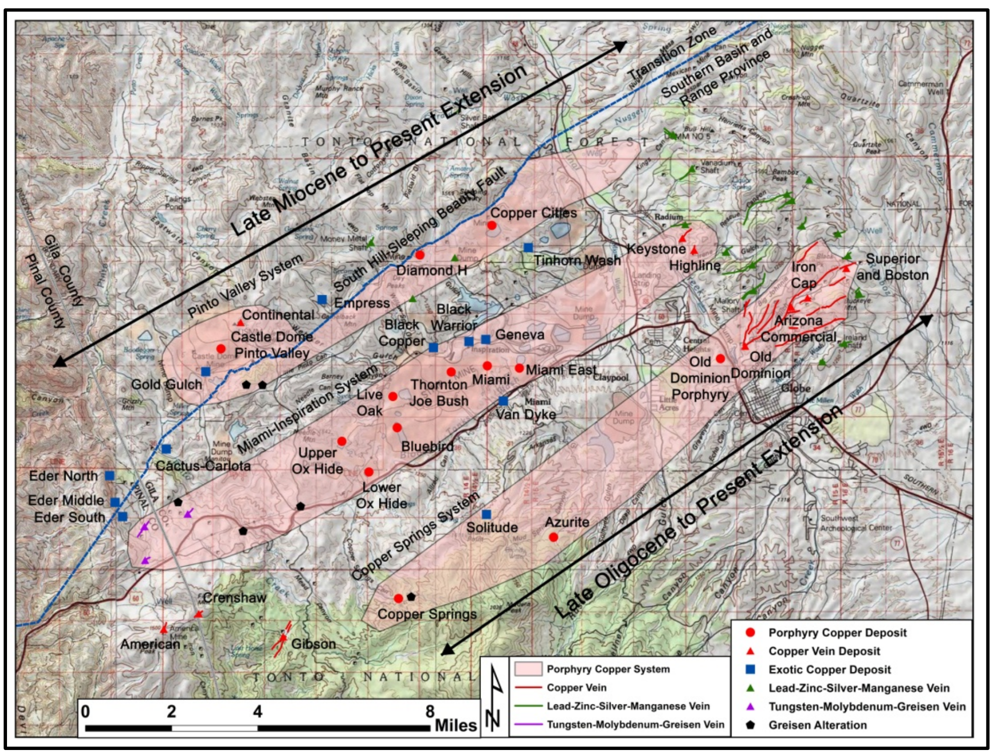


Figure 12. Extensional deformation has dismembered three porphyry copper systems in the Globe-Miami Mining Region. Deposits are classified by deposit type (modified from Maher, 2008)

At the northeast end of each belt, lead-zinc-silver veins with or without manganese occur above and peripheral to the copper veins that occurred within the upper levels of each porphyry copper system (Peterson, 1962). Deep level greisen (i.e., coarse-grained muscovite) alteration, locally accompanied by tungsten and molybdenum-bearing veins, is present in the root zone beneath each of the porphyry copper systems (Stavast, 2006).

Three types of copper occurrences have been recognized; porphyry copper deposits, copper veins and exotic copper deposits. They account for approximately 93.2%, 5.4% and 1.4% of the area's historic copper production, respectively.

Located south of the South Hill-Sleeping Beauty fault zone, the southern two porphyry copper systems (i.e., Miami-Inspiration and Copper Springs) are located entirely within the Southern Basin and Range Province. The northern porphyry copper system (i.e., Pinto Valley system) is cut by the South Hill-Sleeping Beauty fault zone, with the Pinto Valley deposit located in the Transition Zone and the Copper Cities and Diamond H deposits occurring within the Southern Basin and Range Province.

3.1 Porphyry Copper Deposits

Approximately 93.2% of the historic copper production from the Globe-Miami Mining Region has been derived from porphyry copper deposits at Inspiration (Thornton-Joe Bush, Live Oak, Bluebird, Upper Ox Hide, and Lower Ox Hide), Porphyry Mountain (Castle Dome and Pinto Valley), Miami, Copper Cities, and Diamond H (Figure 6). Porphyry copper resources located in the hanging wall of the Miami fault (i.e., Miami East) and deeper portions of the Old Dominion mine remain unmined.

Porphyry copper deposits are very large hydrothermal (i.e., hot water) systems that occupy many cubic miles of rock surrounding and including intrusive bodies that were the source for the metals and served as the thermal engines that drove these systems (Guilbert and Park, 1986).

The term "porphyry copper" is derived from the texture of the igneous rock, which commonly forms the intrusive bodies associated with these mineral systems. Porphyritic textures are characterized by larger crystals of feldspar, biotite and quartz, known as phenocrysts, which are surrounded by a matrix of very fine-grained crystals (Figure 9D). This texture is commonly found in intrusive bodies that have risen to a shallow level (i.e., 10,000 to 16,000 feet) in the earth's crust. They initially cooled slowly, which allowed the large crystals of quartz, biotite and feldspar to form. At some point during the cooling process, the magma was rapidly injected upward, chilled and crystallized, resulting in the finely crystalline matrix surrounding the larger phenocrysts.

As the intrusion was emplaced, its outer edges were the first to crystallize. This crystalline rind and surrounding baked zone of sedimentary, metamorphic and/or igneous wallrock were repeatedly fractured and broken by metal-rich hydrothermal fluids released from the crystallizing magma. These metal-laden hydrothermal fluids reacted with the surrounding rocks to form a large zoned alteration halo within and around the porphyry stock.

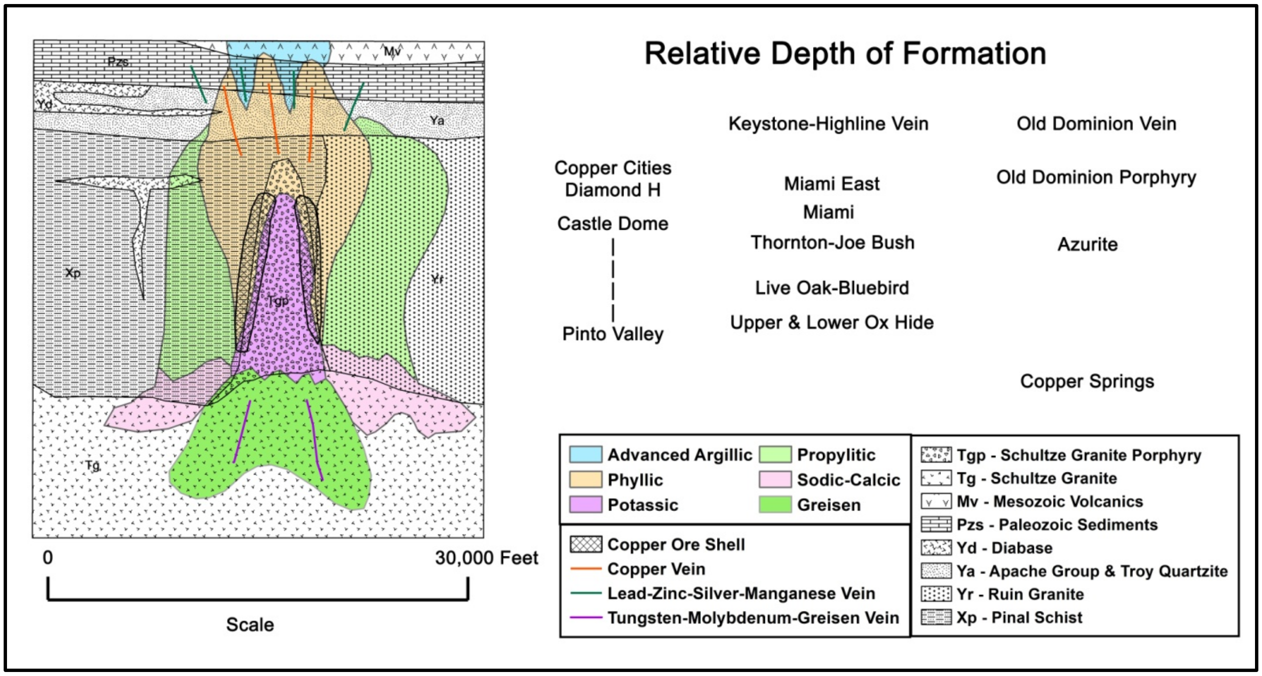


Figure 13. Schematic cross section through a structurally restored porphyry copper system in the Globe-Miami Mining Region, showing distribution of alteration assemblages, primary copper ore body, related vein assemblages, and the relative depths of formation for the copper deposits (modified from Maher, 2008; Breitrick and Lenzi, 1987)

A schematic cross-section of a typical porphyry copper system at Globe-Miami prior to mid-Tertiary extensional dismemberment is shown in Figure 13. The large alteration halo is characterized by a central zone of potassic alteration, overlain and surrounded by an intermediate phyllic zone, which is in turn enclosed by an outer propylitic zone.

Potassic alteration is characterized by the presence of quartz, secondary potassium feldspar, biotite (dark colored, shreddy mica), and anhydrite. It typically contains minor amounts of chalcopyrite, pyrite (i.e., fool's gold) and molybdenite (MoS_2).

Minerals associated with the phyllic alteration include quartz and sericite (fine-grained colorless mica) with abundant pyrite (FeS_2) and lesser amounts of chalcopyrite ($CuFeS_2$) and bornite (Cu_5FeS_4).

Propylitic alteration frequently gives the rock a greenish cast, as it is characterized by green-colored minerals, such as chlorite that replace mafic minerals and epidote, albite and calcite that replace plagioclase feldspar. Minor amounts of pyrite and hematite are also present.

A zone of advanced argillic alteration (quartz, clay, alunite, pyrophyllite, kaolinite, and pyrite) commonly overlies the central portion of porphyry copper systems. Greisen occurs beneath the potassic zone, where it is characterized by coarse-grained hydrothermal muscovite that occurs as vein fillings and associated envelopes. Greisen is commonly associated with quartz, minor pyrite and rare chalcopyrite, fluorite (CaF_2), wolframite ($(Fe,Mn)WO_4$), and scheelite ($CaWO_4$) (Maher, 2008).

Sodic-calcic alteration assemblages are localized in peripheral, deeper levels of the porphyry copper system. It is characterized by the minerals; oligoclase, actinolite, sphene, and epidote. Silica is commonly leached resulting in a vuggy mass of quartz-poor rock (Maher, 2008).

The copper ore body typically occupies a bell-shaped zone of stockwork veining and disseminated mineralization that straddles the boundary between the potassic and phyllic alteration zones and surrounds a low-grade potassic core, located at the center of the porphyry copper system. The primary (i.e., hypogene) sulfide mineral assemblage includes chalcopyrite, bornite and minor molybdenite accompanied by minor to moderate amounts of pyrite.

3.1.1 Miami and Inspiration

Porphyry copper mineralization at the Miami-Inspiration deposit is localized along the northern and western contact of the northeast lobe of the Schultze Granite, where a quartz porphyry stock (Figure 10) represents a peripheral phase of the intrusive body (Creasey, 1980). This intrusive body cuts the Paleoproterozoic Pinal Schist; approximately one-half of the ore occurs in the mineralizing intrusive and the remainder is hosted by the Pinal Schist (Olmstead and Johnson, 1966).

From southwest to northeast, deposits include Upper and Lower Ox Hide, Bluebird, Live Oak, Thornton, Joe Bush, Miami, and Miami East (Figure 10). Upper and Lower Ox Hide deposits are located in the lowest productive level of the Miami-Inspiration porphyry copper system, which is dominated by a potassic alteration assemblage. The Live Oak and Bluebird deposits are characterized by a transition from potassic to phyllic alteration assemblages, while Thornton, Joe Bush, Miami, and Miami East are dominated by a phyllic (quartz-sericite-pyrite) alteration assemblage (Maher, 2008; Swaim, 2020).

As the porphyry copper system was exhumed by erosion, the primary sulfide assemblage (i.e., pyrite, chalcopyrite and bornite), discussed in the previous section, was exposed to oxidization and weathering. During this process, any iron contained in these minerals was transformed into red, reddish-brown, orange, and yellow iron oxides (i.e., hematite, goethite and jarosite) observed in the leached cap, while sulfur was combined with groundwater to produce a weak sulfuric acid solution. The primary copper contained in the rock was dissolved by these acidic solutions, which percolated downward to the water table, where they encountered reducing conditions that allowed the copper to precipitate out as chalcocite (Cu_2S). Over time, this action formed a thick, copper-rich, blanket-like zone, known as the supergene enrichment blanket (Titley and Marozas, 1995).

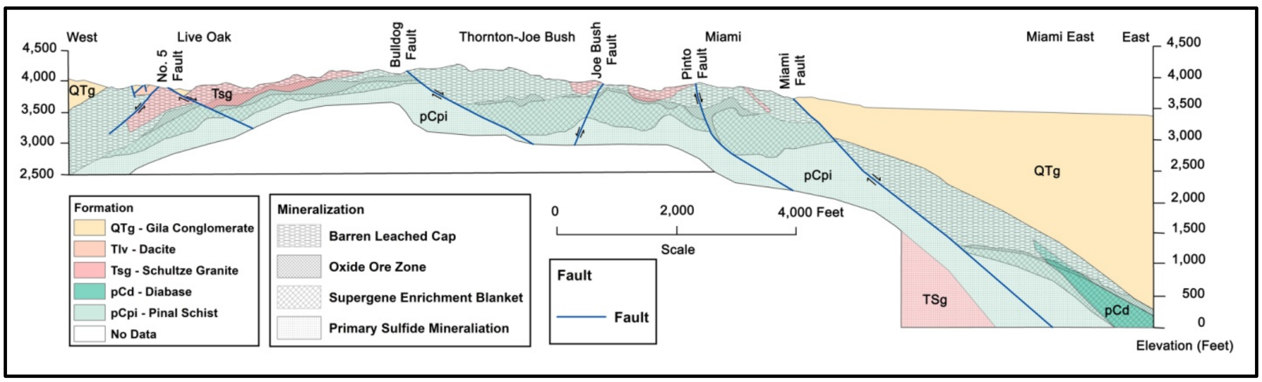


Figure 14. Schematic east-west cross section through the Miami-Inspiration copper deposit, showing the barren leached cap, oxide ore zone, supergene enrichment blanket, and primary sulfide mineralization (modified from Ransome, 1919; Peterson, 1962; Anzalone, 1981)

The barren leached cap at Miami and Inspiration, ranges from 0 to 1,000 feet (averaged 400 feet) in thickness and overlies an oxide ore zone, which is characterized by chrysocolla, malachite, azurite, and ferric hydroxide minerals with minor amounts of copper pitch (i.e., mixture of hydrous oxides of copper, iron and manganese), brochantite, atacamite, lindgrenite, and libethenite (Figure 14). Minor amounts of native copper and cuprite are present along fault zones. The oxide ore zone has an average thickness of approximately 200 feet, although thicknesses vary somewhat along permeable fault zones. Oxide minerals were formed from oxidation of a pre-existing supergene enrichment blanket that resulted from insufficient amounts of pyrite required to remobilize the copper into solution (Olmstead and Johnson, 1966).

The supergene enrichment blanket is characterized by the mineral association: chalcocite, bornite and covellite with trace amounts of chalcopyrite. It has an average thickness of approximately 200 feet, but locally attains thicknesses as great as 450 feet. Copper enrichment within this zone ranges from thin coatings of chalcocite on pyrite crystals in deeper levels of the blanket to the complete replacement of pyrite and chalcopyrite by chalcocite in upper portions of the blanket (Olmstead and Johnson, 1966).

Sub-economic primary sulfide (i.e., hypogene) mineralization (0.15% to 0.40% Cu) underlies the supergene enrichment blanket. It includes pyrite, chalcopyrite and molybdenite with minor amounts of bornite (Olmstead and Johnson, 1966).

The deepest levels of the Miami-Inspiration porphyry copper system are exposed to the southwest in an area bordering Pinto Creek, which formed at a paleo-depth of about 33,000 feet (hornblende barometry, Stavast, 2006). While economic mineralization is not present at this locality, quartz, potassium feldspar and coarse muscovite veining with or without tungsten-bearing minerals and molybdenite are common over an area of several square miles in the root zone of the Miami-Inspiration porphyry copper system (Maher, 2008; Swaim, 2020).

3.1.2 Porphyry Mountain (Castle Dome and Pinto Valley)

The Pinto Valley porphyry copper system is cut by the northeast-trending South Hill-Sleeping Beauty fault zone, a structural boundary that locally separates the Arizona's Transition Zone from the Southern Basin and Range Province (Figure 15). Copper ores at Porphyry Mountain (Castle Dome-Pinto Valley) lie within a structural horst, which is bounded on the east by the northerly trending Jewel Hill fault and on the west by the northerly trending Gold Gulch fault. These Basin and Range structures down-dropped portions of the Porphyry Mountain ore shell northeast and southwest of the main ore body during late Miocene to Pleistocene time (Breitrick and Lenzi, 1987).

Copper ores at Porphyry Mountain are mainly hosted by Mesoproterozoic Ruin Granite (locally known as the Lost Gulch Quartz Monzonite), which has been cut and mineralized by small apophyses of the late porphyritic phase of the Laramide Schultze Granite (Figure 15). The Ruin Granite was also cut by Mesoproterozoic diabase dikes, which commonly contain a higher copper content than the granite (Bush et al., 2016).

Lying within the Arizona's Transition Zone, the ore shell at Castle Dome-Pinto Valley has the shape of a distorted, inverted bowl, which has undergone moderate extension along a N80^{o}E axis and has been tilted about 30^{o} to the southeast (Figure 16). Approximately two-thirds of the original ore shell of the Castle Dome-Pinto Valley porphyry copper system is preserved at Porphyry Mountain. The South Hill fault, a high angle reverse fault, juxtaposes Mesoproterozoic Ruin Granite and Laramide Granite Porphyry in the hanging wall over Paleoproterozoic Pinal Schist in the footwall and truncates the Castle Dome-Pinto Valley ore shell and alteration assemblages to the south (Breitrick and Lenzi, 1987). Minor post-mineral normal displacement occurs along the Dome Fault, a northeast-trending pre-mineral structure that cuts the north limb of the ore shell.

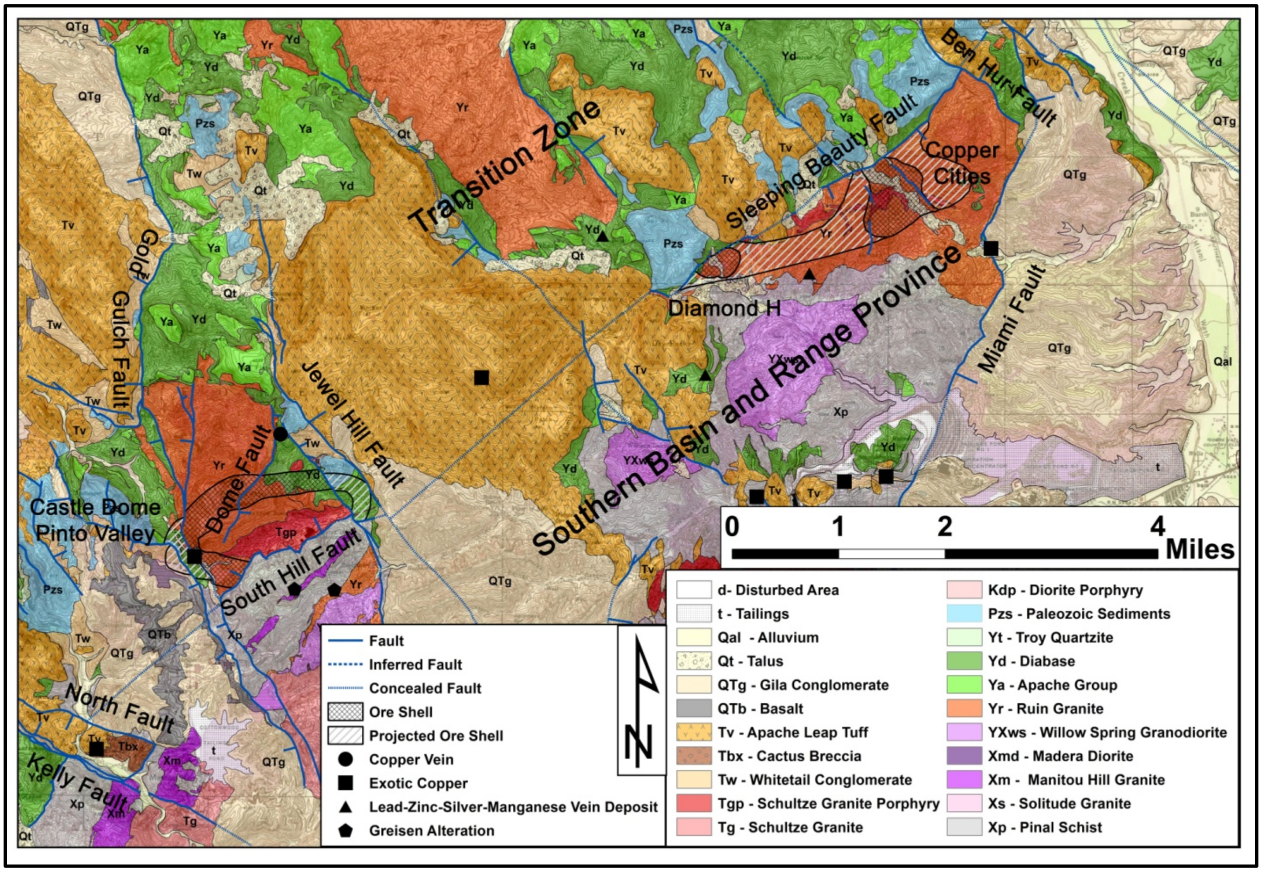


Figure 15. Geologic map of the Pinto Valley porphyry copper system showing the structural relationship between the Castle Dome-Pinto Valley, Diamond H and Copper Cities deposits (modified from Maher, 2008; Breitrick and Lenzi, 1987)

Deposits at Porphyry Mountain (i.e., Castle Dome and Pinto Valley) display a progression from a central low-grade potassic-altered core occupied by granite porphyry (Figure 15 and Figure 17) that grades outwards through an intermediate phyllic zone into an outer peripheral zone dominated by propylitic and supergene argillic assemblages (Craig et al., 2021). Pyrometasomatic skarns containing garnet, magnetite and hematite with minor copper oxides replace carbonates of the Devonian Martin Formation on the south side of Jewel Hill (Peterson, 1962).

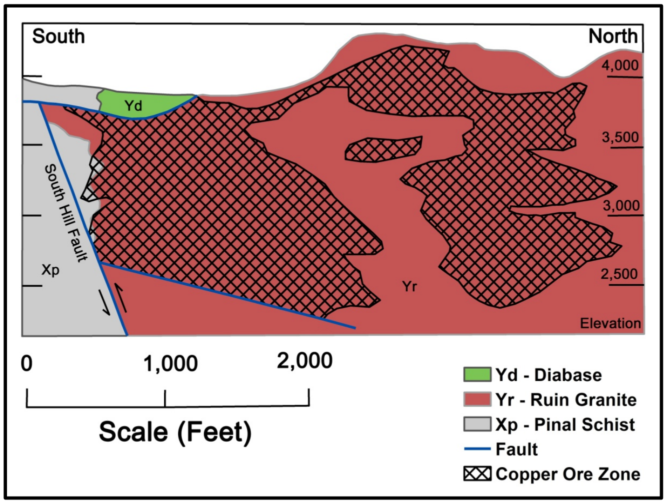


Figure 16. North-south cross section through the Castle Dome-Pinto Valley deposit showing the copper ore shell (0.30% Cu Cut-off) (modified from Breitrick and Lenzi, 1987)

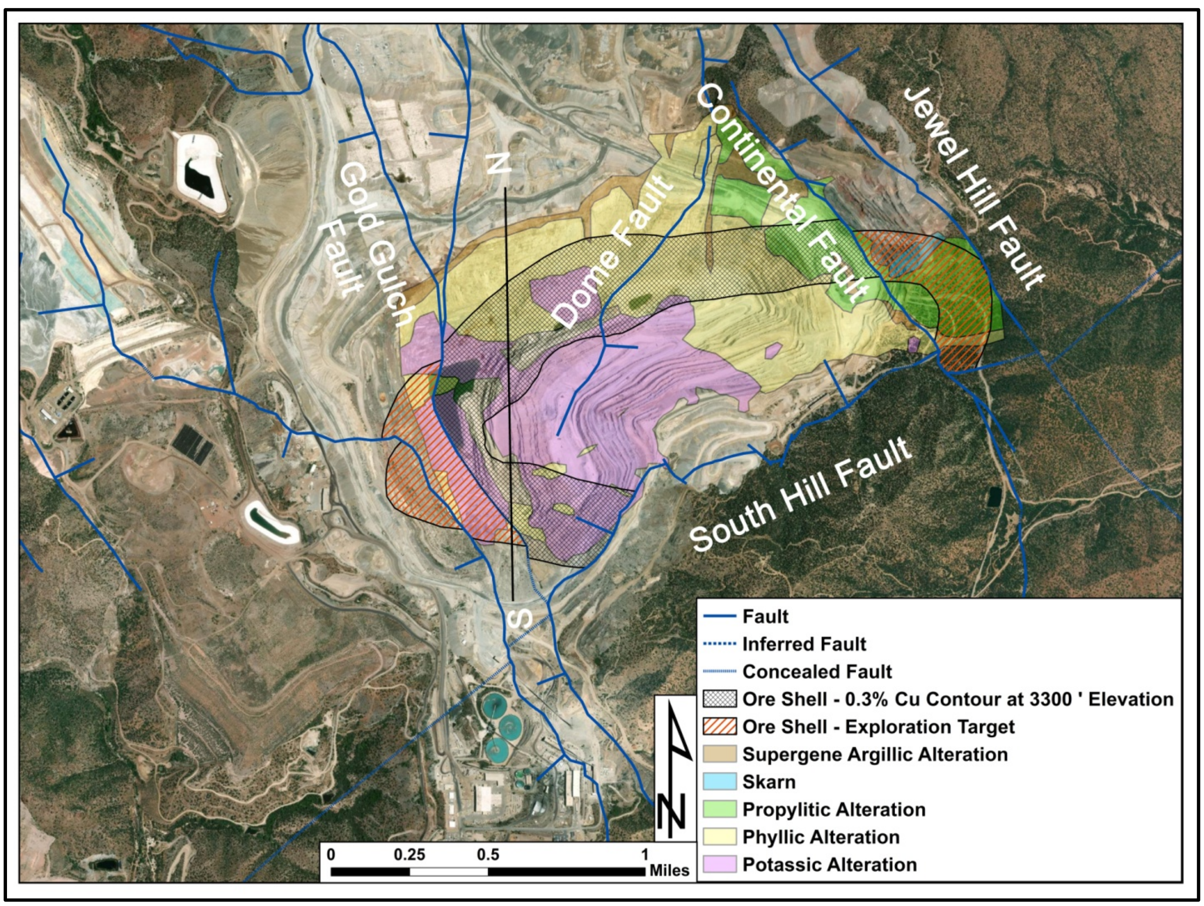


Figure 17. Alteration map of Pinto Valley deposit showing the ore shell (0.3% Cu contour at 3,300' elevation), N-S cross section in Figure 16, major fault zones and surface projection of concealed exploration targets (modified from Craig et al., 2021)

The leached cap at Porphyry Mountain ranges from several feet to a maximum of approximately 250 feet in thickness; but averages about 80 feet. Although oxidation locally penetrates the water table along the south side of Porphyry Mountain, complete leaching rarely extends more than 150 feet below the pre-mine surface. The leached cap generally contains less than 0.1% copper (mainly malachite and cuprite) and the transition from waste to ore occurs over of an interval of less than 15 feet (Peterson et al., 1951). Supergene enrichment (chalcocite and covellite) at Porphyry Mountain is not extensive, but was an important constituent of the ores mined by the Castle Dome operation (Freiman et al., 2014).

The underlying primary sulfide (hypogene) ores mined by the Pinto Valley operation consist of veinlet-controlled pyrite and chalcopyrite with minor amounts of molybdenite. Lesser amounts of disseminated chalcopyrite are commonly associated with biotite or partially replace it. Silver and gold are recovered as by-products (Craig et al., 2021).

3.1.3 Copper Cities and Diamond H

Located southeast of the northeast-trending Sleeping Beauty fault, porphyry copper ores at Copper Cities and Diamond H probably represent the displaced segment of the Porphyry Mountain (i.e., Castle Dome-Pinto Valley) deposit located in the southern footwall of the South Hill fault zone (Figure 15).

Evidence supporting this conclusion includes similar host rocks and mineralizing intrusions (i.e., Ruin Granite and granite porphyry intrusion, respectively) at both sites. The southern third of the ore shell and alteration halo that are missing at Porphyry Mountain is present at Copper Cities and Diamond H. Here a dominate phyllic assemblage adjacent to the Sleeping Beauty fault grades outward to a peripheral propylitic assemblage (Peterson, 1954). There is little evidence of mineralization immediately to the northwest of the Sleeping Beauty fault. Base metal occurrences are present along the southern periphery of the alteration halo, while deep-seated greisen alteration is preserved to the southwest (Figure 15).

Located in the Southern Basin and Range Province, porphyry copper ores in Copper Cities-Diamond H area (Figure 12) have undergone a much more complex southwest-northeast extensional history than those at Porphyry Mountain. Beginning during Late Oligocene time, this involved multiple, superimposed sets of predominately down-to-the-east normal faults that dismembered the portion of the porphyry copper system located southeast of the South Hill-Sleeping Beauty fault zone, tilting the structural blocks up to 40 to 70^{o} to the southwest, exposing numerous structural levels at the present surface (Maher, 2008).

Porphyry copper mineralization at Copper Cities and Diamond H is hosted by the

Mesoproterozoic Ruin Granite (locally known as Lost Gulch Quartz Monzonite), which is cut, altered and mineralized by dikes and small plugs of the porphyry phase of the Laramide Schultze Granite (Simmons and Fowells, 1966). Representing the southeast portion of the Pinto Valley porphyry copper system, it lies within a northeast elongated zone of phyllic alteration. The Copper Cities ore body is located near the northeast end of this zone with Diamond H situated near the southwestern boundary (Figure 15).

The Ruin Granite lies within an uplifted structural block (i.e., horst), bounded on the northeast by the N45^{o}W trending Ben Hur fault, which dips 65^{o} northeast, and on the east by the north-northeast trending Miami fault, which dips 60^{o} to the southeast (Peterson, 1962). The northwest boundary of the horst is defined by the nearly vertical, N45^{o}E trending Sleeping Beauty fault zone (Figure 15), north of which the Mesoproterozoic Apache Group, Troy Quartzite and diabase and Paleozoic sediments are exposed (Simmons and Fowells, 1966).

The Copper Cities ore body is bounded on the east by the N45^{o}W Drummond fault (dips 50 to 60^{o} NE), on the west by the north-south trending Coronado fault zone (dips 60 to 70^{o} W) and on northwest by the Sleeping Beauty fault. The southern boundary of the ore body was defined by a gradual decrease in copper content with its southern limit based entirely on economic factors (Simmons and Fowells, 1966).

The Copper Cities ore body trends N25^{o}W along a central axis, measuring slightly more than 2,000 feet. The northwest portion of the ore zone was 1,000 feet wide, but expanded to approximately 2,000 feet in width at its southeastern extremity. The thickness of the ore zone ranged from 100 feet to 700 feet (Simmons and Fowells, 1966).

The ore body at Copper Cities is overlain by a leached cap, which ranges from 20 to 115 feet in thickness, but averages approximately 65 feet. The leached cap is generally thicker beneath hills and ridges and thinner under drainages (Peterson, 1962). Few sulfides remain within the leached cap, which assays slightly less than 0.1% copper. Rare copper oxide minerals include malachite, azurite and turquoise (Simmons and Fowells, 1966).

Averaging slightly more than 0.7% Cu, the zone of supergene enrichment at Copper Cities is primarily chalcocite and covellite. Enrichment is generally incomplete with primary chalcopyrite and pyrite only being partially replaced by these secondary sulfides (Simmons and Fowells, 1966). The underlying primary (hypogene) sulfide mineralization at Copper Cities (averages 0.4% Cu) is characterized by veinlets of quartz, pyrite and chalcopyrite with minor amounts of molybdenite (Peterson, 1954). Sphalerite and galena are locally present in trace amounts.

3.1.4 Copper Springs

Widespread, sub-economic copper mineralization at Copper Springs is associated with a porphyry center in the southeastern lobe of the Schultze Granite, which cuts the Pinal Schist (Figure 10). Representing deep levels of the Copper Springs porphyry copper system (Figure 12), alteration is characterized by a widespread greisen assemblage (coarse-grained muscovite), which surrounds and overlaps a central zone of quartz-K-feldspar veining with high chalcopyrite to pyrite ratios in the Laramide porphyry (Maher, 2008).

A large zone of leached cap is characterized by boxwork and residual limonite after sulfides with rare copper oxide staining in the Pinal Schist along the southwestern contact of the porphyry (Peterson, 1963). This leached zone is underlain by a thin zone (40 to 50 feet) of secondary chalcocite enrichment (~0.4% copper), which grades downward into weak primary sulfide mineralization (i.e., pyrite and chalcopyrite ~0.1% copper) (Corn, 1990).

3.1.5 Azurite

Sub-economic porphyry copper mineralization at Azurite is hosted by a small, severely shattered, brecciated, and moderately oxidized wedge of phyllic altered Pinal Schist in the hanging wall of a low-angle fault along the northern range front of the Pinal Mountains (Figure 10). A thin surficial zone of copper oxides (azurite and malachite) is underlain by primary/secondary sulfides (pyrite, chalcopyrite, chalcocite, and molybdenite) (Gatchalian, 1975).

3.2 Copper Veins

The upper levels of each of the three porphyry copper systems of the Globe-Miami Mining Region are located in the Globe Hills structural block (Figure 10), and comprise northeast-striking, steeply dipping, vein deposits containing copper, lead, zinc, silver, and manganese (Maher, 2008). The copper-bearing veins are located in two areas; 1) the Old Dominion vein system in the southern portion of the Globe Hills, and 2) Keystone-Highline veins along Pinal Creek approximately 3.5 miles northwest of Globe. Situated northeast and around the margins of these copper centers (Figure 12 and Figure 13), lead-zinc, lead-zinc-vanadium-molybdenum and manganese-lead-zinc-silver vein assemblages represent the upper-most and peripheral portions of these porphyry copper systems (Peterson, 1962).

3.2.1 Old Dominion Vein System

Much of the early copper production from the Globe-Miami Mining Region came from the Old Dominion, Arizona Commercial, Iron Cap and Superior and Boston mines, which occur along the northeast-striking, Old Dominion vein system, located in the southern portion of the Globe Hills structural block (Figure 10 and Figure 12). The Old Dominion vein system includes the Old Dominion, Maggie, Josh Billings, Buffalo, Copper Hill, Iron Cap, Great Eastern, Buckeye, Black Oxide, Dime, Stonewall, Arizona, North, and Black Hawk veins (Peterson, 1962). A structural reconstruction of this area prior to mid-Tertiary Basin and Range extension suggests the Old Dominion vein system represents the upper levels of the Copper Springs porphyry copper system (Maher, 2008).

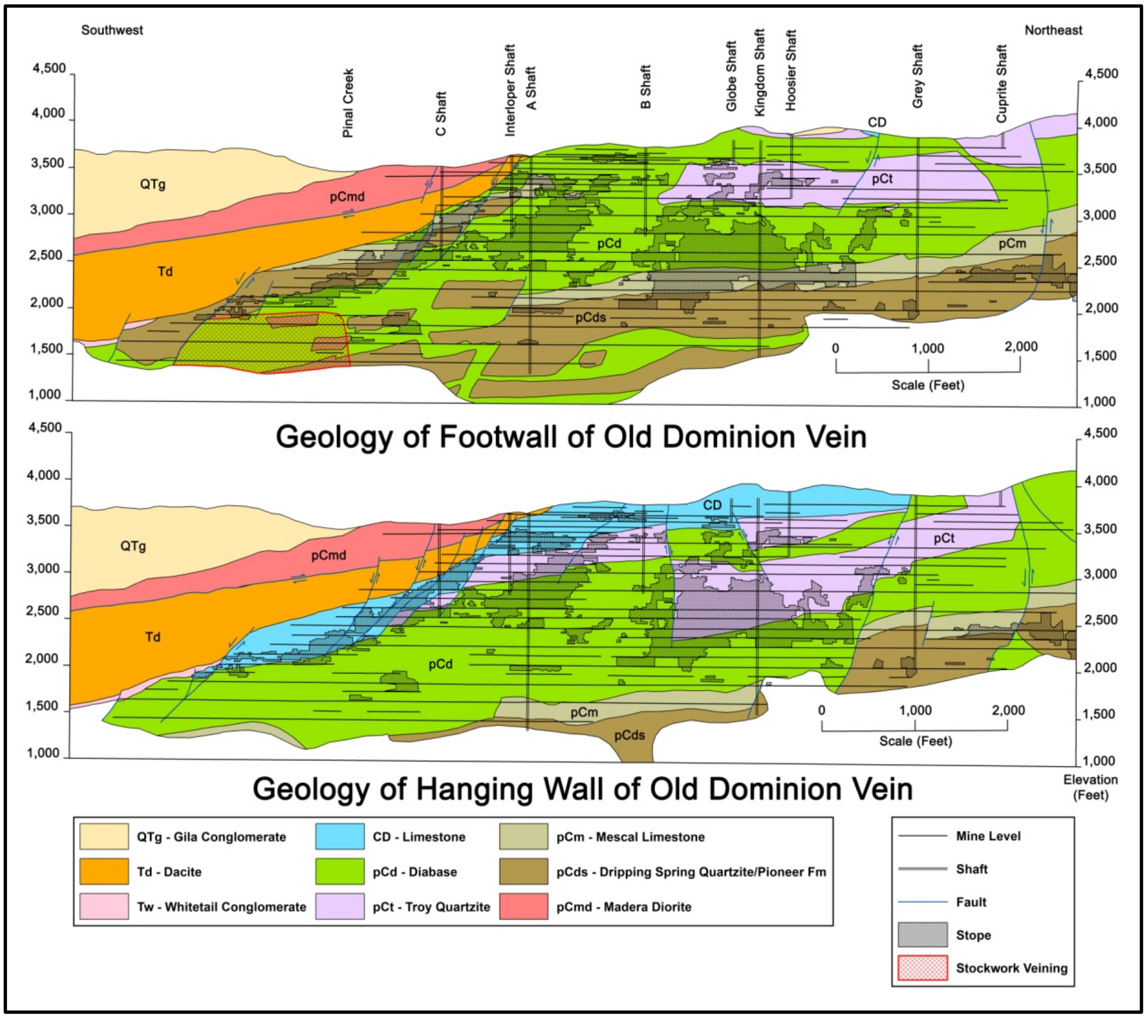


Figure 18. Schematic cross-section of the Old Dominion mine (looking northwest), showing the geology of the footwall and hanging wall of the Old Dominion vein, mine workings, ore stopes, and a zone of stockwork veining in the footwall of the Old Dominion fault (modified from Peterson, 1962)

The Old Dominion vein ranges from 2 to 60 feet in thickness, and dips 60° to the southeast, but locally varies from 45° to vertical. The ores occur as localized shoots, which display a flat rake that plunges to the southwest (Shoemaker, 1930).

Veins along the Old Dominion vein system are characterized by replacement of breccia and wall rock along faults and fissures that cut the Apache Group, Troy Quartzite, diabase, and Paleozoic sedimentary formations. While movement along faults hosting these veins range from several hundred feet to little or no displacement, the most productive and most continuous ore bodies are localized along structures exhibiting relatively large displacements (Peterson, 1962).

The character and thickness of the copper veins appears to be a function of wall rock lithologies (Figure 18). Except for the Paleozoic carbonates, vein geometry is primarily due to the physical characteristics of the rock that control permeability along the structural zone. Paleozoic carbonates are most susceptible to chemical replacement and commonly host thick lenses of rich ore. Large productive stopes are also developed within Mesoproterozoic Mescal Limestone and between the walls of formations composed of various quartzite and sandstone lithologies. Rich ores are also found in areas where diabase formed one wall and any of the sedimentary units occupied the other wall. However, in areas where diabase occupied both the footwall and hanging wall of the structure, the veins are commonly narrow and poorly mineralized or barren (Peterson, 1962).

With depth, there is a normal sequence of oxidized, enriched and primary ores. The oxide assemblage consists of chrysocolla with minor amounts of malachite, native copper and cuprite, while chalcocite occurs as thin coatings on pyrite in the enriched zone (Shoemaker, 1930). Most of the production was derived from high-grade oxide ore or enriched chalcocite ore above the 18th level of the mine.

Shallow high-grade vein and replacement ores at Old Dominion transition downward into porphyry-style alteration and mineralization. A large zone of primary stockwork sulfide mineralization (quartz, pyrite, chalcopyrite, bornite, and specular hematite) is hosted by diabase in the footwall of the Old Dominion fault in the southwestern portion of the Old Dominion mine below the 21th level (Figure 18) (Bjorge and Shoemaker, 1933; Peterson, 1962).

3.2.2 Keystone and Highline Veins

The Keystone (also known as the Original Old Dominion) and Highline mines are located approximately 3.5 miles north of Globe (Figure 10).

The steeply dipping copper vein at the Keystone mine is generally less than 1 foot in thickness (Peterson, 1962). The ore occupies a northeast-striking fissure that cuts the Dripping Spring Quartzite and is characterized by a dark red ocherous mixture of cuprite and iron oxides, containing finely streaked chrysocolla and malachite. It locally contains native gold in the form of short wires and thin leaves embedded within the iron oxides (Ransome, 1903).

Copper ores at the Highline mine are localized along a N10^{o}E trending fault zone that cuts the Dripping Spring Quartzite, which is sporadically mineralized with copper and manganese oxides (Peterson, 1962).

Structural reconstruction of the post-ore extensional deformation (Figure 12 and Figure 13) suggests these veins represent the upper levels of the Miami-Inspiration porphyry copper system (Maher, 2008).

3.2.3 Gibson Copper Mine

The Gibson copper mine is located in the headwaters of Pinto Creek, approximately 7.5 miles southwest of Miami (Figure 6). High-grade copper ores (20 to 40% copper) were localized along the sub-parallel Summit and Pasquale veins, which cut the Pinal Schist. Located approximately 300 feet apart, both veins strike N25^{o}E and can be traced over a distance of approximately 6,500 feet. Dipping approximately 55^{o} to the northwest, the Summit vein is concordant with bedding and foliation of the schist. It was characterized by lens-like ore shoots, ranging from 0.7 to 1.25 feet in thickness. The Pasquale vein occupies a 35^{o} northwest-dipping, 5 to 10-foot thick fault zone that clearly cuts across bedding and ranged from a few inches to 3 feet in thickness (Peterson, 1963).

Chalcocite enrichment played an important role in developing the high-grade copper ores localized along the Summit and Pasquale veins (Peterson, 1963). Underlying primary sulfide mineralization along these structural zones is characterized by massive chalcopyrite with considerable bornite in a quartz gangue, lesser amounts of calcite, and minor amounts of specular hematite and gypsum (Stevens, 1911).

3.3 Exotic Copper Deposits

Exotic copper deposits are a type of secondary copper mineralization that is formed when migrating meteoric waters, containing ionic copper leached from nearby oxidizing primary copper deposits, transport dissolved copper laterally before re-depositing it at a favorable site downstream. Commonly associated with porphyry copper systems; exotic copper deposits in the Globe-Miami Mining Region account for approximately 1.4% of the area's historic copper production. Examples of exotic copper deposits include Van Dyke, Cactus-Carlota, Eder North, Eder Middle, Eder South, Black Warrior, Black Copper, Geneva, Gold Gulch, Tinhorn Wash, Empress, and Solitude (Figure 6).

3.3.1 Van Dyke

Situated in the southeastern hanging wall of the northeast-striking Miami fault zone, the Van Dyke copper deposit does not outcrop at the surface (Figure 10). Bedrock in this area is unconformably overlain by 600 to 2,000 feet of post-mineral Gila Conglomerate (Bird et al., 2020).

Exotic copper mineralization at Van Dyke occurs along the southern periphery of the Miami-Inspiration porphyry copper system, where it is localized along a gently southeast-dipping breccia zone that cuts altered Pinal Schist in the leached cap (Figure 19). The drill defined resource measures 4,900 feet long by 4,300 feet wide and ranges from 130 to 750 feet in thickness (Bird et al., 2020).

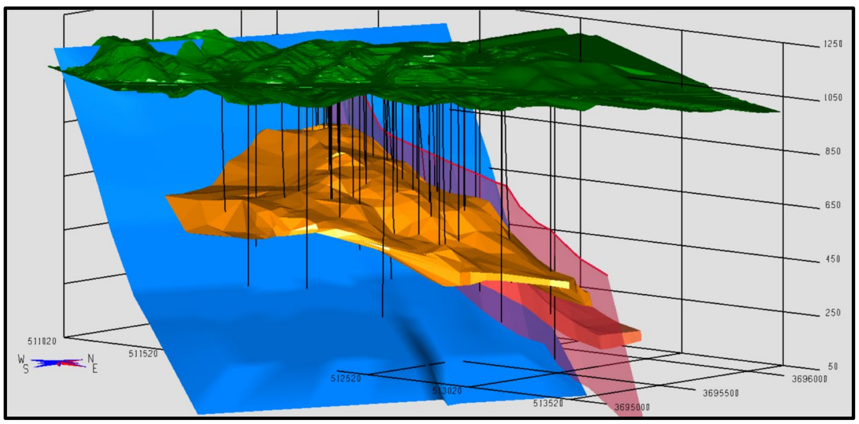


Figure 19. Three dimensional view of the Van Dyke copper deposit; mineralized copper resource (orange), Van Dyke fault (red), Miami fault (blue), topography (green), and drill holes (from Bird et al., 2020)

Secondary copper mineralization at Van Dyke consists primarily of malachite, chrysocolla, azurite, cuprite, and tenorite. Hosted by tectonically brecciated and fractured panels within the Pinal Schist, oxide copper minerals fill open spaces and occur as staining on cleavage planes and fractures (Bird et al., 2020). A permeability barrier developed along N70^{o}W striking, 70^{o}NE dipping Van Dyke fault zone played an important role in channeling the lateral and/or descending supergene ore solutions that formed the copper ores at Van Dyke (Peterson, 1962).

Entirely confined to the leached cap, exotic copper mineralization at Van Dyke occurs approximately 220 feet above a poorly developed zone of supergene enrichment (primarily chalcocite) that gradually grades downward into weak primary sulfide mineralization (i.e., pyrite and chalcopyrite) at depth (Peterson, 1962).

3.3.2 Cactus-Carlota

Cactus-Carlota occurs within the northwest elongated Carlota Graben, which is bounded on the southwest by the Kelly fault and on the northeast by the North fault (Figure 10). This structurally down-dropped fault block measures 7,500 feet in length and typically ranges from 1,200 to 1,500 feet in width (Independent Mining Consultants, 2005).

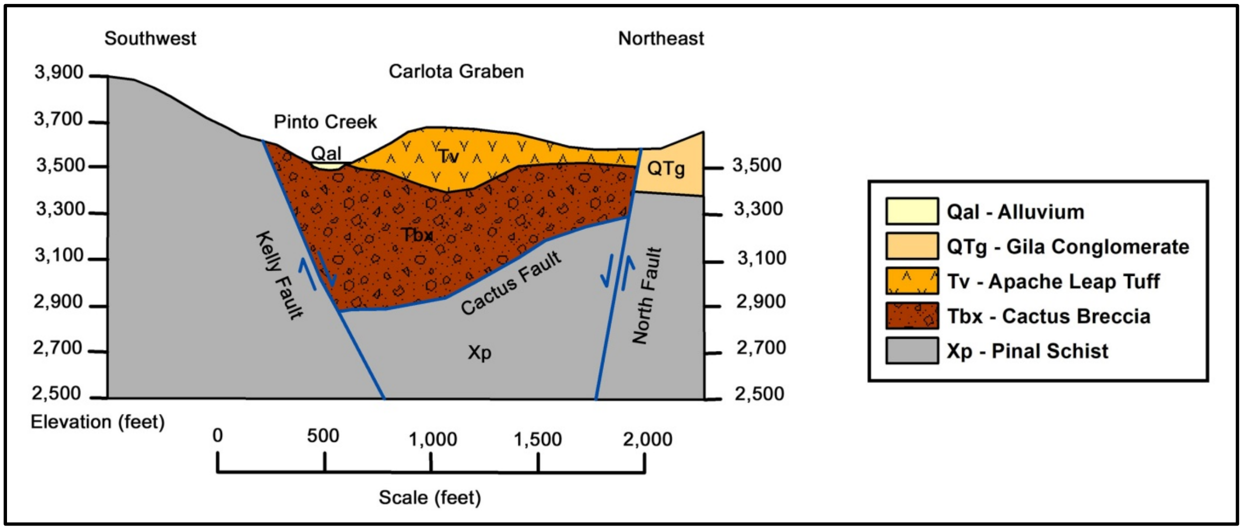


Figure 20. Schematic cross-section through the Cactus-Carlota deposit, looking northwest (modified from Independent Mining Consultants, 2005)

Units within the Carlota Graben include the Cactus Breccia, which is unconformably overlain by the Apache Leap Tuff (Figure 20). Exceeding 600 feet in thickness, the Cactus Breccia is clearly of sedimentary origin. It is primarily composed of clasts of the Pinal Schist with lesser amounts of Ruin Granite, Schultze Granite and the Apache Group (Independent Mining Consultants, 2005).

Lithologies outside of the Carlota Graben (mainly Pinal Schist and diabase) are unaltered as are the Apache Leap Tuff and younger units. However, clasts of Pinal Schist and Ruin Granite within the Cactus Breccia exhibit quartz-sericite alteration, which is typical of porphyry copper systems. The deposit represents a product of mass wasting (i.e., sub-aerial landslide) and is characterized by a chaotic and unsorted assemblage of angular clasts that range from house-size boulders to sand-size fragments within a limonitic clay matrix (Independent Mining Consultants, 2005).

The primary host for the exotic copper mineralization at Cactus-Carlota is the Cactus Breccia. Lesser amounts of ore also occur in the overlying Apache Leap Tuff. Copper mineralization is also localized along approximately 3,300 feet of the Kelly fault zone, where it occurs within brecciated diabase and Pinal Schist. The low-angle Cactus fault separates the mineralized Cactus Breccia from the underlying Pinal Schist, which is generally barren. Mineralization is strongest (>0.50% total copper) adjacent to or in close proximity with the Kelly fault and diminishes away from this structural barrier (Independent Mining Consultants, 2005).

Chrysocolla with locally minor amounts of copper pitch and/or neotocite generally fills the clay-rich matrix of the Cactus Breccia and the Kelly fault zone. Copper oxides also occupy open fractures within the Pinal Schist and diabase in the immediate footwall of the Kelly fault, the overlying Apache Leap Tuff and larger clasts of the Cactus Breccia. Malachite and chalcocite occur at the southeast end of the deposit, where it is present as veinlets and individual grains within the breccia clasts (Independent Mining Consultants, 2005).

3.3.3 Eder North, Eder Middle and Eder South

Located approximately 1 mile southwest of Cactus-Carlota, the Eder deposits (North, Middle and South) are located along the western slope of Powers Gulch (Figure 10).

Exotic copper mineralization at Eder North is hosted by the Cactus Breccia, where it occupies a northeast-southwest trending paleo-channel that cuts the underlying Pinal Schist and Whitetail Conglomerate. Roughly 1,000 feet in width, the copper content of the ore zone appears to diminish away from the central axis of the channel. Its northeast boundary is defined by erosion, while the poorly defined southwestern limit extends approximately 1,300 feet down dip beneath barren Apache Leap Tuff. Ranging up to 200 feet in thickness, the richest mineralization occurs near the base of the Cactus Breccia (Independent Mining Consultants, 2005).

Fracture-controlled exotic copper mineralization (mainly chrysocolla) at Eder South is hosted by the Pinal Schist, which has been extensively broken along a series of closely spaced northeast-trending fault zones. Extending to depths of 200 to 300 feet, near-surface oxide copper mineralization outcrops over an area measuring 2,400 feet north-south and 1,000 feet east-west. The eastern edge of the deposit outcrops at the surface, while its western economic boundary is defined by a western-thickening section of overlying Apache Leap Tuff (Independent Mining Consultants, 2005).

3.3.4 Black Copper, Black Warrior and Geneva

The Black Copper mine is situated approximately 800 feet north of Inspiration Consolidated Copper’s main production shafts along Webster Gulch (Figure 6). The ore body is localized along a north-south striking fault that dips 35^{o} to the east. Dacite in the hanging wall of this structure is juxtaposed against Pinal Schist in the footwall. A short distance south of the mine, this structure splits; the east branch is the Pinto fault, while the west branch may be a continuation of the Bulldog fault (Figure 10). Both the Pinto and Bulldog faults cut and displace the Miami-Inspiration ore body and may have served as conduits for copper-bearing supergene solutions that formed the Black Copper deposit. Exotic copper mineralization at Black Copper consists of chrysocolla, which replace dacite breccia and tuffaceous gouge along the structural zone. Ore grades range from 10 to 22% copper (Peterson, 1962).

Exotic copper mineralization at the Black Warrior and Geneva mines (Figure 6) is localized along the Warrior fault zone, which consists of two sub-parallel, steeply dipping, east-west striking faults, that define a narrow graben. The continuity of this structure is broken by several branching and cross-cutting faults (Peterson, 1962).

Structurally controlled exotic copper ores (mainly chrysocolla) at Black Warrior and Geneva occur in similar settings, hosted by a tuffaceous conglomerate that occupies the narrow graben between two sub-parallel structural zones. Ore grades range from 7 to 20% copper (Peterson, 1962).

3.3.5 Tinhorn Wash and Gold Gulch

Stream gravels in drainages below Copper Cities and Porphyry Mountain host exotic copper mineralization (Figure 6). Gravels along Tinhorn Wash are cemented by limonite and copper carbonates, which were deposited by supergene solutions that carried iron and copper leached from the Copper Cities deposit (Peterson, 1962). Gravels along Gold Gulch, below Porphyry Mountain are also locally cemented by copper carbonates (Peterson et al., 1951).

4 HISTORY OF GLOBE-MIAMI MINING REGION

Prehistoric cultures in east-central Arizona include the Hohokam (A.D. 200-1450) and Salado (A.D. 1150-1450). Ancient ruins of a 200-room Salado pueblo (i.e., Besh-Ba-Gowah – Apache for “the metal village”) and older Hohokam archaeological sites are present along a broad ridge overlooking Pinal Creek, 1 mile southeast of Globe (Hohmann, 1984). Flourishing for more than a millennium, these ancient cultures also established large permanent agricultural communities along the Gila, Salt and Verde river valleys in the area of Phoenix, where an extensive network of canals was excavated to irrigate their crops (Meserve, 2003).

Hohokam and Salado cultures began to decline around A.D. 1300 before disappearing entirely by A.D. 1450. Various reasons for their demise range from internal political strife to conflicts with the Apache, but there is little consensus as to what actually happened (Meserve, 2003).

One of the more interesting hypotheses for this decline is climate change that coincided with the onset of the Little Ice Age (A.D. 1300-1850). Periods of prolonged drought, damage of irrigation infrastructure during intermittent periods of severe flooding (Huckleberry et al., 2018), and/or the salinization (i.e., overabundance of salt) of irrigated fields may have made it impossible to sustain their large communities. Successfully adapting to their way of life to cope with these challenges, their descendants, the Tohono O'odham (i.e., Papago), Akimel O'odham (i.e., Pima) and Pee-Posh (i.e., Maricopa) continue to reside in these lands today (Meserve, 2003).

4.1 Western Apache

The Apache are an Athabaskan culture that originated in the Canadian Yukon. Their migration south began in response to a major volcanic eruption at Mount Churchill in the Saint Elias Mountains of southeastern Alaska around A.D. 803. Archeological evidence suggest small groups migrated south along the eastern flank of the Rocky Mountains over the next six to seven centuries before arriving in New Mexico, Arizona and Texas (Lewandowska, 2020).

The western-most tribe of the Apache is the Western Apache (Figure 21), who settled the headwaters of the Salt and Gila river systems of east-central Arizona sometime between A.D. 1400 and A.D. 1600 (Tagg, 1985; Goodwin, 1969). Five pre-reservation groups of the Western Apache included: the Northern Tonto, Southern Tonto, San Carlos, Cibecue, and White Mountain. The Globe-Miami Mining Region lies within the area occupied by the San Carlos group, which has been sub-divided into the Pinal, Apache Peaks, San Carlos, and Arivaipa bands (Goodwin, 1969).

The Western Apache were a nomadic people, who lived in small, isolated extended family groups during most of the year, when they worked small farms, gathered wild plant foods and hunted. During the winter months, they moved down from the high country, congregating in the river valleys (e.g., Pinal Creek, Gila River, Tonto Basin), which allowed more opportunities for social contact between local groups and families (Kaut, 1956). Their lifestyle was supplemented by raiding and to a lesser extent through commerce with neighboring tribes. Some bands of Western Apache occasionally allied themselves with other tribes (e.g., Yavapai and Chiricahua Apache) against a common foe (e.g., Tohono O'odham, Akimel O'odham and Pee-Posh) (Goodwin, 1969).

Raiding of Spanish and later Mexican settlements in southern Arizona and northern Sonora was an integral part of the Western Apache culture. Traveling south through the San Pedro and Santa Cruz river valleys into Sonora, these raids acquired a wide variety of spoils, including horses, mules, burros, cattle, cloth, clothing, blankets, occasional firearms, saddles, bridles, leather, cowhide for moccasin soles, and metals that were made into spearheads, arrowheads and knives (Goodwin, 1969).

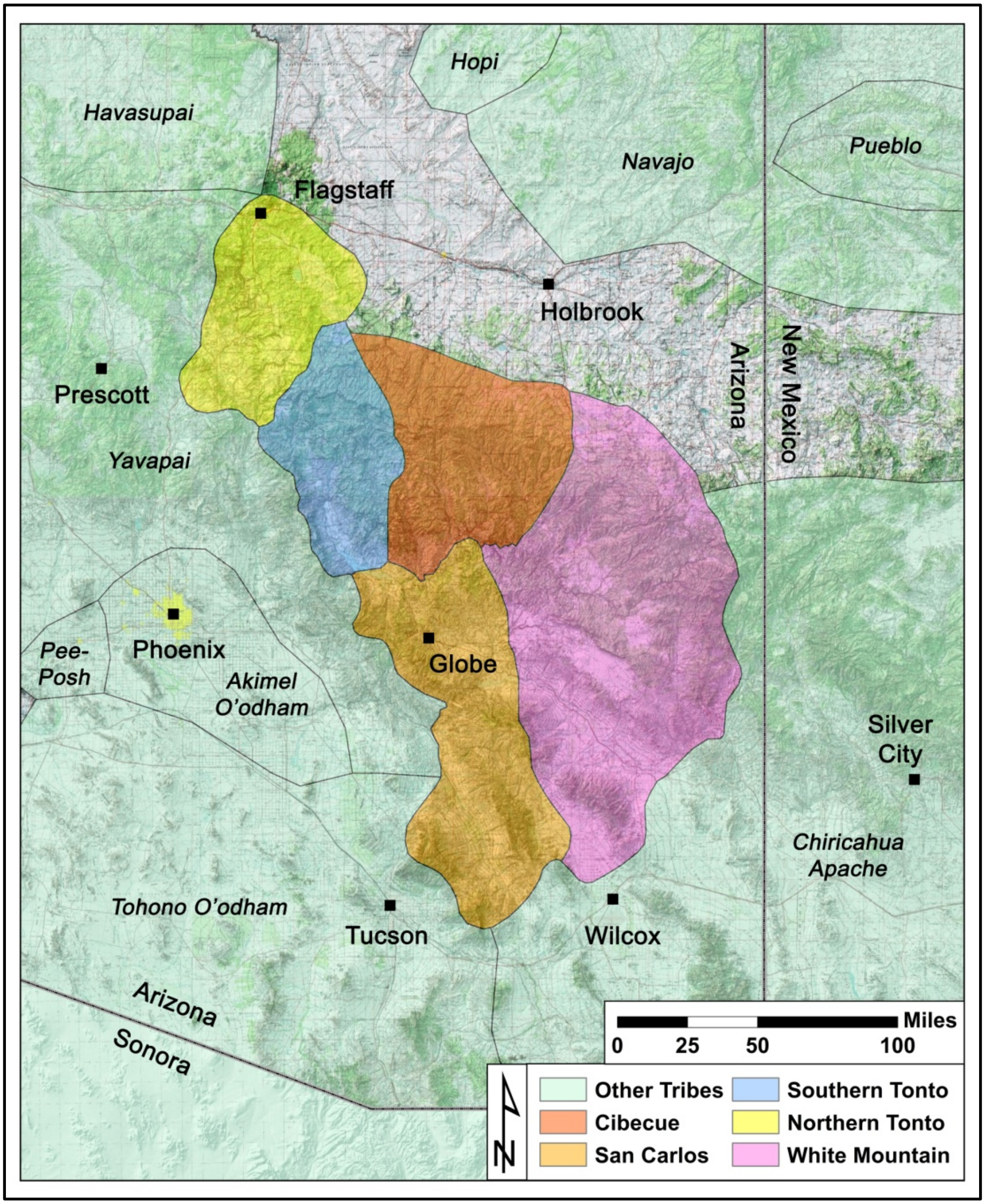


Figure 21. Pre-reservation homeland of the five groups of Western Apache and neighboring tribes in eastern Arizona and western New Mexico, circa 1850 (modified from Goodwin, 1969)

Following the Mexican-American War (1846-1848), Mexico was forced to cede much of its northern territory to the United States under the terms of the Treaty of Guadalupe Hidalgo. This concession comprised much of Arizona (a part of the New Mexico Territory until February 1863) located north of the Gila River, including a portion of the region that was inhabited by the Western Apache. The remainder of Arizona and lands occupied by the Western Apache were acquired by the United States with the ratification of the Gadsden Purchase in June 1854 (Greeley, 1987).

As a result of the Apache's animosity toward Mexico and the presence of few American settlers in Arizona, there was a brief period of peace between the Apache and the United States following the end of the Mexican-American War. However, tensions gradually rose during the 1850s as more Americans settled in the new territory. Cultural intolerance escalated from minor acts of theft and raiding into violent confrontations, initially with the Chiricahua Apache (1861-1886) in southeastern Arizona and southwestern New Mexico and later with the Western Apache (1871-1873) in east-central Arizona (Thrapp, 1967; Siegrist, 2005).

4.2 Prehistoric Indigenous Mining Activity

Native Americans were adept at using a wide variety of mineral resources to cope with the rigors of everyday life and during sacred ceremonies. Prior to the arrival of Europeans in Arizona, aboriginal cultures mined salt, clay, asbestos, garnet, quartz, stone, coal, and turquoise from surface outcrops and shallow underground workings at numerous sites (Greeley, 1987).

Quarrying of omnipresent chert and obsidian were used to manufacture a variety of tools and weapons. Common minerals such as hematite (red to reddish brown), malachite (green) and carnotite (yellow) were used as pigments for body decoration and pottery. Early Spanish explorers reported Apaches commonly used cinnabar (vermillion) as body paint. Prehistoric turquoise mines associated with Arizona's numerous copper deposits were the source for some of the oldest jewelry crafted in the United States (Greeley, 1987).

4.3 Early Expeditions to Globe-Miami Mining Region (1864-1870)

The vacuum resulting from the transfer of Federal troops east at the beginning of the Civil War (1861-1865) left residents of Arizona's frontier communities to deal with real or perceived Apache threats themselves. This was accomplished by large-scale, civilian, "Indian-hunting" expeditions that were commonly combined with prospecting and exploration ventures to relieve the monotony of everyday pioneer life (Thrapp, 1967).

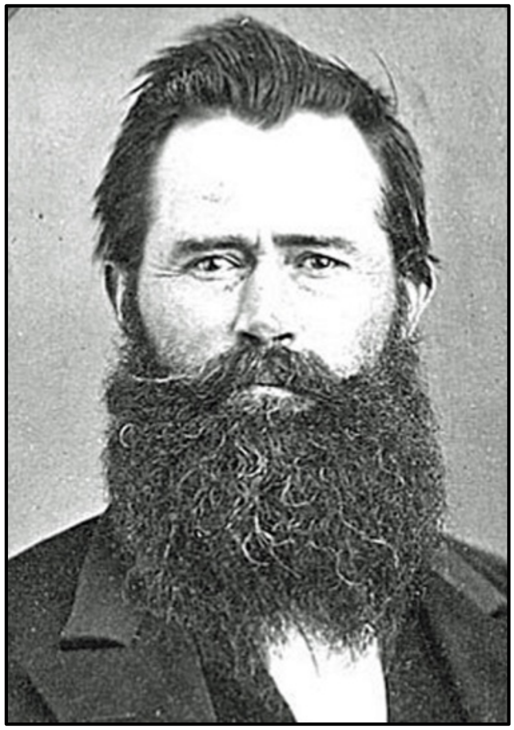


Figure 22. King S. Woolsey (1832-1879), pioneer, rancher, prospector and politician (photo from the Sharlot Hall Museum)

One of the first expeditions to the region bordering Pinal Creek occurred in January 1864. Led by King Woolsey (Figure 22), a rancher on the Aqua Fria River, this expedition included approximately 18 ranchers, miners and traders as well as 14 members from the Maricopa tribe, who were attempting to retrieve livestock that had been stolen in the Prescott area, purportedly by Apaches (Thrapp, 1967).

Having trailed an unknown group of Apaches to a site approximately 2 miles southwest of present-day Miami, Arizona, they made camp for the night. The next morning, they encountered a group of Pinal Apaches, who were invited to join them for breakfast under the pretense of discussing the matter of the stolen livestock. This meeting abruptly ended with the deaths of 19 to 24 Apaches, including Paramuca, chief of the Pinal Apaches. The site of this massacre is known today as “Bloody Tanks” (Figure 23) (Thrapp, 1967).

During a later expedition to the upper Salt River country and Apache Peaks (Figure 23), Woolsey’s group was attacked by a small band of Apaches during which they lost several men and horses. It was during this encounter they learned that the Indians were using silver to make bullets (Chilson, 1926). This only spurred their interest in finding the source of this silver. Although gold was found along Tonto Creek, it was not present in paying quantities. Small gold-bearing quartz lodes were also discovered in the Pinal Mountains (Woody, 1962).

In July 1869, Corydon Cooley and Alfred Banta accompanied by a friendly band of Apaches left Zuni, New Mexico to search for a butte that looked like a hat, where gold and silver-streaked rocks had been observed by an army doctor during the early 1860s. They prospected around Sombrero Peak (Figure 23), near Cherry Creek, approximately 37 miles north of Globe, Arizona, but failed to find anything. After regrouping at Fort McDowell, this expedition headed for the upper reaches of the Salt River, but encountered an unfriendly band of Apaches (Haak, 1991).

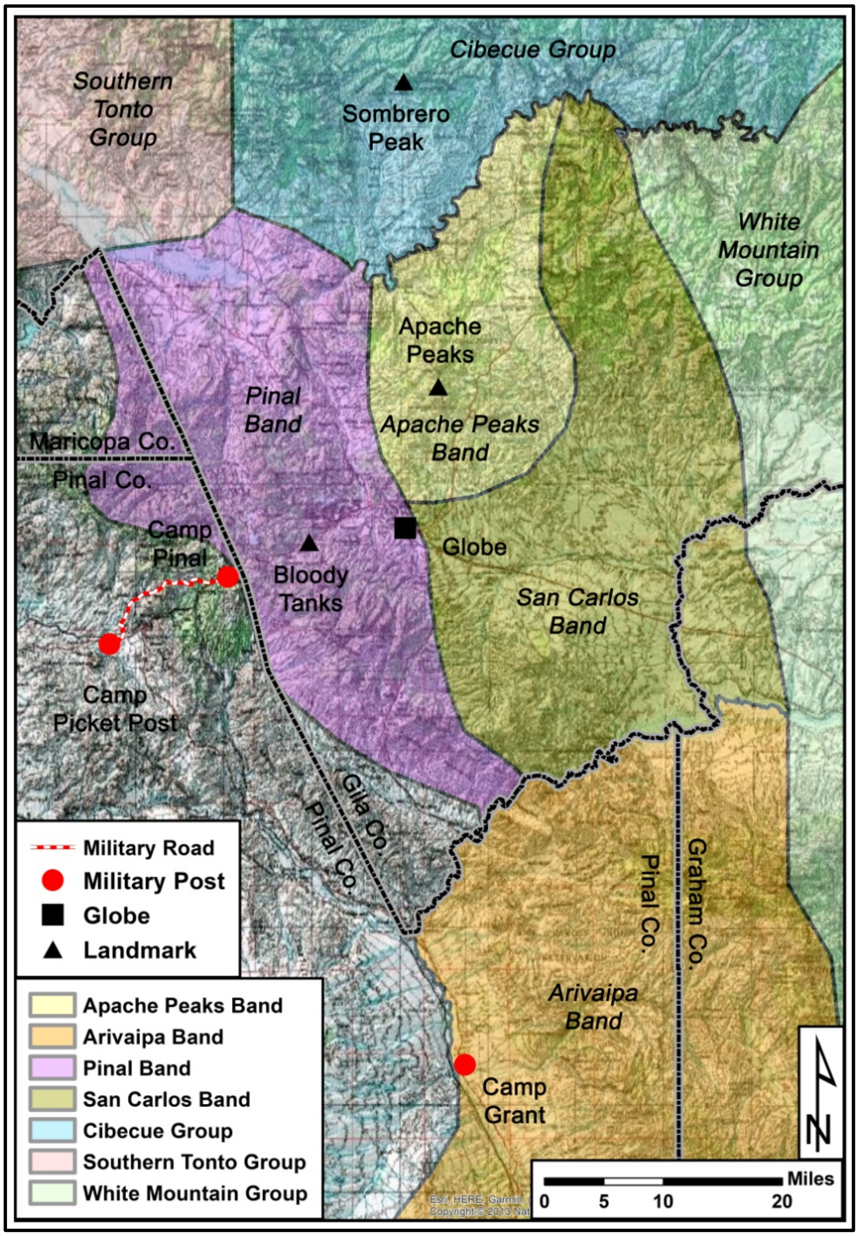


Figure 23. Pre-reservation boundaries showing location of various bands of the San Carlos group of Apaches, military posts and other landmarks (modified from Goodwin, 1969)

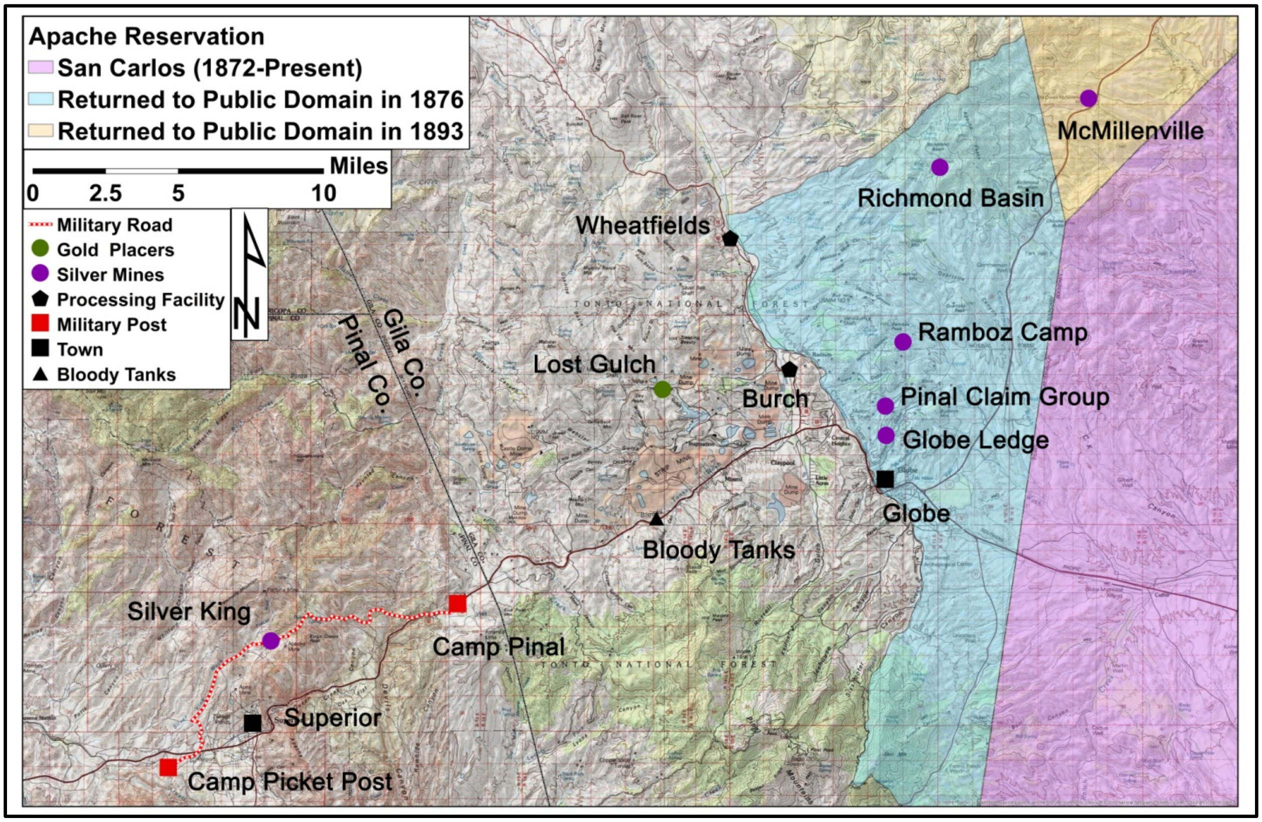


Figure 24. Early mill and smelter sites and precious metals mines in the Globe area showing location of San Carlos Apache Reservation and portions of the reservation that were later returned to the public domain (modified from Welch, 2017)

The Cooley party joined an expedition led by Calvin Jackson from Prescott in late September 1869 and prospected about 30 miles up the Salt River without success. Discouraged Cooley and most of his party returned to the Salt River Valley. However, Jackson and his party were joined by William A. Holmes, a member of the Cooley party, and turned south to prospect along streams that flowed north from the Pinal Mountains. While exploring Big Johnnie Gulch several miles north of Globe in late October 1869, this group of prospectors constructed a crude rock fort in the mouth of a cave for protection against an Apache war party. After the danger had subsided, they found some good-looking black ore, which was subsequently assayed when they returned to Prescott, revealing the presence of abundant silver. Calvin Jackson and his men returned to the site of their discovery along Big Johnnie Gulch with an escort of cavalry from Camp McDowell in November 1870 and located 15 mining claims of the Pinal claim group (Figure 24). These were the first mining claims to be located in the Globe-Miami area (Haak, 1991).

4.4 Military Campaigns against the Western Apache (1870-1873)

During the early years, excursions by prospectors into the region were impeded by conflicts with the Western Apache and Yavapai tribes, making it not only difficult but hazardous to develop any discoveries. In an effort to resolve this situation, General George Stoneman (Figure 25) erected a small military camp near the base of Picket Post Mountain in November 1870 and commenced construction of a road to the proposed site of Camp Pinal, a second military post in the Pinal Mountains.

Figure 25. General George Stoneman (1822-1894), military commander of Arizona (1869-1871) (photo from the Library of Congress)

Completed in April 1871, this road meandered north from Camp Pickett Post (Figure 24) on Queen Creek, about 3 miles west of the present town site of Superior, to a point along Silver King Wash; then followed Silver King Wash north to its junction with Comstock Wash. The road crossed the Pinal Mountains at "Stoneman's Grade", where it dropped into the upper reaches of the Queen Creek drainage before emerging just north of Oak Flat and crossed Devils Canyon before continuing east to Camp Pinal (Figure 24), located near the present-day community of Top of the World.

Frustrated the army was not doing enough to protect the citizens of Pima County from Apache raids, a group of six Anglo-Americans, 42 Mexican Americans, and 92 Tohono O'odham led by William S. Oury and Jesús M. Elias attacked a Western Apache

(Aravaipa and Pinal Bands) encampment near the confluence of Aravaipa Creek and the San Pedro River on April 30, 1871 (Thrapp, 1967). While the number of Apache killed in the Camp Grant Massacre (Figure 23) varied from 85 to 144, almost all of the dead were women and children. An additional 27 Apache children captured by the Tohono O'odham were sold into slavery in Mexico. A second expedition against the Apaches at Camp Grant by a mob of 200 armed Tucsonans was thwarted by the army in September 1871 (Hastings, 1959).

Pressured by the military and Eastern press, President Grant threatened to place Arizona under martial law if the perpetrators were not brought to trial. In October 1871, a Tucson grand jury indicted 100 of the participants in the Camp Grant Massacre with 108 counts of murder. However, two months later, the trail focused solely on Apache depredations, resulting in Judge Titus to instruct the jurors to decide whether the defendants acted in self-defense or with malice. On December 11, 1871, all were acquitted after five days of testimony and only 19 minutes of deliberation by a Tucson jury. Only six of the twenty-seven Apache children kidnapped by the Tohono O'odham were eventually repatriated from slavery in Mexico (Hastings, 1959).

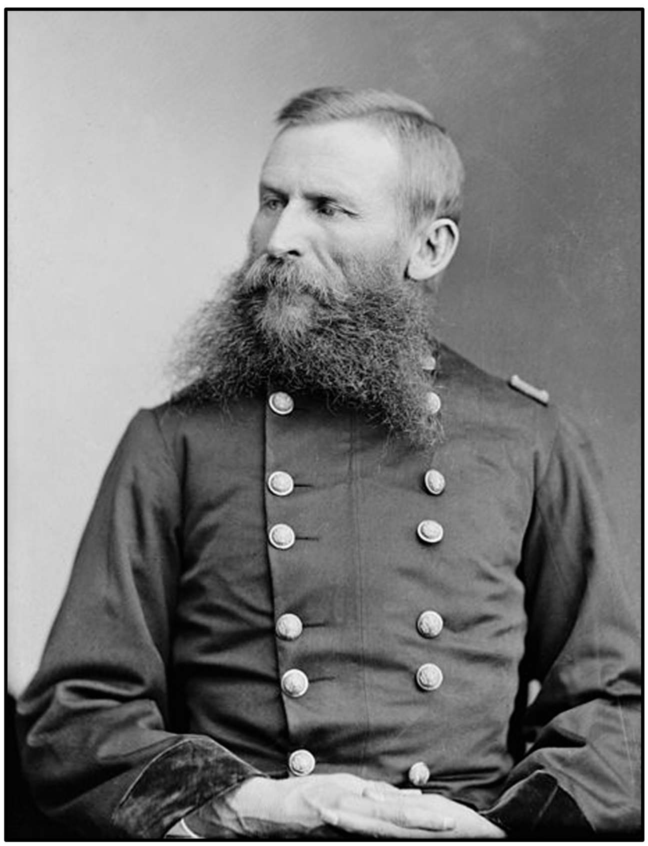


Figure 26. General George Crook (1828-1890), military commander of Arizona (1871-1875 and 1882-1886) (photo from the Library of Congress)

By presidential order dated May 2, 1871, General Stoneman was relieved of command and replaced by General George Crook, effective June 4, 1871 (Hastings, 1959). Unlike his predecessor, General Crook confronted the problem at hand (Figure 26). Camp Pinal was abandoned in July 1871 (Machula, 1996). Peaceful bands of Western Apache were permitted to settle on the White Mountain Reservation formed in November 1871 and the San Carlos Reservation (Figure 24), which was established in December 1872. (Harte, 1972).

Western Apache bands that refused to relocate to the reservations were relentlessly pursued by numerous well-coordinated military patrols during winter campaigns that forced the hostiles to remain on the move, denying them an opportunity to hunt, get to cached supplies or rest (Bahm, 1966). Members of friendly Apache bands and other tribes were recruited as scouts, who had the skills to find their elusive foe. By the spring of 1873, resistance had ceased as most of the Western Apache were now residing on reservations (Thrapp, 1967).

4.5 Silver Boom (1874-1882)

A pause in hostilities with the Apaches encouraged prospectors to venture into the Globe-Miami area. Over the next several years, major silver discoveries were made at Richmond Basin, Ramboz Camp and McMillenville (Figure 24).

4.5.1 Richmond Basin

During 1874, Gip Chilson and Henry Wagner found silver nuggets ranging from small flakes up to 12 pounds in streams that drained a small basin west of Apache Peaks. Tracing the placer silver upstream, rich silver lodes were soon discovered at the Richmond Basin (Figure 24), located approximately 12 miles north of the Globe, Arizona. Lode ores from this site were treated by a stamp mill located along Pinal Creek at Wheatfields (Chilson, 1926). By the 1883, the bonanza ore shoots had been mined and production declined significantly (Bishop, 1935).

4.5.2 Ramboz Camp

The first settlement of the region, known as Ramboz Camp, was established by Henry Ramboz, following the discovery of rich lead-silver ores at the Rescue and Ramboz veins in August 1875. These lead-silver ores assayed 50 to 60% lead and up to $1,000 of silver per ton of ore (equivalent to more than $26,000 per ton in 2020 dollars). Ramboz Camp (Figure 24) consisted of a few houses and a small store (Haak, 1991).

4.5.3 McMillenville

In March 1876, rich silver ores were discovered by Charles McMillen and Theodore Harris at the Stonewall Jackson mine, near McMillenville, located approximately 15 miles northeast of Globe (Figure 24). Within a month, hundreds of prospectors descended on the area, establishing a community with stores, a post office, saloons, and boarding houses. McMillen and Harris sold their property to a Santa Rosa, California party for $120,000 in the fall of 1877. Production peaked in January 1880 and lodes were played out by late 1882. The once thriving community of 1,700 moved on looking for opportunities elsewhere (Haak, 1991).

4.5.4 Globe Hills Mining District Organized

By the summer of 1875, a potentially explosive situation arose as many of the silver discoveries had been made on lands that had been set aside for the San Carlos Apache Reservation. Prospectors disregarded reservation boundaries, which had never been clearly delineated or surveyed.

In late October 1875, a group of Arizonans petitioned the Secretary of Interior to restore the area to the public domain (Harte, 1972). The region was opened up to prospecting, when President Grant issued an executive order returning it to the public domain in April 1876 (Figure 24) (Anonymous, 1912).

On November 25, 1875, the Globe Hills mining district was organized by Bill Hope, Doc Hammond, Jim Winters, Dr. Brown, Robert Metcalfe, Al Wheelock, George Scott, and Black Jack Harvey. They set up regulations governing the locating, filing and recording of mining claims. Records of all of the mining claims filed were kept by the leader of this group, Dr. Frank, until Gila County was established in February 1881 (Ziede, 1939).

Over the next several years, numerous prospectors ventured into the mountains bordering Pinal Creek discovering rich silver lodes with most of this early activity occurring east of Pinal Creek. Placer gold was recovered from gravels along Lost Gulch (Figure 24) (Sain, 1944).

The Miami Mining and Milling Company erected a ten-stamp mill along Miami Wash around 1877 to process ores from nearby silver mines. Located approximately 2,500 feet south of its confluence with Pinal Creek, the site was named Miami (now known as Burch - Figure 24) after the Miami Valley in Ohio (Sain, 1944).

According to the Globe City Chronicle, there were 20 organized mining companies in the district operating 12 stamp mills (with 82 stamps) treating silver and gold ores during 1880. Other small mining camps that dotted the landscape north of Globe included Cottonwood Springs, Mineral Hill, McNelly, Oakville, and Watsonville (Haak, 1991).

During the 1880s and early 1890s, vast quantities of silver were extracted from western mines resulting in an oversupply driving the price of silver down despite government purchases required under Bland-Allison Act of 1878 and the Sherman Silver Purchase Act of 1890. By the time the Sherman Silver Purchase Act was repealed in November 1893, virtually all silver mining activity in the Globe area had ceased (Bishop, 1935).

4.6 Early Days of Globe, Arizona (1876-1915)

The need for a more centralized commercial hub to supply the numerous small mining camps scattered throughout the region resulted in the establishment of Globe City in July 1876 (Figure 24). Located immediately south of the confluence of Alice Gulch with Pinal Creek, this site had an abundant supply of water and offered good protection from potential Indian attacks (Ziede, 1939).

Renamed Globe in 1878, its name was reportedly derived from the discovery of a large, nearly pure silver nugget, whose spherical shape and surface markings resembled the planet earth. Globe (Figure 27) later became the seat of the newly established Gila County in February 1881 (Haak, 1991).

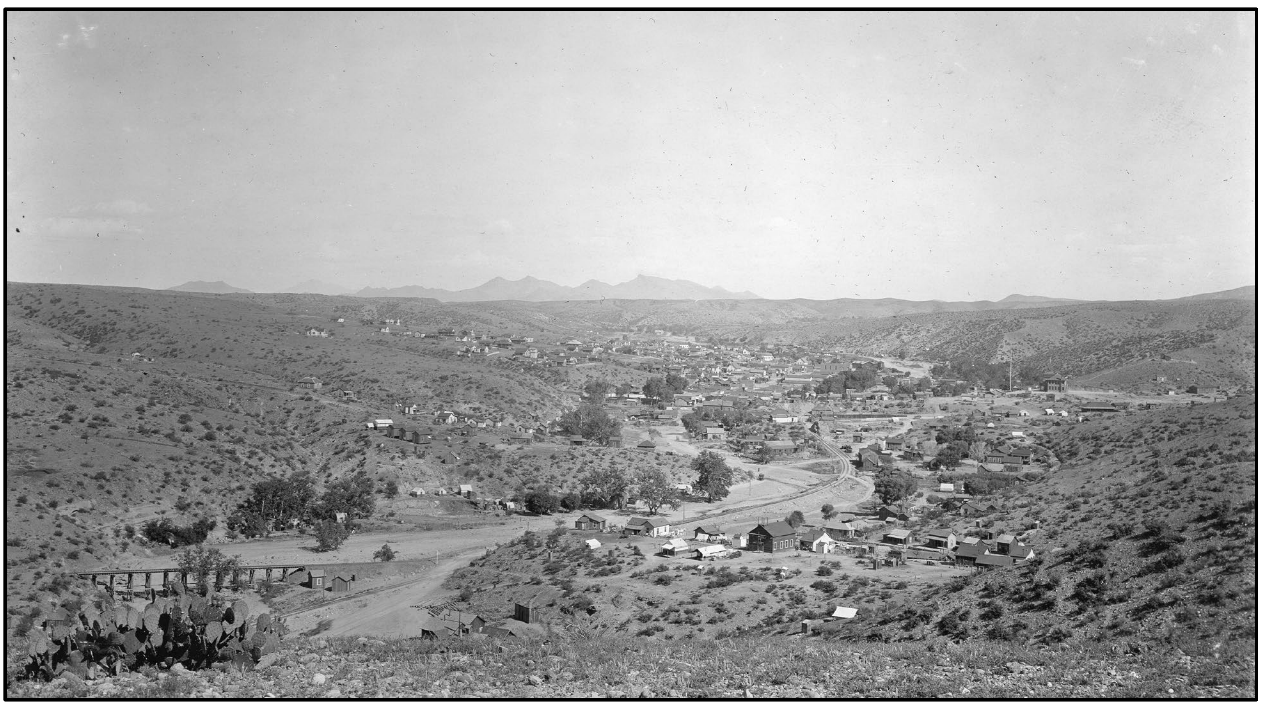


Figure 27. Panoramic view of Globe, Arizona, looking southeast along Pinal Creek from an area near the Old Dominion mine, circa June 1901 (photo from the U. S. Geological Survey)

Globe's remote location was a major impediment to its early growth. Rugged mountains blocked access to the south and west, while the San Carlos Indian Reservation was located along more accessible terrain to the east. During the early days, supplies were hauled over a poorly maintained wagon road that connected Globe with Silver City, New Mexico, a distance of 150 miles (Plateau Resources LLC, 2015). Supplies arriving from the west were transported on the backs of mules via a primitive, precipitous trail that connected Globe with Pinal City (near the site of Camp Picket Post, Figure 28), located approximately 3 miles west of present-day Superior, Arizona (Sain, 1944).

Regular stage coach service from Silver City, New Mexico was established in 1878. This express passed through the San Carlos Indian Reservation, where its stages were occasionally waylaid by Apaches (Ziede, 1939).

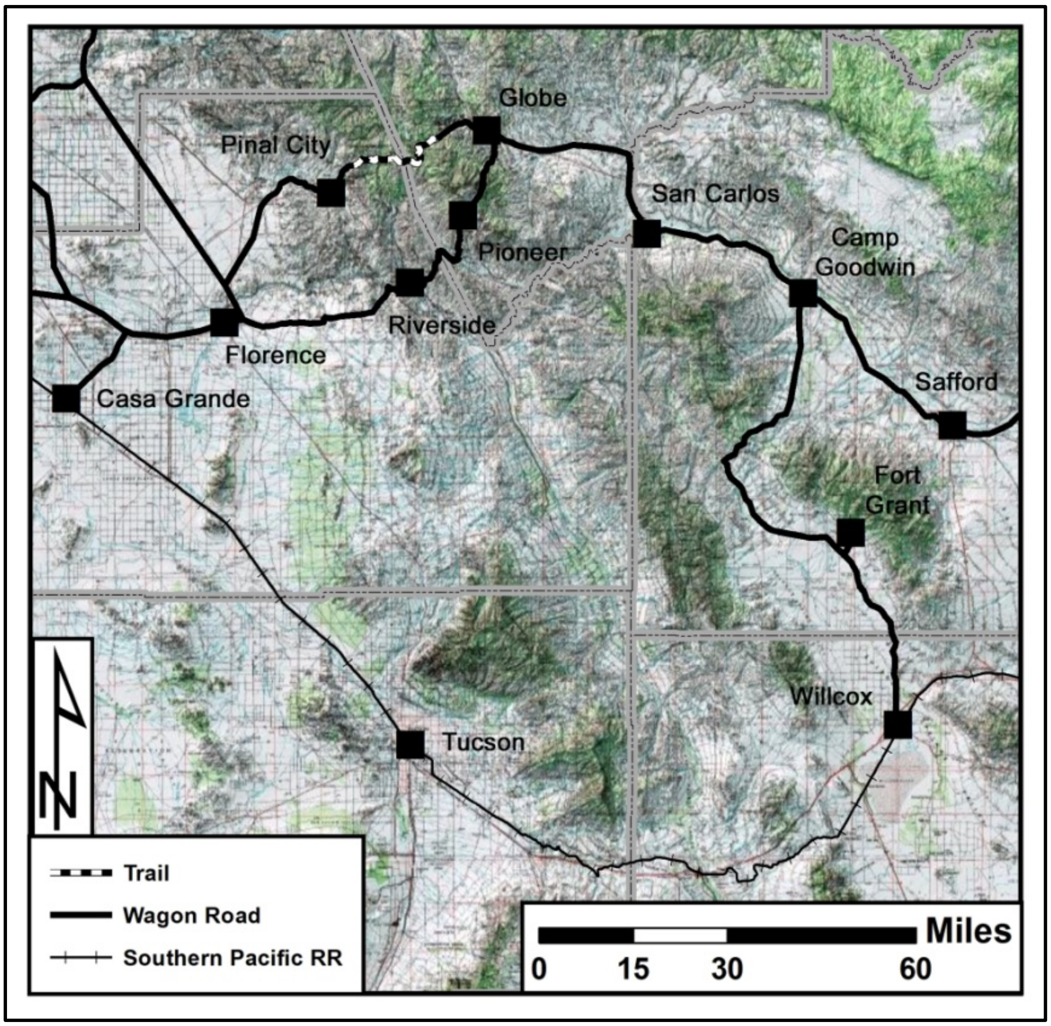


Figure 28. Early roads and trails connecting Globe with nearby communities in southeastern Arizona Territory (1880-1898) (modified from Plateau Resources LLC, 2015)

In an effort to resolve Globe's transportation issues, the Gila County Board of Supervisors began granting toll road franchises in January 1882. The first to be franchised was the Saxe Toll Road, which connected Bloody Tanks and Globe from 1882 until 1902, when it was declared a public highway (Figure 28). After crossing the mountains by mule, travelers from Pinal City would rest at Saxe's Hotel at Bloody Tanks before continuing their journey to Globe by stagecoach (Plateau Resources LLC, 2015).

By 1883, a wagon supply road crossed the Pinal Mountains to the south, connecting Globe with Florence via way of Pioneer and Riverside (Figure 28) (Plateau Resources LLC, 2015).

With the completion of the Southern Pacific Railroad during the early 1880's, the railhead at Willcox became increasingly important as a shipping center for Globe via wagon road through Fort Grant and San Carlos (Figure 28). Two attempts to construct a rail line to Globe during the 1880s failed. Rail service finally reached Globe in December 1898 with the completion of the Gila Valley, Globe and Northern Railroad from Teviston, Arizona (renamed Bowie in 1908) (Irvin, 1987).

Many of Globe's early residents came from Silver City, New Mexico. Globe's first building was erected during the summer of 1876 by Charles Shannon and Robert Metcalfe, who participated in the discovery of copper ores at Morenci during the early 1870s (Haak, 1991). The community's first buildings were constructed with adobe. The first brick structure was erected in May 1878 (Ziede, 1939).

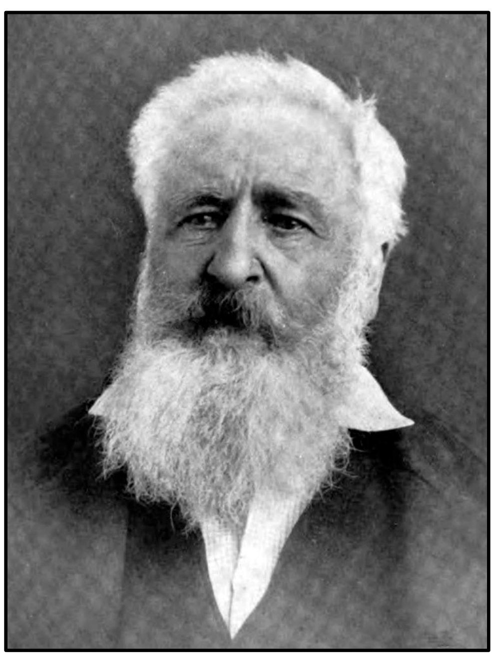


Figure 29. Judge Aaron H. Hackney (1815-1899), founder of the Arizona Silver Belt, Globe's first newspaper (photo from McClintock, 1916)

Mrs. A. C. Swift opened the first school in Globe with 20 pupils in December 1877. The first edition of the Arizona Silver Belt, Globe's newspaper, was published by Judge Aaron H. Hackney (Figure 29) on May 2, 1878 (McClintock, 1916). Reverend J. J. Wingar established the St. Paul's Methodist Church in April 1880. The 1880 census documented 704 individuals living in Globe (Haak, 1991).

Globe's business district grew rapidly, supplying its residents with the necessities of life and conducting substantial commerce with nearby mining camps. Arriving in Globe while it was still a part of the San Carlos Indian Reservation, T. C. Stallo initially sold his merchandise from a tent located near the hangman's tree. After learning it was not legal to sell liquor on the reservation, he sold the potatoes for $1 apiece and provided the customer in a small flask of whiskey for free (Haak et al., 2008). By 1881, Globe's business community included 12 mercantile houses, a bank, two hotels, several restaurants, two drug stores, blacksmith, a brewery, an ice factory, and several lumber yards and feed lots (Ziede, 1939).

Like many early mining communities, much of the social life in Globe was centered on the many saloons that provided the only diversions available for its residents, alcohol and a place to gamble. It is not known when the first "soiled doves" arrived in Globe, but by 1883 there were a considerable number of prostitutes frequenting the bars. Mayhem reigned in the saloons at the lower end of town, where gamblers, dance hall girls and ladies of the evening plied their trade (Ziede, 1939).

During its early days, Globe was a rough-and-tumble community of miners, prospectors, merchants, servitors, gamblers, prostitutes, and drifters. Drawn by rich discoveries of mineral wealth in the nearby hills, everyone was seeking a share in this prosperity by one means or another. In most cases this was accomplished legally, but in others crimes were committed. Crime was more common in Globe than in older established communities and with few exceptions, when apprehended, justice was swift and harsh for the perpetrators of lawless acts. Nearly every murder or well-known robbery was concluded with an execution (Ziede, 1939).

An example of one deplorable crime occurred on Sunday, August 20, 1882. On that day a mule train hauling a strongbox with $10,000 in gold from the Pioneer Pass stage station to Globe was robbed by Lafayette Grime and John Hawley. During the course of the hold-up Wells Fargo & Company shotgun messenger, Andy Hall, was shot and killed, but his assistant, Frank Porter was able make it to Globe to report the robbery. Dr. William Vail inadvertently arrived at the scene a short time later; finding the robbers as they were dividing the gold and was shot and left for dead. Vail was later found by the posse and described the robbers before succumbing from his wounds (Ziede, 1939).

Figure 30. Hanging tree in Globe, Arizona. The hanging tree, damaged by the June 1894 fire that devastated much of Globe, was later declared a public hazard and cut down (photo from Warner, 2019).

By late Tuesday, Lafayette Grime and John Hawley had been arrested and confessed to the crime, implicating Cicero Grime, who only served as a scout to find when the gold was being shipped, but had not participated in the actual robbery or murders. After retrieving the stolen gold from its hiding place, Lafayette Grime and John Hawley were brought before Justice of the Peace, George Allen on Wednesday evening, found guilty and sentenced to hang. After given time to prepare their last will and testaments, Lafayette Grime and John Hawley were marched to a sycamore tree in the middle of Broad Street (Figure 30) and hung at 2:00 AM on Thursday, August 24, 1882 (Ziede, 1939). Cicero Grimes was sentenced to 21 years at Yuma Territorial Prison, but was later declared insane and sent to an asylum in Stockton, California. A short time later, he simply walked away and vanished (Warner, 2019).

During its early years, one calamity after another plagued the community of Globe. The collapse of the silver market in 1882 was followed by a fire on April 4, 1885, which destroyed much of the downtown business district. This was followed by closure of the Old Dominion copper mine in May 1885 (Ziede, 1939). On the afternoon of May 3, 1887, residents fled from their homes into to streets upon feeling the shocks of the Great Sonoran Earthquake. Fortunately, very little damage resulted from this event (DuBois and Smith, 1980).

On February 18, 1891, unusually heavy rainfall in the Pinal Mountains melted snow in the high country, resulting in a flash flood along Pinal Creek that forced many residents to abandon their homes and businesses along its banks. The lumber yard at the Old Dominion mine was washed downstream. Three years later, another fire swept through Globe on June 9, 1894. Forty buildings, comprising several blocks were consumed by the flames (Ziede, 1939). On August 19, 1904, a heavy monsoon storm resulted in a flash flood that swept through Globe resulting in six deaths, destroying 20 businesses and washing way railroad bridges.

By the early 1900s, a moral revival took hold in Globe. Attempts were made to clean up its red-light district and ordinances were passed prohibiting all games of chance, such as faro, poker and blackjack. This was accompanied by many arrests and fines designed to discourage unacceptable conduct. In 1907, the Arizona Territorial Legislature passed an ordinance that prohibited the employment of minors and women in saloons. This forced Globe's brothels to relocate to another portion of the town (Ziede, 1939).

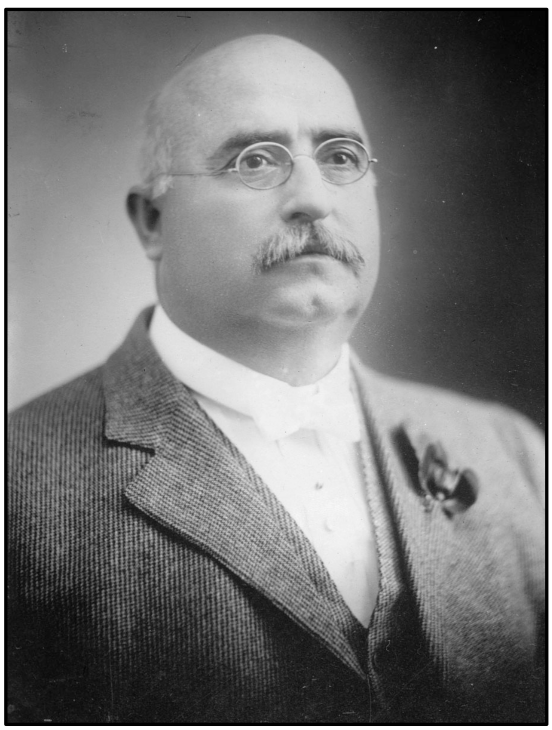


Figure 31. A businessman and politician, George W. P. Hunt (1859-1934) became Arizona's first state governor on February 14, 1912 (photo from Library of Congress)

Arriving in Globe in October 1881 and residing there for much of his life, George W. P. Hunt (Figure 31) worked as a waiter at a restaurant, miner, cowboy and got a job as a clerk with the Old Dominion Commercial Company in 1890, eventually becoming a partner in the business in 1896 and its president in 1900 (Chapman Publishing

Company, 1901). Successfully running for the Territorial House of Representatives in 1892, he became a dominate figure in Arizona politics by the early 1900s, becoming Arizona's first state governor on February 14, 1912 (Ziede, 1939). He would go on to serve a total of seven 2-year terms as governor between 1912 and 1933.

4.7 Transition to Copper (1878-1886)

David and Robert Anderson of Florence, Arizona, along with Benjamin Reagan, Charles Mason, William Long, and Isaac Copeland located the Globe and Globe Ledge claims (Figure 24) at the future site of the Old Dominion mine in September 1873 (Haak, 1991). Initially staked for silver, these claims were intermittently worked, but little was accomplished due to its remote location on lands that had been set aside for the San Carlos Indian Reservation.

Returning home from one of their prospecting forays to the Globe area, Benjamin Reagan, Charles Mason, William Long, and Isaac Copeland camped out at the base of Stoneman's Grade, north of Superior, Arizona, where they found black silver nuggets. Tracing the nuggets back to their source, they discovered Silver King mine in March 1875 (Short et al., 1943).

After prospective sites in Globe-Miami area had been restored to the public domain during the spring of 1876, Benjamin Reagan acquired his partners' interests in the Globe and Globe Ledge claims and drove a 100-foot tunnel at the site, upon which to base an application for a patent. This work was completed during the spring of 1877 (Hamel, 1922).

By the early 1880s the collapse of the silver market hastened the demise of silver mining in the Globe Hills area as much of the rich near-surface ores were mined out. It was at this time, prospectors began examining the economic potential of the region's widespread copper mineralization.

The first reported copper production in Globe-Miami area occurred at the Hoosier mine in 1878, which was worked for only a few months. This ore was hauled to Wheatfields (Figure 24), where it was treated by a primitive smelter to produce approximately 80,000 pounds of copper. The Hoosier mine was sold to John Saltzman in 1881, who erected a smelter along the east bank of Pinal Creek just north of Globe. However, this facility only operated for about six months before closing, as the price of copper declined to 8 cents per pound (Hamel, 1922).

In September 1881, the Devereux Bros. erected the Carrie smelter near Globe to treat ores from the True Blue, Carrie and Big Johnnie mines. These ores were treated in the first water-jacketed blast furnace used in the Globe Hills mineral district. This short-lived venture only lasted for four weeks before ceasing operations (Rickard, 1987).

In 1878, Mitchell H. Simpson acquired the Chicago and New York claims located about a mile southwest of present-day Miami, Arizona. He also purchased the Original Old Dominion mine (also known as Keystone, Figure 12) in December 1880 and incorporated the Old Dominion Copper Mining Company (Haak, 1999).

The Old Dominion Copper Mining Company erected two 30-ton furnaces near the confluence of Bloody Tanks Wash and Smelter Canyon to treat copper ores from the New York and Chicago claims in April 1881. However, this initial effort was not successful. These ores proved to be refractory and self-fluxing ores were scarce (Ziede, 1939). They ended up freezing up both furnaces and burning the water jacket on one of them. By March 1882, they were producing small amounts of copper, but only operated for several months, before relocating the furnaces to the Original Old Dominion mine, located along the east side of Pinal Creek, approximately 3.5 miles north of Globe (Peterson, 1962).

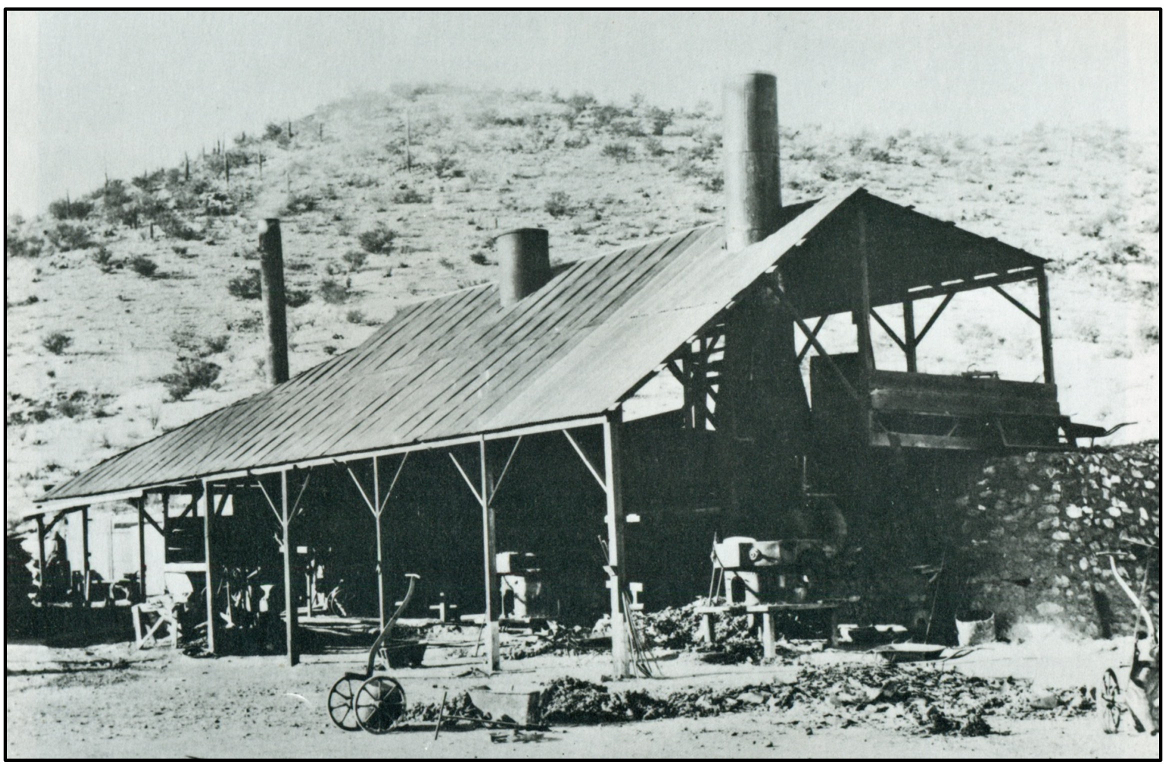


Figure 32. Buffalo Mining and Smelting Company smelter at Globe, circa 1882, (photo from the Arizona Historical Society)

The Buffalo Mining and Smelting Company began smelting operations (Figure 32) in December 1881, treating copper ores from the Buffalo and Hoosier mines. Other early copper producers included the Old Globe Copper Company in the spring of 1882, Long Island Copper Company in October 1882, and Takoma Copper Company in February 1883 (Rickard, 1987).

After conducting operations at the Original Old Dominion mine for a short period, the management of the Old Dominion Copper Mining Company purchased the assets of the Old Globe Copper Company in September 1882 (Rickard, 1987). They relocated the two furnaces from the Original Old Dominion mine site to join Old Globe's existing smelter. From this time on, the Old Globe mine became known as the Old Dominion mine, while the Original Old Dominion mine was abandoned.

During the early years, the Mooney Tunnel was the only access to the Old Dominion mine. Its entrance was located along the bank of Pinal Creek and provided access for the miners and mules, which were used to haul the copper ore from the mine (Haak, 1999).

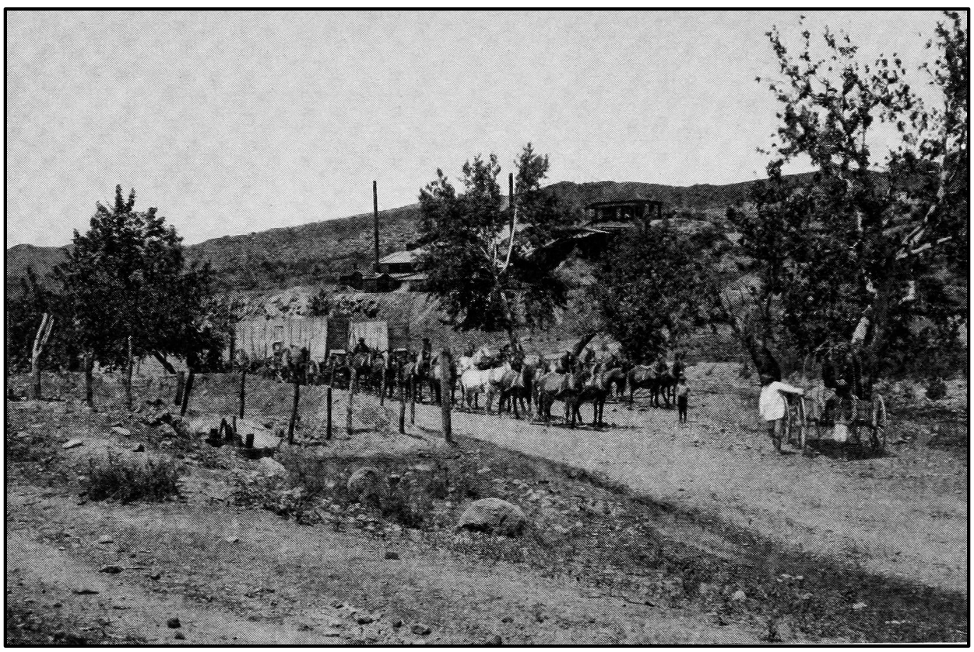


Figure 33. Mule teams hauled coke from the Willcox railhead to Old Dominion smelter (in background) and copper bullion on the return trip (circa 1880s or 1890s) (photo from Walker, 1935)

Early copper operations around Globe were impeded by the high freighting costs of transporting coke to fuel the smelters from the Willcox railhead on the Southern Pacific Railroad (Figure 33). Teams of 10 to 12 mules normally took several weeks to make the 260-mile round trip to Willcox (Plateau Resources LLC, 2015). However, coke deliveries were disrupted by seasonal monsoons that made the wagon roads impassable, frequently halting smelting operations until conditions improved (Willis, 1922a). Only the richest copper oxide ores could be mined at a profit (Peterson, 1962).

In March 1881, the Southern Pacific Railroad linked with the Atchison, Topeka & Santa Fe Railroad at Deming, New Mexico, completing America's second transcontinental railroad (Janus Associates, Inc., 1989). With the Southern Pacific Railroad located only 75 miles from Globe, efforts to connect this remote mining camp with the outside world began. In November 1882, the Arizona Narrow Gauge Railroad was incorporated to build a 36-inch (narrow gauge) line from the Southern Pacific railhead at Tucson to Globe. After a long delay, construction on this line began in September 1886, but only laid 10 miles of track and constructed a 368-foot bridge before the project was abandoned in 1887 (Irvin, 1987).

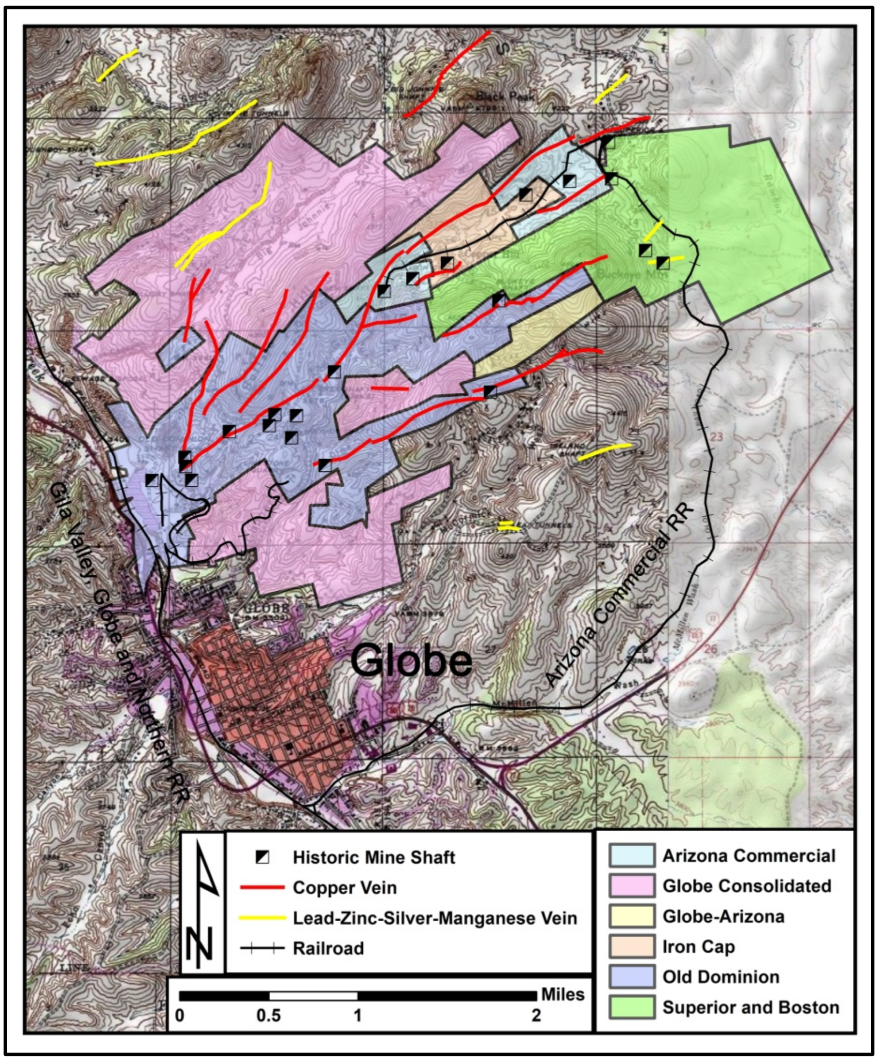


Figure 34. Property map (circa 1908) of major copper operations, showing surface traces of the major copper-bearing vein system in the Globe Hills area (modified from Nordberg, 1999)

Falling copper prices halted production at the Buffalo, Long Island and Takoma operations by the summer of 1883. Only the Old Dominion Copper Mining Company remained in operation. Efforts to maintain steady production included excavation of a 1,000-foot tunnel connecting the Old Dominion and Old Globe underground workings and construction of a 200-ton bin to stockpile coke to fuel the smelter (Haak, 1999). After several years of diminishing output, Old Dominion Copper ceased operations in May 1885 and declared bankruptcy (Ziede, 1939).

By the late 1880s, mining in the Globe Hills area had transitioned from silver to copper. Over the next four and half decades, the Old Dominion (1882-1931), Arizona Commercial (1905-1930), Iron Cap (1908-1927), and Superior and Boston (1908-1927) operations mined rich copper ores from a northeast-trending vein system that ultimately accounted for 99.4% of the Globe Hills Mineral District's reported historical ore production (Figure 34).

4.8 Old Dominion Mine (1886-1931)

In February 1886, the assets of the Old Dominion Copper Mining Company were sold at auction to William Keyser of Baltimore for $130,000. Although the copper price remained very low, operations resumed at Old Dominion during the spring of 1886. By the end of July 1886, teamsters arrived daily from Willcox, supplying the coke required to fuel the smelter and hauling copper bullion (i.e., black copper – 94% copper) destined for eastern markets on the return trip. By March 1887, the Old Dominion smelter was producing 7 tons of copper daily at a cost of 8 to 9 cents per pound (Ziede, 1939).

A second attempt was made to connect Globe with the outside world in January 1887. The Arizona Mineral Belt Railroad began construction on a standard gauge line from the Atlantic and Pacific railhead at Flagstaff, but only completed laying 40 miles of track before financial problems halted the project in October, 1887, when the Atlantic and Pacific Railroad refused to pay its commitment of $175,000 for the completion of work to date. Unable to resolve its financial difficulties, the assets of the Arizona Mineral Belt Railroad were sold for $40,140 at a sheriff's auction to Dennis M. Riordan and Francis E. Hinckley, who operated the line to haul timber (Trennert, 1970).

The Old Dominion Copper Mining Company was reorganized as the Old Dominion Copper Company of Baltimore City in January 1888 and collared the Interloper shaft, which was sunk to the sixth level of the mine (Peterson, 1962). By December 1891, this mining venture had proven profitable and its huge debt had been extinguished.

One of the early problems encountered by this operation was the transportation of ores from the mine entrance to the smelter, a distance of approximately 1,300 feet. The ores were initially hauled down a steep hill by wagon, which made it difficult to keep the heavily loaded ore wagons from running over the mule team on the downgrade, and nearly impossible to move the empty wagons up the hill on the return trip (Trennert, 1999).

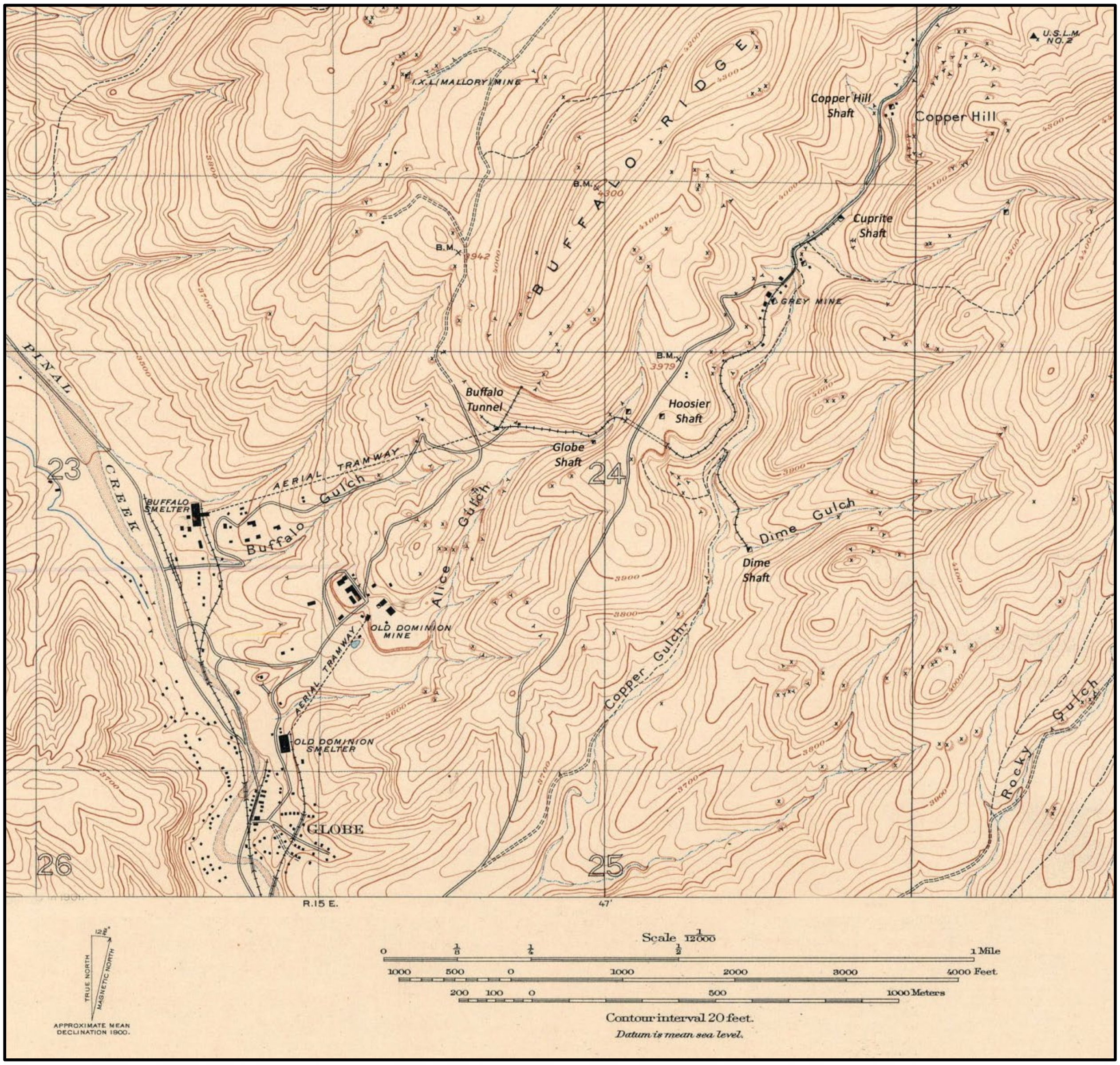


Figure 35. Old Dominion and United Globe smelters, mines and aerial tramways, circa 1901 (modified from Ransome, 1903)

Three 42-inch water-jacketed (185-ton capacity) blast furnaces were commissioned at a new smelter in January 1892 (Rickard, 1987). Ore was supplied to this facility by a 1,224-foot Bleichert double rope-type tram system that was constructed by Cooper, Hewitt and Company of Trenton, New Jersey (Figure 35). It employed 11 buckets of 800 pounds capacity each, which enabled Old Dominion Copper to deliver by gravity as much as 170 tons of ore per ten-hour shift to the smelter at a cost of 9 cents per ton, compared to 20 cents per ton by wagon (Trennert, 1999). Over the period, January 1888 until May 1895, Old Dominion Copper Company of Baltimore recovered approximately 7 million pounds of copper, annually (Peterson, 1962).

In January 1894, the Gila Valley, Globe and Northern Railroad (Figure 36) was incorporated to build a 126-mile standard gauge line from the Southern Pacific railhead at Teviston (renamed Bowie in 1908) to Globe. Construction commenced at Teviston in February 1894. By January 1896, the line reached Geronimo, where construction was halted for two years while an agreement to cross the San Carlos Indian Reservation was negotiated with the Apache Tribe and Federal Government. The Gila Valley, Globe and Northern Railroad finally arrived in Globe in December 1898. Branch lines were later extended to Arizona Commercial's Copper Hill property in March 1907 and to Miami in October 1909 (Irvin, 1987).

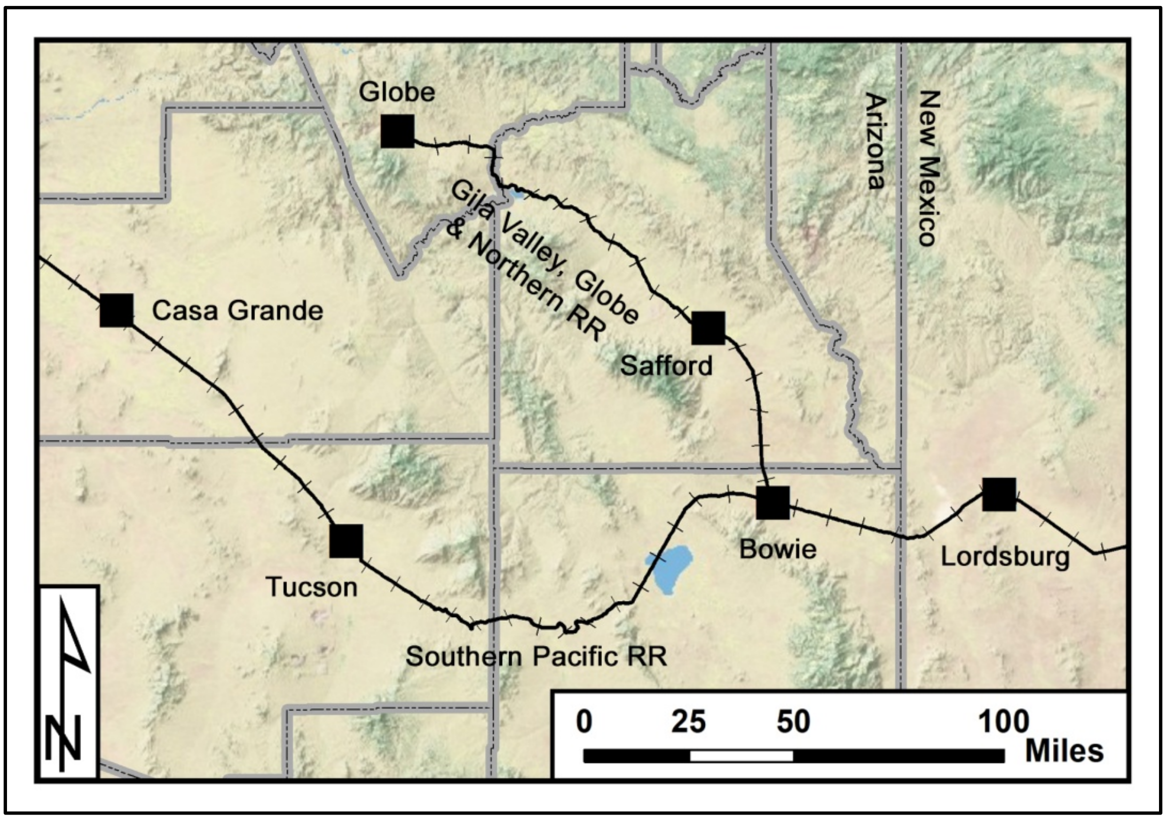


Figure 36. Topographic relief map showing Southern Pacific Railroad and the Gila Valley, Globe and Northern Railroad

In May 1895, the Old Dominion Copper Company of Baltimore City was sold to Lewisohn-Bigelow interests for $1 million, who reorganized it as the Old Dominion Copper Mining and Smelting Company in July 1895. Following a brief renovation of the smelter, limited operations resumed in December 1895 (Ziede, 1939). As the mine reached eighth level in 1896, water was encountered requiring the installation of pumps to keep the deeper levels from being flooded.

Over the next several years, the water problems were made worse as a result of an erroneous geologic interpretation that identified the Apache Leap Tuff (a volcanic formation that overlies the upper Precambrian and Paleozoic host rocks in the southwestern portion of the Old Dominion mine) as a dike, because it underlies highly shattered Madera Diorite. Efforts to locate the southwest continuation of Old Dominion vein by driving an exploration drift through the supposed dike, tapped underground water channels in the overlying Gila Conglomerate (Ransome, 1903).

Following the purchase of the Old Dominion mine by Lewisohn-Bigelow interests, attempts were made to reduce the costs of producing copper. Daily wages were cut from $3.00 to $2.50 and in June 1896 a second cut was made to $2.25. Following a month-long strike, the miners succeeded in getting the daily wages restored to $3.00, but failed to gain the recognition of their union (Tenny, 1927-1929).

Over the next several years, a large amount of copper had accumulated at the smelter in anticipation of lower shipping rates when the railroad arrived in Globe. Shortly after the completion of the Gila Valley, Globe and Northern Railroad to Globe in December 1898, the tracks were extended to the Buffalo smelter of the United Globe Mines Company. Several hundred yards from the terminal, spurs were also laid to service the Old Dominion smelter (Haak, 1999).

In January 1899, the Old Dominion mine shipped 1,120,000 lbs. of copper, which is reported to have been the largest single shipment of copper in Arizona until September 1902 (Rickard, 1987). By late 1901, underground workings of the Old Dominion mine extended down to the 12th level and flooding had become a very serious problem. Additional pumping capacity was installed and the mine was finally dewatered by 1903 (Peterson, 1962).

4.8.1 United Globe Mines Company (1891-1903)

Alex Trippet leased the Buffalo mine and smelter in 1887 and operated it until November 1891, when it was purchased by Phelps Dodge and Company. Phelps Dodge consolidated several properties, including the Buffalo, Hoosier, Grey, Cuprite, and other claims that adjoined Old Dominion’s holdings to the north and east, forming the United Globe Mines Company (Peterson, 1962).

United Globe Mines Company expanded its plant in 1895 and resumed operations in January 1896, mainly concentrating on development of the Hoosier claim, which derived its production from rich, near-surfaces ores hosted by Paleozoic limestone (Peterson, 1962). A 3,000-foot Bleichert double rope-type tram system from the Trenton Iron

Company was commissioned in February 1897, connecting its mines with the Buffalo smelter (Figure 35) (Trennert, 1999).

Once the Gila Valley, Globe and Northern Railroad reached the Buffalo smelter, United Globe Mines began to produce copper at a profit, aided by its aerial tram system. The scarcity of fluxing ores in the Globe Hills mineral district led to the closure of the Buffalo smelter around 1900 (?). Following its closure, production was shipped to El Paso for smelting (Stevens, 1902).

4.8.2 Old Dominion Company (1903-1931)

In December 1903, 95% of the outstanding stock of the Old Dominion Copper Mining and Smelting Company and all of the stock of the United Globe Mines Company were acquired by the Old Dominion Company, a holding company controlled by Phelps Dodge and Company (Willis, 1922a). This enterprise was formed for the purpose of operating both properties under the same management, while complying with an injunction that prevented the merger of the two corporations. The Old Dominion mine (Figure 37) was operated under this arrangement until early 1917, when the Old Dominion Company acquired the remaining assets of the Old Dominion Copper Mining and Smelting Company (Weed, 1920).

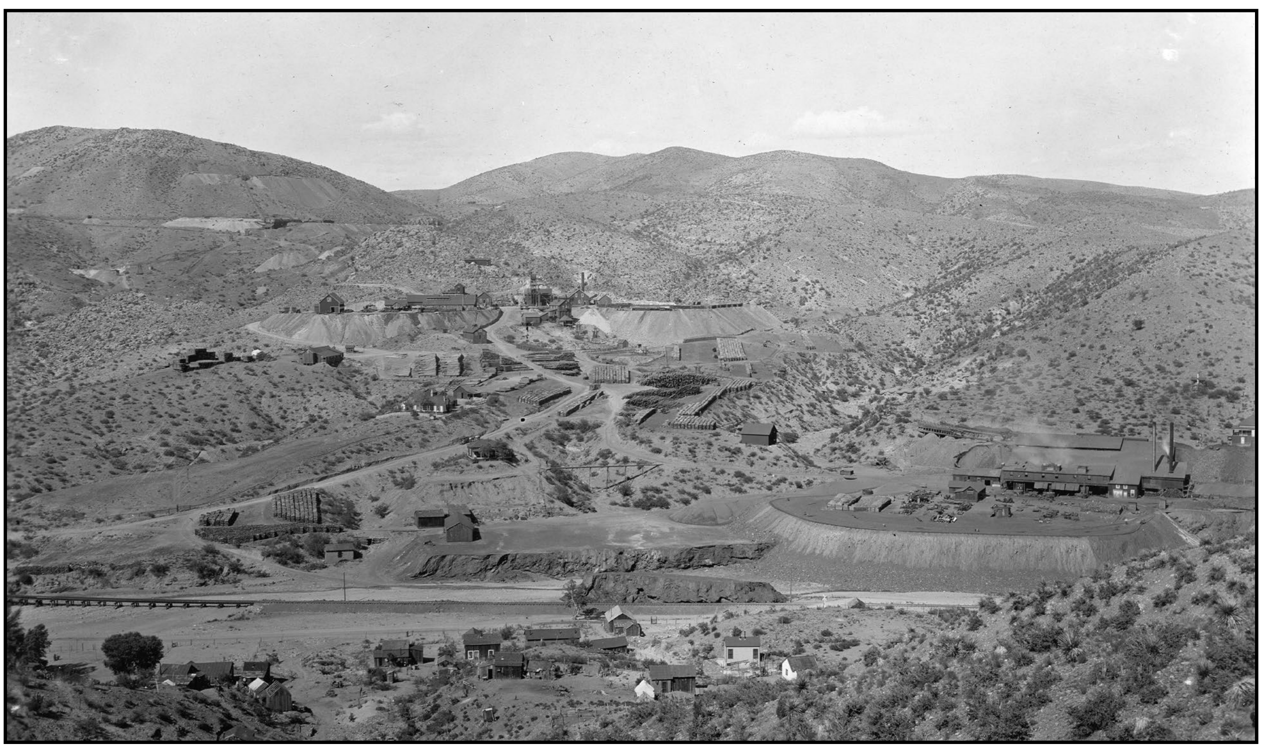


Figure 37. Old Dominion mine (center) and smelter (right), circa 1901 (photo from the U. S. Geological Survey)

The operation was placed under the management of Louis D. Ricketts, who arrived at the site in February 1904. The “A” shaft was sunk and improvements to the processing facilities included a completely refurbished smelter, which began operation in September 1904; and a 300-ton per day gravity concentrator, which was commissioned in August 1905 (Peterson, 1962).

Prior to 1904, Old Dominion’s smelter primarily produced a black copper product (~94-96% copper) with lesser amounts of copper matte (71% copper), which were shipped off-site for additional treatment (Kirchhoff, 1904). With the addition of a converter to its modernized smelter, Old Dominion was able improve its metallurgical results upgrading an intermediate copper matte product to produce a blister copper product, containing 99.5% copper (Rickard, 1987).

Figure 38. A crowd watches the Interloper shaft fire at Old Dominion mine on February 20, 1906 (photo form the Arizona State University)

On the afternoon of February 20, 1906, a fire started on the ninth level of the recently decommissioned Interloper shaft (Figure 38), which was being used as a man-way and for ventilation. While its cause remains unknown, it appeared a careless miner left a lighted candle behind that ignited the timbers. By the time the fire had been discovered it had grown considerably. When the alarm sounded, five brave men descended into the shaft with a hose to fight the flames. The flow of air at the time was down the Interloper shaft, which was free from smoke and gas. However, within a few minutes, air currents changed, driving a dense plume of smoke and gas up the shaft, trapping the men. Only two of five escaped; Leroy Ikenberry and Richard Jones. Jack James, Joe Karpinsky and Jack Moffitt were overcome by the deadly gases, lost consciousness and fell to their deaths in the blazing inferno (Anonymous, 1906).

As tragic as the Interloper fire was, it could had been much worse. Had the downdraft in the burning shaft continued a few minutes longer carrying the dense smoke and gas into the mine, many others would had perished. Within 30 minutes after the alarm had sounded, all of the workers on shift had safely made it to the surface (Anonymous, 1906)

Efforts to confine the fire to the Interloper shaft were challenging due to its number of connections on many of levels with the mine. At their own risk, emergency crews re-entered the mine and quickly erected bulkheads on some levels isolate the fire. On other levels, explosives were used seal passages. Work crews managed to close all important openings leading to the fire, except for the twelfth level, which was flooded. The fire burned intensely for four to five hours before gradually dying down. By 9:00 PM much of supporting timbering had been consumed by the flames, resulting in the collapse of the walls of the Interloper shaft, which forced gases back into the mine, compelling those still working on the bulkheads to return to the surface (Anonymous, 1906).

Mine dewatering operations were conducted through the Pump shaft, which was sunk following the destruction of Interloper shaft (Woodbridge, 1906). Flooding in lower levels of the mine following the fire diminished to 3.5 million gallons per day by June 1906 (Stevens, 1906). With the completion of the Arizona Commercial Railroad to Copper Hill in March 1907, the aerial tramway at the Old Dominion mine was abandoned (Haak, 1999).

By the end of 1908, $2.5 million had been spent remodeling and expanding the Old Dominion smelter (Haak, 1999). This facility had six 44-inch by 180-inch blast furnaces, giving it a capacity of 2,400 tons per day. A 20-foot by 20-foot by 250-foot dust-flue chamber was connected to a 200-foot smoke stack. Flue-dust was briquetted for re-smelting. The blast furnaces produced a matte product containing 50% copper, which was treated by one of three converters to produce a blister copper product, containing

99.5% copper. The smelter was fueled by coke supplied by Phelps Dodge and Company's subsidiary in Dawson, New Mexico at a cost of $9.65 per ton (Stevens, 1908).

The 300-ton per day gravity concentrator initially employed a combination of jigs, 18 Frue vanners and nine Wilfley tables (Figure 39). The capacity of this facility was expanded to 800 tons per day in October 1914, when it was modified to use a combination of gravity and flotation methods to produce a copper concentrate product. All water used by the concentrator was pumped from the mine and none of it was recycled (Forrester and Cramer, 1931).

Figure 39. Old Dominion concentrator, circa April 1914. Note: Like many mills, both past and present, it was located on a slope of a hill, which allows gravity to move the ore from one stage of processing to the next (photo from Gila County Historical Museum).

In 1918, an 8-foot by 36-inch Hardinge ball mill was added to regrind the sand tails from the Deister tables, which had been previously rejected. The flotation circuit was upgraded to treat the reground sands as well as the slimes product. The concentrator was converted to all flotation treatment in 1923 and its production capacity expanded to 1,400 tons per day in 1926 (Forrester and Cramer, 1931).

Underground workings of the Old Dominion mine were accessed by "A", "B", "C", Kingdom, Grey, and Pump shafts (Figure 18). The 2,300-foot, five compartment "A" shaft and 2,400-foot, two-compartment Kingdom shaft were used for hoisting; the "A" shaft being the primarily hoisting shaft and the Kingdom shaft being used in an emergency. The “A” shaft was equipped with a steam-powered hoist, while the Kingdom shaft employed an electric hoist (Willis, 1922a). Mine ventilation was performed by three large surface fans at the “C”, Kingdom and Grey shafts which pumped 229,000-cubic feet of air per minute into the mine, while the “A” and Pump shafts served as a common up-cast for the downcast circuits. Virgin rock temperatures on the lowest level (2,600-foot level) were 109^{o} F. Located adjacent to the “A” shaft, the single-compartment Pump shaft was used solely for handling the large amounts of water encountered by the operation (Shoemaker, 1930).

Main haulage levels were placed at 200-foot vertical intervals, with intermediate levels for mining nearly always located mid-way between the main haulage levels. The copper veins at Old Dominion were extracted by a variety of methods, including top slicing and square set methods (Willis 1922a).

Three- and four-ton trolley electric locomotives were employed throughout the mine, hauling 20-cubic foot side-dump ore cars. A full train consisted of 35 ore cars. The electric-powered engines were operated on a 250-volt direct current. Thirty-pound rails were used for motor haulage with a track gauge of 18-inches. Maximum haulage distance to the hoisting shaft was 6,000 feet, but averaged 3,100 feet (Shoemaker, 1930).

Separate storage pockets adjacent to the main hoisting shaft were provided for direct smelting ore, concentrating ore and waste. The hoisting shaft employed 3.5-ton skips to hoist approximately 1,500 tons of ore and 400 tons of waste to the surface, daily. All hoisting was performed during two shifts, six days a week, leaving the remainder of the time for inspection and necessary maintenance of the shaft (Shoemaker, 1930).

The Old Dominion mine was plagued by problems with water in one way or another throughout much of its life. Flash floods were common along Pinal Creek, often resulting in severe damage to both the community of Globe and mine infrastructure. Industrial railroad spurs that provided access to the smelter, concentrator, power house, ore bins, and other facilities at the Old Dominion mine were particularly susceptible to flood damage (Haak, 1999).

By 1896, mine workings in the Old Dominion mine extended down to the 8th level, where the first serious problem with water was encountered. By the time the underground workings reached the 18th level (around 1915), dewatering operations were pumping 3.75 million gallons of water per day to keep the mine dry (Peterson, 1962).

In November 1908, a concrete dam was constructed across Pinal Creek approximately 1,400 feet south of the mine in an effort to obviate the heavy seepage of water that resulted in high pumping costs. All water running in the creek was diverted around the area underlain by the mine workings by means of a flume before it re-entered the creek bed, 2,300 feet downstream. This attempt failed to stem the flow of water into the underground workings (Beckett, 1917).

Heavy rains during the winter of 1914-15 resulted in an unusually high rate of flow into the underground workings. The pumping rate increased from 6.5 million gallons per day in January 1915 to a peak of 14.5 million gallons per day in early March 1915. Every available pump was placed into service and temporary air-lifts were rapidly installed to save the mine. During the month of March 1915, 407 million gallons of water were pumped from the mine. Herculean efforts by the mine crew saved the mine by the end of July 1915, when the inflow subsided to four million gallons per day (Peterson, 1962).

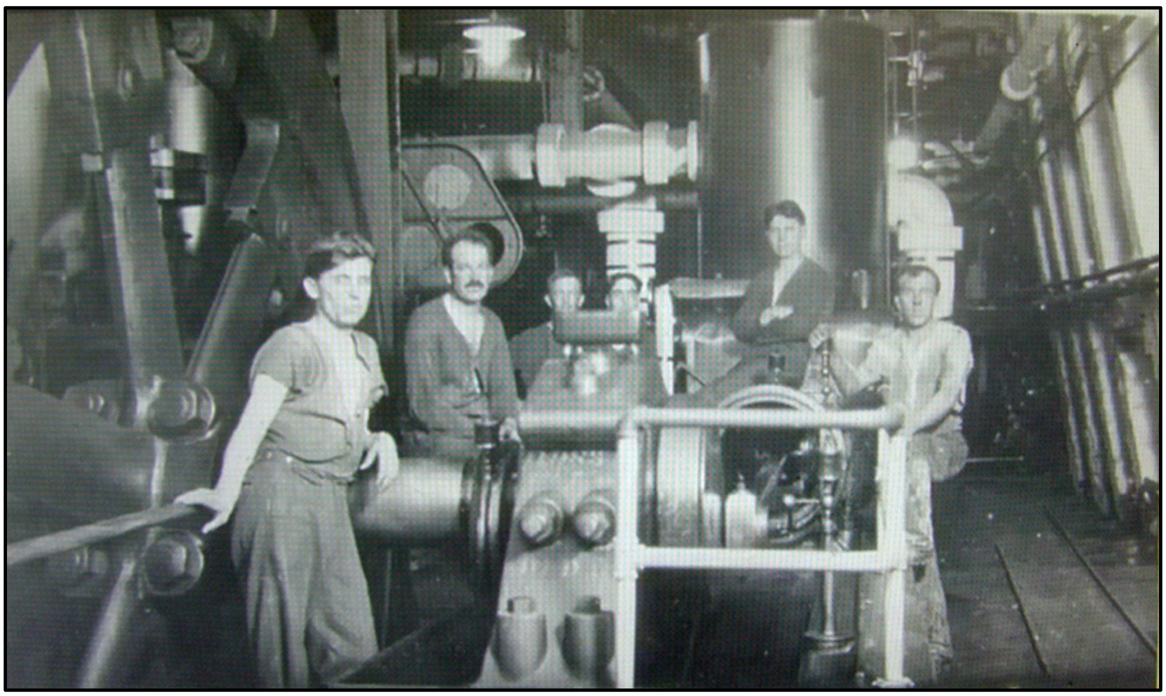


Figure 40. Triplet-expansion flywheel Nordberg steam pump on 12th level pumping station at Old Dominion, circa April 1917 (photo from Gila County Historical Museum)

During 1928, the Old Dominion was pumping approximately 3,659,000 gallons per day from the mine. Approximately two-thirds of this water originated between the 24th and 26th levels. Water was pumped to surface in three stages. It was initially pumped from the 26th level to the 22nd level, then to the 12th level (Figure 40) and from there it was pumped to water storage tanks on the surface or to a drain tunnel located 40 feet above the 5th level (Shoemaker, 1930).

Sarah H. Sorin (Figure 41), an attorney who specialized in mining law, became the first woman to argue a case before the U. S. Supreme Court in November 1913 (Cleere, 2014). She represented the Old Dominion Company in *Work v. United Globe Mines*, which involved a dispute over the ownership of a mining property. In January 1914, the U. S. Supreme Court affirmed the decision of the lower court, ruling in favor of her client.

Figure 41. Sarah Herring Sorin (1861-1914) became the first woman admitted to practice law in the Arizona Territory in November 1892 (photo from Franklin-Carroll Family Collection)

Soaring profits resulting from an increased demand for copper during World War I lead to labor unrest as many hard-working miners demanded a share of the wealth. By early 1917 rumblings of discontent gradually increased until July 1, 1917 when the miners went on strike. Attempts to completely shut down the mining operation failed as 60 workers stayed on the job to operate the pumps to keep it from flooding. Fourth of July celebrations were canceled and four units of the Seventeenth U. S. Cavalry (Figure 42) were dispatched from Douglas, Arizona on July 5 to maintain law and order in Globe. An uneasy peace followed, but was punctuated by acts of violence that resulted in the deaths of two soldiers. After a short time, the explosive situation was largely defused (Riel, 1977). Miners gradually returned to work and production resumed. An uneasy settlement was eventually negotiated between management and union representatives, allowing operations to return to normal in October 1917 (Haak, 1999). A token military force remained in Globe until 1920, but no further labor unrest occurred.

Figure 42. Approximately 500 troops from the Seventeenth U.S. cavalry were mobilized to keep peace during labor unrest of 1917 (photo from Gila County Historical Museum)

During its heyday (1904-1920), Old Dominion was a steady copper producer. In addition to the mine, mill and smelter personnel, its workforce also included numerous skilled craftsmen and unskilled laborers without which operations would have been much more difficult.

Primary infrastructure at Old Dominion included the smelter, coke, ore and lime storage bins, crusher, sampling mill, and the concentrator (Figure 43). In addition to processing their own ores, Old Dominion also treated ores from other operators at their smelter and concentrator on a custom basis (Forrester and Cramer, 1931).

Electrical power was provided by diesel and steam-powered generators located adjacent to the Old Dominion smelter. A boiler plant located adjacent to the main "A" shaft, generated power for steam-operated pumps employed in the underground dewatering operations (Beckett, 1917). A company-owned standard gauge railroad connected the concentrator, smelter, lime quarry, and ore and coke bins (Irvin, 1987). Old Dominion also maintained a saw mill and large lumber yard, which supplied the needs of both surface and underground operations.

Medical services were provided by an on-site company-owned hospital. Other supporting infrastructure included an administrative office, assay office, mine warehouse, mine office, mess hall, and electric, carpenter, machine, boiler, and blacksmith shops.

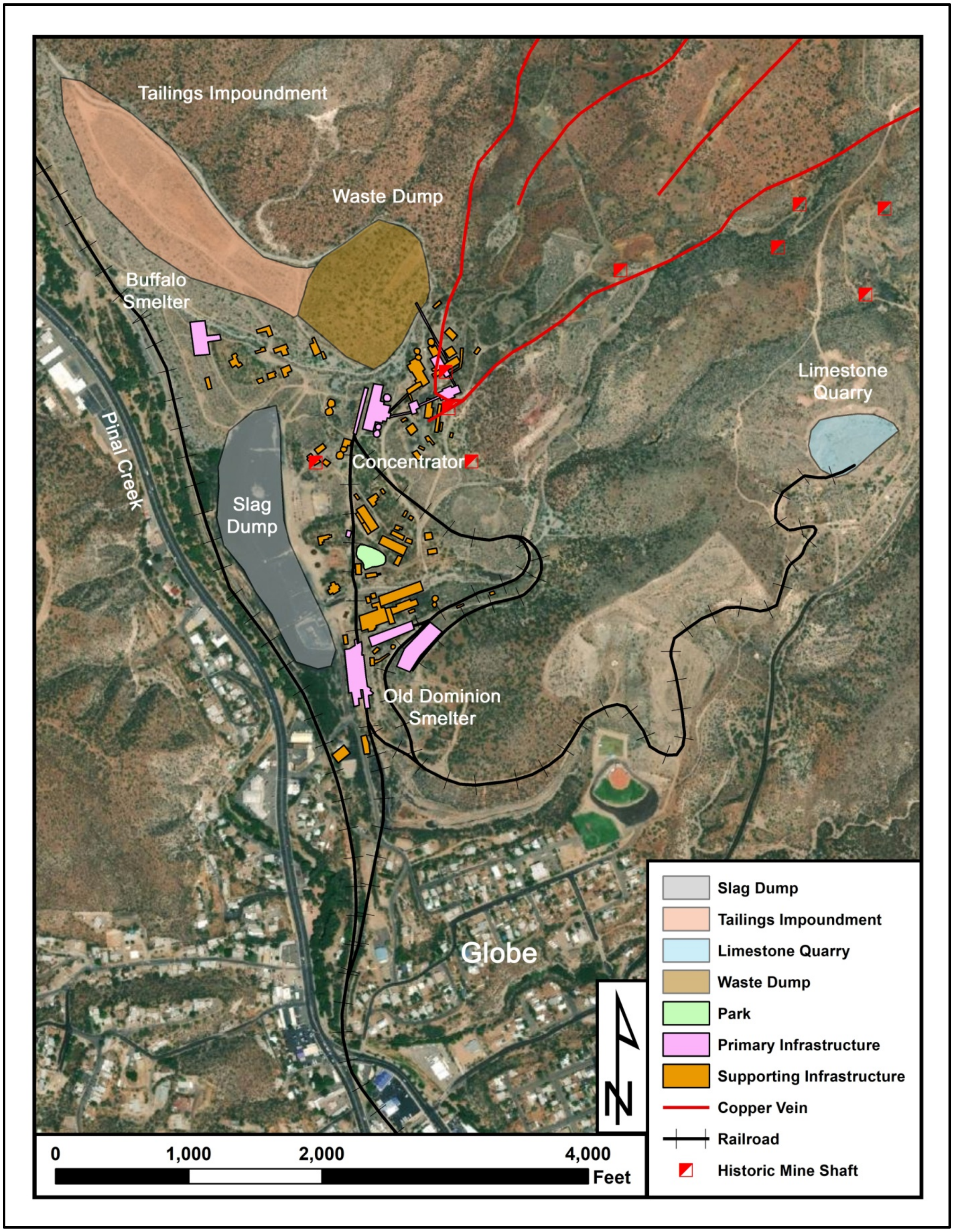


Figure 43. Primary and supporting infrastructure at the Old Dominion mine (modified from Gila County Historical Museum)

At the end of World War I, 1,400 workers were on the Old Dominion's payroll and its concentrating and smelting facilities were processing 500 tons of ore per day. However, the operation was never able to surpass its production record of 33.7 million pounds of copper during 1916. Neglected repairs, damage resulting from flooding of its underground workings and declining ore grades all played a role in its gradual decline (Haak, 1999).

The post-World War I collapse of the copper price from 26.0 to 12.4 cents per pound resulted in the temporary suspension of operations at the Old Dominion mine from April 1921 until February 1922. The Old Dominion smelter resumed operations in April 1922, but was permanently closed in November 1924. Direct smelting ore and concentrate production after that date were shipped to the International Smelter at Miami. The Old Dominion concentrator was expanded to 1,400 tons per day in 1926 (Peterson, 1962). During the late 1920s, the copper content of the ore mined from the Old Dominion mine steadily declined from 4.16% in 1925 to 2.27% in 1930 (Julihn and Meyer, 1933).

The Old Dominion Company purchased the assets of the Arizona Commercial property in December 1930. By early 1931, the price of copper had fallen to less than 10 cents per pound. Development of the 26th level failed to find any high-grade ores that could be profitably extracted. All operations were suspended at Old Dominion on October 14, 1931 and the mine was allowed to flood below the 12th level (Julihn and Meyer, 1934).

4.8.3 Later Years (1932-1959)

Over the next several years, the mine infrastructure was dismantled and relocated elsewhere or sold for scrap. Limited production was derived from clean-up operations during mid-1930s. The Miami Copper Company purchased the assets of the Old Dominion Company for $100,000 in May 1940 and used the mine as a source of water for its metallurgical operations at Miami and Castle Dome. For a time, the City of Globe also used water from the mine for its domestic water supply (Haak, 1999).

With the assistance of a Reconstruction Finance Corporation loan, lessees salvaged high-grade siliceous copper ores from shallow underground workings around the Globe and Transit shafts from 1943 until 1947. During this period, 45,338 tons of ore was shipped to the International Smelter at Miami, recovering approximately 2.7 million pounds of copper (U. S. Bureau of Mines data).

An additional 4.9 million pounds of copper was recovered from copper precipitate derived from leaching waste dumps at the Interloper shaft during 1959 (U. S. Bureau of Mines data).

Table 6. Historical production from the Old Dominion property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1882-1931	9,280,570	798,402,507	40,635	0	73,484	3,240,294
1932-1959	57,330	8,449,141	158,815	24,400	374	65,730
1882-1959	9,337,900	806,851,648	199,450	24,400	73,858	3,306,024

Reported historical production from the Old Dominion property is summarized in Table 6. Prior to its closure in October 1931, approximately 9.3 million tons of ore were treated at its smelter and concentrator, recovering 798.4 million pounds of copper. An additional 8.5 million pounds of copper was derived from salvage operations and waste dumps between 1932 through 1959.

4.9 Arizona Commercial Copper Company (1905-1930)

In January 1905, the Arizona Commercial Copper Company was incorporated under the laws of Maine with capitalization of $2.5 million at $25 per share. Formed to develop two groups of mining claims along the northeastern extension of the Old Dominion vein system, $1 million of the stock was transferred to the Arizona Commercial Company and $1 million was distributed to the Metamora Company for their respective properties (Figure 34). The remaining funds were retained in the treasury for working capital (Stevens, 1906).

The Copper Hill group of claims consisted of the Copper Hill claim and three fractional claims, which included the apex of the Old Dominion vein from the United Globe property line to the Budget fault, which was acquired from the Arizona Commercial Company (Peterson, 1962).

Separated from the Copper Hill claim group by the intervening Iron Cap property to the northeast, the Eureka claim group also included a northeast projection of the Old Dominion vein and a segment of the Great Eastern vein, which had been explored by the previous owner, Metamora Company (Peterson, 1962).

Arizona Commercial Copper began shipping direct smelting ores from the Great Eastern vein to the Old Dominion and Copper Queen smelters in July 1905 and September 1905, respectively. By the end of December 1905, its workforce of nearly 100 men was producing 100 tons of ore daily (Stevens, 1906). Arizona Commercial Copper's operations at Copper Hill were connected to the Gila Valley, Globe and Northern Railroad via the Arizona Commercial Railroad in March 1907 (Irvin, 1987).

Arizona Commercial Copper commissioned a 500-ton per day water-jacketed blast furnace (near the Eureka shaft) in October 1909 at a cost of $260,000 (Figure 44). A custom smelting contract was signed to process ore from Superior and Boston's operation in February 1910. However, smelting operations ceased after the failure of its water jacket in April 1910. Although the manufacturer assumed full responsibility and repaired the water jacket at no cost to the Arizona Commercial Copper Company, the smelter was never returned to service (Rickard, 1987).

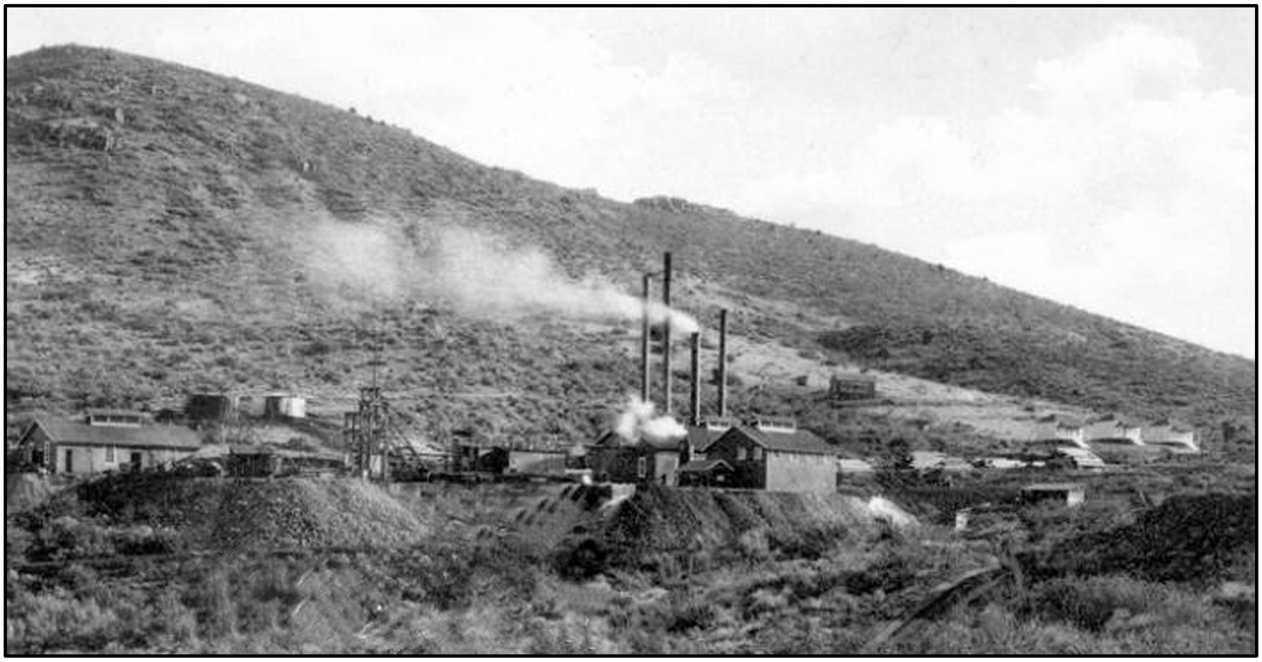


Figure 44. Arizona Commercial's Eureka shaft and smelter, circa 1910, (photo from Arizona State University)

Following the suspension of smelting operations, work was mainly confined to mine development due to financial difficulties. These difficulties were compounded by flooding of the mine workings in late 1909. By the end of 1910, dewatering operations amounted to two million gallons per day. Negotiations to sell Superior and Boston a 50% interest in Arizona Commercial's smelter failed in September 1911, resulting in the suspension of all mining activities (Tenney, 1927-1929).

In October 1911, the Arizona Commercial Copper Company was reorganized as the Arizona Commercial Mining Company, with a large portion of its shares underwritten to insure sufficient working capital. Mining operations resumed in February, 1912. Mine development was confined to the 800-foot Copper Hill shaft (Figure 45), with it being retimbered and equipped with the steel headframe and large hoist from the Eureka shaft. By 1913, it had been sunk to a depth of 1,200 feet (Tenney, 1927-1929). Regular shipments of lower grade ores (< 4% copper) to the Old Dominion concentrator began in October 1914 (Peterson, 1962). Direct smelting ores were shipped to Copper Queen's smelter in Douglas, Arizona.

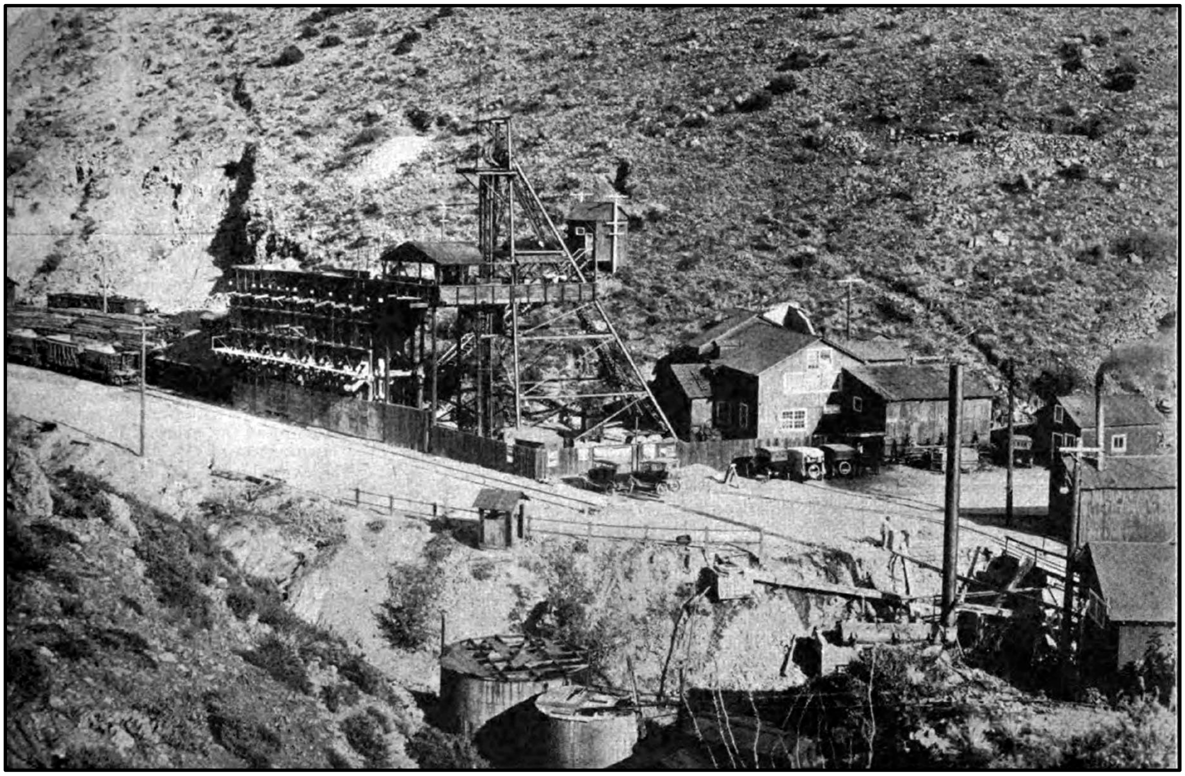


Figure 45. Arizona Commercial's Copper Hill shaft and surface workings with loading bins and railroad (photo from Willis, 1922b)

Post World War I collapse of the copper price resulted in the temporary closure of the Arizona Commercial mine from January 1921 until March 1922. After resuming operations, the Copper Hill shaft was deepened from the 1,600 to 1,800-foot level. Dewatering operations pumped 85 million gallons from the mine during 1922, compared to 117 million gallons the previous year (Heikes, 1925).

Table 7. Historical production from the Arizona Commercial property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1905-1930	1,108,351	99,889,938	0	0	18,304	495,472
1943-1981	976,163	6,378,182	0	0	29	19,271
1905-1981	2,084,514	106,268,120	0	0	18,333	514,743

The Arizona Commercial Mining Company ceased operations in December 1930 after depleting its remaining reserves and its assets were sold to the Old Dominion Company for $20,000 (Gerry and Miller, 1933). Total production from 1905 until its closure in December 1930 was 1.1 million tons of ore, recovering approximately 99.9 million pounds of copper (Table 7).

Lessees have intermittently shipped low-grade silica flux ores from mine dumps at Copper Hill to regional smelters since 1955. Production of low-grade silica flux from 1955 until 1981 totaled 976,163 tons, recovering nearly 6.4 million pounds of copper.

4.10 Iron Cap Copper Company (1905-1927)

In November 1905, the National Mining Exploration Company was organized under the laws of Maine to develop seven claims held by the Iron Cap Mining Company (Figure 34) (Stevens, 1906). National Mining deepened the Williams shaft to 802 feet and drove a cross-cut on the 350-foot level that reached the Great Eastern vein in 1908. A second cross-cut on the 667-foot level intercepted the Iron Cap vein in June 1910. However, both of these structures were oxidized and leached, containing no ore (Peterson, 1962). The Iron Cap shaft (Figure 46) was sunk to a depth of 600 feet in early 1909.

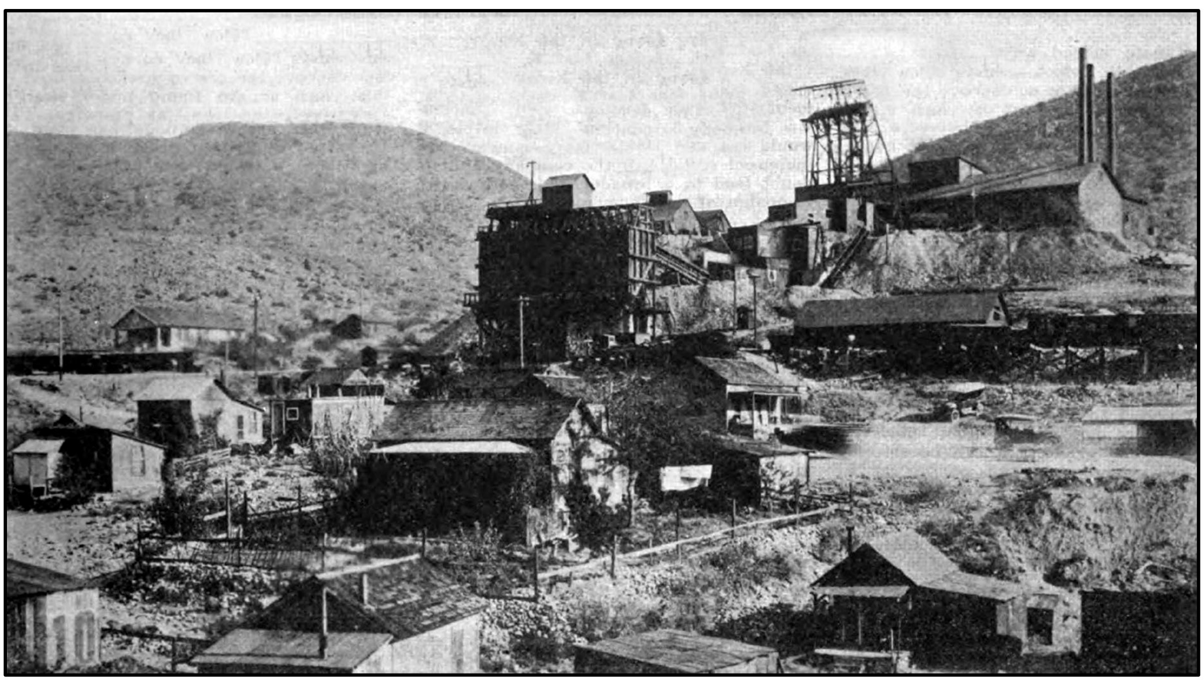


Figure 46. Iron Cap shaft and plant site at Copper Hill (photo from Willis, 1922c)

Lacking capital for mine development, National Mining secured a $100,000 loan by a mortgage on the property from N. L. Armster, who was the president of the Arizona

Commercial Copper Company. In September, 1910, Armster foreclosed on the mortgage, forcing National Mining to declare bankruptcy (Peterson, 1962).

The National Mining Exploration Company was reorganized as the Iron Cap Copper Company in February 1911, and reacquired its property at a foreclosure sale in May 1911 (Weed, 1916). Mine development resumed in July 1912 and soon encountered an ore zone on the 667-foot level of the Williams shaft. Initial shipments of direct smelting ores to the Old Dominion smelter began in September 1912. Within a year, the Iron Cap mine was shipping a carload of development ore per week to the El Paso smelter; with production soon reaching three to four carloads per week (Peterson, 1962).

Production rose steadily during World War I with shipments of high-grade direct smelting ores being treated at the El Paso smelter. In April 1917, Iron Cap Copper commenced shipments of lower grade sulfide ores to the Old Dominion concentrator. Iron Cap Copper commissioned a 350-ton per day gravity-flotation concentrator in June 1920. Falling copper prices after the end of World War I resulted in the suspension of operations at the Iron Cap mine from February 1921 until February 1922 (Peterson, 1962).

Between 1919 and 1925, the Iron Cap Copper Company was involved in costly litigation, which severely handicapped operations. In February 1919, the Arizona Commercial Mining Company filed a law suit in the State of Massachusetts, claiming the Iron Cap Copper Company extracted more than 250,000 tons of its ore, valued at $3 million (Peterson, 1962).

This lawsuit was based on geological evidence that suggested the North vein, which outcropped on Arizona Commercial's claims was a northeast projection of the Old Dominion vein and the upper continuation of the Iron Cap vein in the footwall of the Black Hawk fault (Peterson, 1962).

When the Massachusetts Court refused to hear the case and remanded it to an Arizona Court in September 1919, Arizona Commercial Mining filed a second law suit in Maine, requesting an injunction to prevent Iron Cap Copper from disposing of any of its assets until the case could be resolved (Weed, 1922).

In October 1920, the Iron Cap Copper Company filed a counter-suit in Arizona to resolve issues of title to the ore in question. Proceedings of the Maine Court were stayed, pending resolution of the Arizona case. After prolonged litigation involving testimony from a number of eminent mining engineers and geologists, this case was finally settled in November 1925, in favor of the Iron Cap Copper Company (Peterson, 1962).

Table 8. Historical production from the Iron Cap property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1908-1927	661,843	66,061,049	0	0	7,130	1,384,831
1928-1963	18,024	656,552	0	0	49	7,753
1908-1963	679,867	66,717,601	0	0	7,179	1,392,584

By the time these legal issues had been resolved, known ore reserves at the Iron Cap mine were nearly depleted. Milling operations at the Iron Cap concentrator were suspended in November 1926. Production of siliceous fluxing ores continued until November 1927 (Table 8). The concentrator was subsequently dismantled and relocated to the Christmas mine, where Iron Cap Copper had acquired control of the Gila Copper Sulphide Company.

4.11 Superior and Boston Copper Company (1906-1927)

In November 1906, the Superior and Boston Copper Company was incorporated under the laws of Arizona to develop a large group of claims located east of the Arizona Commercial and Iron Cap properties (Figure 34). Mine development commenced in January 1907. Shipments of development ores from a small ore body along the Great Eastern vein began in February 1908. By May 1908, approximately 1,000 tons of ore per month were being shipped to the El Paso and Old Dominion smelters (Stevens, 1908). This small ore pocket was mined out in August 1910, resulting in a temporary suspension of production (Stevens, 1911).

With the discovery of ore along the Great Eastern vein northeast of the McGaw fault zone, ore shipments resumed in March 1913. Following an extensive development program, the Footwall and Rigby veins were discovered in 1919 and 1920, respectively.

Shipments of ore were suspended from April 1921 until December 1921, due to the closure of regional smelters that resulted from the collapse of the price of copper following the end of World War I (Weed, 1922).

Operations from 1920 through 1926 benefited from the high copper-silver content of ores from the Rigby vein. Only constituting a small portion of Superior and Boston's annual production, the Rigby vein averaged 1 to 2 feet in width and was reported to contain very rich ores, assaying up to 25% copper and 300 to 400 ounces of silver per ton (Peterson, 1962).

Table 9. Historic production from the Superior and Boston property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1908-1927	235,484	22,793,901	0	0	255	1,370,334
1931-1959	11,412	610,194	0	0	15	10,160
1908-1959	246,896	23,404,095	0	0	270	1,380,494

Superior and Boston Copper Company suspended operations in early 1927 and its mines were permanently closed (Table 9). The property was subsequently sold for delinquent taxes. During World War II, lessees extracted limited amounts of fluxing ores from shallow workings on the Buckeye and Great Eastern veins (Peterson, 1962).

4.12 Miami-Inspiration Area – Early Years (1890-1929)

By the early 1880s silver mining had declined significantly. This encouraged prospectors to examine the economic potential of the widespread copper mineralization in the Globe-Miami area. While much of this early copper development was confined to the area immediately north of Globe, prospectors also ventured into the area located north and west of present day Miami. However, the low tenor of the widespread copper resources of this region made it impossible to profitably recover the copper from these deposits with the technology available at that time.

By the early 1890s, economic potential of high-grade copper deposits north and west of present day Miami were being examined and developed by several parties. Early mining ventures included the Live Oak, Black Warrior, Keystone, Inspiration, Cordova Copper, Miami Copper, Southwestern Miami, and Barney Copper properties.

4.12.1 Black Warrior Copper Company (1895-1920)

Initially developed by Havaly, Higdon and Beard around 1895, the Black Copper group of claims in Webster Gulch was leased to James A. Fleming and J. M. Ford, who organized the Black Warrior Copper Company in October 1896 with total capitalization of $1 million (Tenney, 1927-1929). A quarter of the stock was sold to eastern investors to provide working capital for mine development.

The Jewel property located near Jewel Hill was acquired to provide a source for iron and lime flux to treat the siliceous ores at Black Copper (Tenney, 1927-1929).

By July 1897, a workforce of 45 men was developing Black Warrior Copper's holdings at the Black Copper and Black Warrior mine sites along Webster Gulch (Figure 6). Development ores were hauled to United Globe's Buffalo smelter near Globe (Sain, 1944).

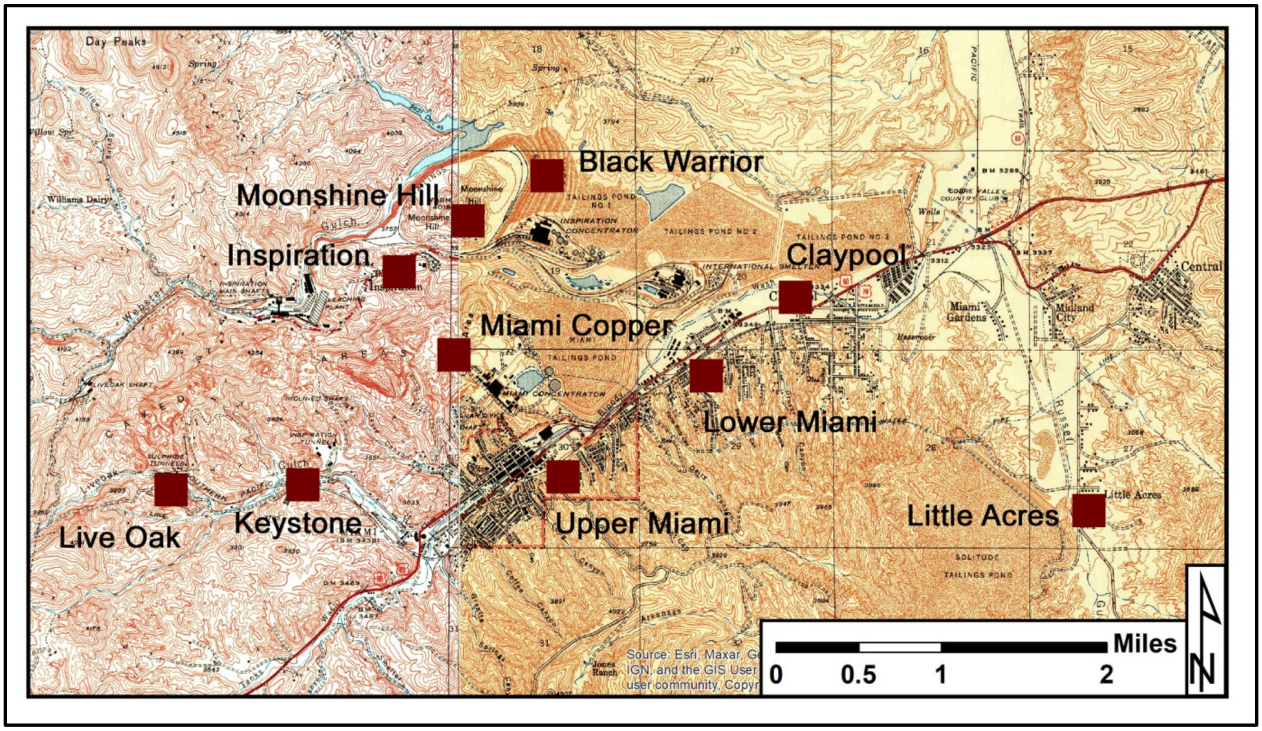


Figure 47. Location of Upper Miami, Lower Miami, Claypool, Little Acres, and company-owned town sites in the Miami-Inspiration area

The Black Warrior town site (Figure 47) included a boarding house, company store, warehouse, school, blacksmith and machine shop, assay lab, barns, and stables. Next to the company store was a large cave cut into the hillside where all smoked meats and perishable goods were stored (Anonymous, 1899). By October 1903, there was a stage line operating between Globe and Black Warrior.

A 6,000-foot narrow gauge (18-inch) rail line (2% down grade) was constructed from the mine site to a 100-ton per day leaching plant (Figure 48), which was commissioned at the Black Warrior town site in September 1899. All of the machinery at this facility was manufactured by the Colorado Iron Works Company in Denver, Colorado (Anonymous, 1899).

Run-of-mine ore was initially crushed before reporting to one of 12 tanks (12-ton), where it was leached by sulfuric acid. The copper was recovered from the solution by precipitation onto scrap iron, which was smelted in a 9-foot by 16-foot reverberatory furnace with a 56-foot stack (Anonymous, 1899).

Figure 48. Black Warrior leach plant and furnace at Black Warrior, Arizona, circa 1900. The Black Warrior town site and remains of its processing plant are now buried by tailings derived from Inspiration Consolidated Copper's operation (photo from Anonymous, 1902)

The sulfuric acid for this operation was obtained from acid works in Denver, Colorado. It was hauled via rail tank car to a storage tank at a siding on the Gila Valley, Globe and Northern Railroad near United Globe's Buffalo smelter. From there the acid was hauled by wagon to a storage tank located at the Black Warrior Copper processing facility (Anonymous, 1899).

Black Warrior Copper's initial venture was a commercial failure because it was unable to secure a reliable source of sulfuric acid to treat its ores. It only operated for one month before ceasing operations (Tenney, 1927-1929).

The Black Warrior Copper Company merged with the Donellan Company to form Black Warrior Company Amalgamated in 1900 (Petersen, 1962). In an effort to resolve earlier difficulties, they erected a 100-ton per day concentrator at the Black Warrior mine site, expanded the capacity of the leaching plant to 300 tons per day and added a new refining furnace. Initial attempts to resume operations in February 1901 were delayed until a sulfuric acid plant was commissioned in early 1902. On-going difficulties continued to plague this business venture, which intermittently recovered copper until August 1903, when all operations ceased (Tenney, 1927-1929).

Black Warrior Company Amalgamated was reorganized as the Warrior Copper Company in March 1906 with capitalization of $1.6 million at $10 per share. Daily shipments of direct smelting ores resumed to the Old Dominion smelter in early 1906 (Stevens, 1906). The concentrator and furnace were subsequently demolished and the leach plant was destroyed by fire in May 1911 (Stevens, 1911).

The Warrior Development Company acquired a 3-year lease and an option to purchase the Black Warrior property from the Warrior Copper Company in October 1909. Over the next two years, approximately 75 to 100 tons of ore per day were shipped to the El Paso smelter with lesser amounts delivered to the Old Dominion smelter. Warrior Development surrendered its option in October 1911 (Peterson, 1962).

Table 10. Historic production from the Black Warrior property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1902-1919	348,474	44,397,083	0	0	0	29,041

After considering sites for its planned concentrator, Inspiration Consolidated Copper purchased the Black Warrior town site for $175,000 in May 1912 (Weed, 1922). Southwestern Leasing and Development Company acquired a lease on the Black Warrior mine property in January 1912, and shipped direct smelting ores from the site (Table 10) until Inspiration Consolidated Copper Company acquired the property for $400,000 in January 1920 (Weed, 1922). Inspiration Consolidated Copper continued production of high-grade oxide ores from its Black Warrior division until 1925.

4.12.2 Keystone Copper Company (1897-1915)

Mining activities began at the Keystone property in 1897 (Figure 49). Over the next eight years, 1,067 tons of hand-sorted, high-grade (22 to 27% Cu), oxidized copper ores were shipped to regional smelters netting a profit of $37,277 (Stevens, 1906).

The Keystone Copper Company was incorporated in 1905 with a capitalization of $1 million at $1 per share with the goal of continuing development of the property. Over the next several years, shipments of low grade (3 to 5% Cu) siliceous flux to the Old Dominion smelter helped to offset mine development costs (Stevens, 1906).

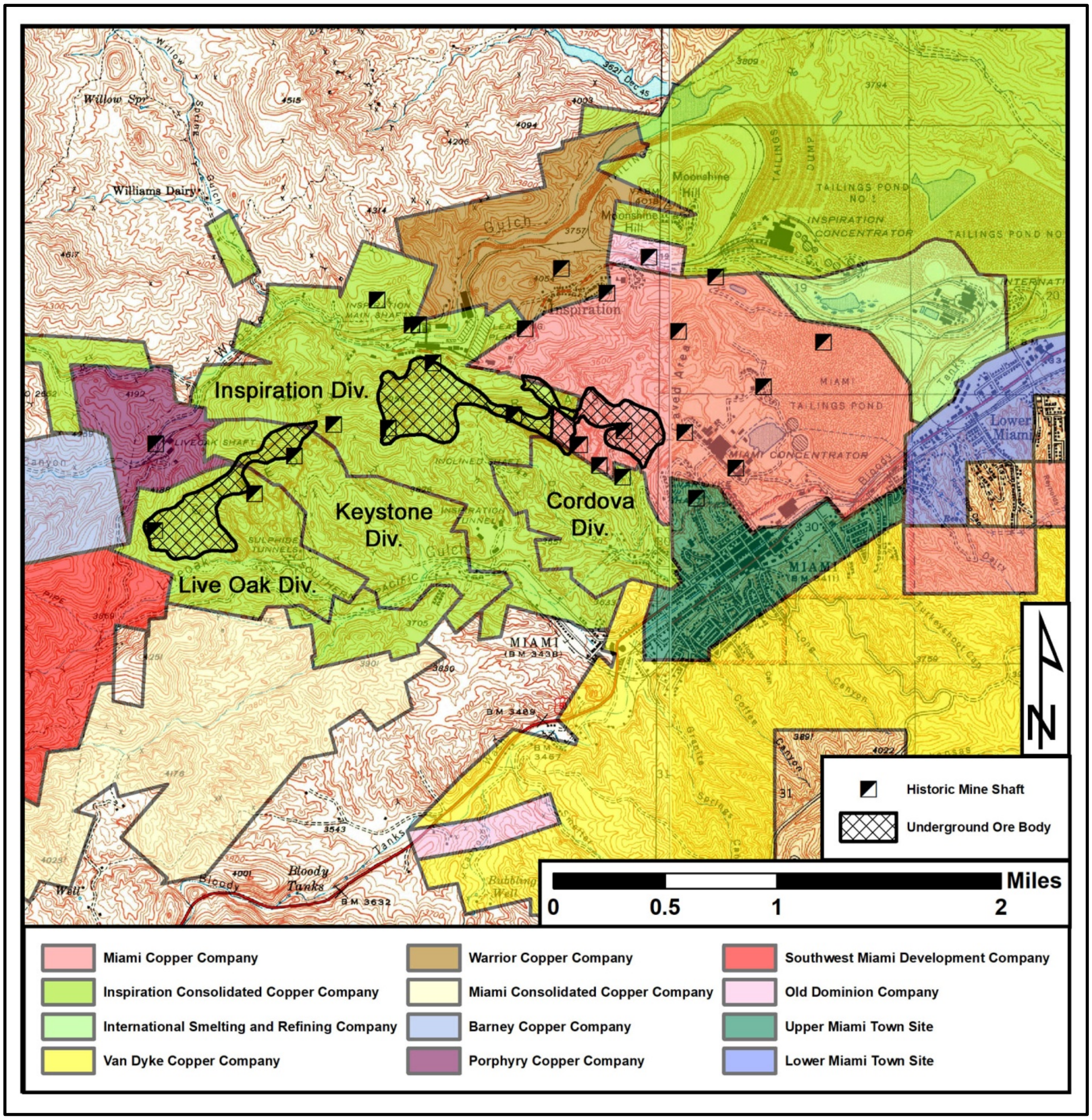


Figure 49. Property map of main portion of Miami-Inspiration area, circa 1915-1920 (modified from Ransome, 1919)

A 25-ton experimental leaching plant was erected at the site during 1905. This pilot plant employed a modification of the Hoepfner Sulfide Process, which was designed to leach both chrysocolla and carbonate ores and could recover copper from sulfide ores after roasting. The copper ores were finely crushed and leached for three hours in a slowing rotating chlorination barrel. It employed a cupric chloride leaching solution, which was converted to cuprous chloride by the absorption of one copper atom. The pregnant solution reported to precipitation tanks, where the extra atom of copper was precipitated on large copper sheets. During this process, the cupric chloride was regenerated and reported to a storage tank for reuse (Stevens, 1906).

Site preparation for a 100-ton roasting furnace designed to treat the sulfide ores commenced in 1906, but the furnace was never built. The failure to develop a commercially viable process to treat its ore resulted in the commencement of foreclosure proceedings during 1907 (Stevens, 1908).

In May 1908, stockholders of the Old Dominion Mining and Smelting Company agreed to pay the $65,000 outstanding debt, spend $50,000 on property development and reorganize the Keystone Copper Company. However, this attempt to acquire the Keystone property failed, when John B. (Black Jack) Newman paid the $65,000 judgment, agreed to spend $4,000 per month on development with the option to acquire title to the property for $400,000 (Stevens, 1908).

John B. Newman sold the Keystone property to the General Development Company, who incorporated the New Keystone Copper Company in July 1909 to further develop the ground (Stevens, 1911). This underground development program soon discovered sulfide mineralization, assaying 2.5 to 3% copper (Sain, 1944). Reported production for the Keystone property through 1910 is shown in Table 11.

Table 11. Historic production from the Keystone property (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1899-1904	1,067	426,800	0	0	0	0
1905-1910	4,142	606,536	2,994	0	131	617
1899-1910	5,209	1,033,336	2,994	0	131	617

Inspiration Consolidated Copper Company entered negotiations to purchase the Keystone property in May 1912 in order to consolidate its holdings in the district. Unable to reach an agreement, Inspiration began to drive an underground drift through intervening New Keystone ground to connect its Inspiration and Live Oak holdings. This action forced the New Keystone Copper Company to file a lawsuit to halt this development. The lawsuit was finally settled in December 1914, in favor of the New Keystone Copper Company (Tenney, 1927-1929).

In January 1915, the assets of the New Keystone Copper Company were purchased by the Inspiration Consolidated Copper Company for $795,940, payable in 39,797 shares of stock at $20 per share (nine shares of New Keystone for one share of Inspiration) (Weed, 1916).

4.12.3 Live Oak Copper Mining and Smelting Company (1890-1911)

J. J. Marshall staked the first four claims at the Live Oak property in 1890 and sank a 160-foot shaft on a showing of oxide and silicate ore (Figure 49). Forest Kaldenberg acquired the Live Oak property and organized the Live Oak Copper Mining and Smelting Company in June 1898, with capitalization of $1.25 million at $1 per share (Stevens, 1908).

Early development of the Live Oak property included approximately 2,700 feet of tunnels and drifts, which were developed on the Big Silicate vein (Stevens, 1911). By 1899, weekly shipments of two carloads of development ore were made to El Paso and Silver City smelters at a cost of $25 per ton. Development work was performed by a workforce of 17 miners, who resided at the small community of Live Oak (Figure 47), which included a boarding house, mine office and other dwellings (Sain, 1944).

Little additional development of the Live Oak property occurred until August 1905, when Joseph Erman made an agreement to ship enough ore from the site to fund construction of a leach plant at no cost to the company. By March 1906, sufficient ore was shipped to pay all operating expenses as well as funding the purchase of $20,000 of mining equipment and a large amount of mine development (Stevens, 1906). However, this business arrangement was dissolved in late 1906 after a disagreement resulted in a lawsuit that was settled in 1907 (Tenney, 1927-1929).

In January 1909, Hoval A. Smith and Henry B. Hovland acquired a lease and 3-year option to purchase the assets of the Live Oak Copper Mining and Smelting Company for $438,600 (Stevens, 1911). They organized the Live Oak Development Company in March 1909 to manage the on-site mine development program. It is interesting to note that in 1910 Hovland and Smith were negotiating with the Hayden-Stone group to underwrite a bond issue, when Anaconda Copper purchased enough stock to fund the on-going development of the Live Oak Property (Parsons, 1933).

The original Live Oak No. 1 shaft was deepened to delineate the sulfide resource underlying the copper silicate ore body. It encountered sulfide mineralization at 300 feet, passing through 150 feet of chalcocite ore. By October 1910, an underground development program had delineated approximately 10 million tons of ore, assaying approximately 2% copper (Tenney, 1927-1929). Encouraged by these results, Live Oak Development increased its capitalization to $1 million in January 1911 to fund the on-going exploration effort, which included a churn drilling program (Stevens, 1911). The Live Oak No. 2 shaft was collared in the western portion of the property in April 1911 and encountered high-grade ore from a depth of 709 to 890 feet (Tenney, 1927-1929).

In December 1911, the Live Oak Development Company and Inspiration Copper Company merged to form the Inspiration Consolidated Copper Company with a total capitalization of $30 million at $20 per share (Weed, 1916). As of December 31, 1911, the company had an ore reserve of 45.3 million tons assaying 2.00% copper, consisting of 30.3 million tons averaging 1.95% copper on the Inspiration property and 15 million tons averaging 2.11% copper on the Live Oak holdings (Peterson, 1962).

4.12.4 Cordova Copper Company (1906-1911)

Situated between the Miami Copper and Inspiration Copper properties, the Eureka mine showed considerable chrysocolla at a shallow depth, assaying between 5 and 6% copper (Figure 49). Shipments of high-grade silicate ores were made from the site to the Old Dominion and Calumet and Arizona smelters during 1906-1907 (Stevens 1911).

Hoval A. Smith and Henry B. Hovland acquired an option to purchase the Eureka property in January 1909 for $300,000. They organized the Cordova Copper Company in May 1909 to explore a couple of areas in the Globe-Miami area, including the Eureka claim group (Stevens, 1911).

The Cordova Copper Company sank the three-compartment 475-foot Sullivan shaft, which encountered mineralized Pinal Schist at a depth of 360 feet, containing considerable oxide copper with lesser amounts of disseminated chalcocite, assaying 1.5 to 2.0% copper. Underground exploration was suspended during the fall of 1909 and was followed by a limited churn drilling program before halting work during the summer of 1910 due to a lack of funds (Stevens, 1911). The assets of the Cordova Copper Company were acquired by the Inspiration Copper Company during the fall of 1911 (Ransome, 1919).

4.12.5 Barney Copper Company (1910-1921)

John D. Coplen of Globe incorporated the Barney Copper Company in August 1910. Having a capitalization of $5 million at $5 dollars per share, this company was formed to explore and develop a 560-acre property located immediately west of the Live Oak and Keystone properties (Figure 49), much of which was concealed by post-mineral Gila Conglomerate. In January 1912, it was optioned to the General Development Company, which conducted a brief drilling program before relinquishing their option (Weed, 1916).

Little additional work was done until 1916, when the Porphyry Copper Company was organized to acquire the eastern 114 acres of the Barney Copper property. They sank an 850-foot shaft, which encountered 82 feet of copper carbonate ore and 373 feet of chalcocite ore. After considerable development, the Barney Copper Company and Porphyry Copper Company were reconsolidated in June 1919 as the Porphyry Consolidated Copper Company (Peterson, 1962). The Inspiration Consolidated Copper

Company acquired Porphyry Consolidated Copper's property in 1921 for $1 million (Weed, 1922).

4.12.6 Southwestern Miami Development Company (1911-1929)

The Southwestern Miami Development Company was incorporated in June 1911 to explore and develop a group of mining claims located immediately southwest of the Live Oak property (Figure 49). In 1911, the first hole of a deep exploration drilling program encountered ore from a depth of 1,110 to 1,285 feet. From 1911 through 1914, eighteen drill holes, totaling 21,600 feet were completed, delineating approximately two million tons of ore averaging 1.25% copper. No further efforts were made to develop this resource and the property remained inactive until May 1929, when it was purchased by the Inspiration Consolidated Copper Company for $500,000 (Peterson, 1962).

4.13 Early History of Miami, Arizona (1908-1925)

During the first decade of the 20th century, much of the needs for workers at the Live Oak, Keystone, Cordova, Miami, and Inspiration projects were provided by businesses located in the community of Globe, along Pinal Creek, 6 miles to the east. It was not long before real estate speculators recognized this business opportunity and began purchasing tracts of land to develop a community that could better serve the demands of the area's growing workforce (Sain, 1944).

During 1908 Globe-based real estate businesses, the Miami Realty Company and the Miami Land and Improvement Company acquired favorable sites at Miami Flat (i.e., Lower Miami) and along Bloody Tanks Wash (i.e., Upper Miami), respectively. It was soon learned these ventures were not popular with other Globe businessmen, who feared the loss of commerce to this new community. Furthermore, larger mining ventures exploring the area favored less competitive company-owned towns (Figure 47) to supply the needs of their workers (Sain, 1944).

In November 1908, Cleve W. Van Dyke (Figure 50) purchased a large tract of land along Bloody Tanks Wash (now known as Upper Miami) from the Miami Land and Improvement Company for $25,000. At the time of the purchase, it consisted of two 40-acre lots and ten mining claims. Only one of the 40-acre lots was patented. After purchasing the property, Van Dyke began working on securing patents for the remainder of the property. Although he secured the patent of the second 40-acre lot in March 1909, attempts to acquire mineral patents on eight of the ten unpatented mining claims failed. After a great deal of expense, Van Dyke eventually secured ownership of the remainder of the property through homestead entry (Van Dyke, 1922).

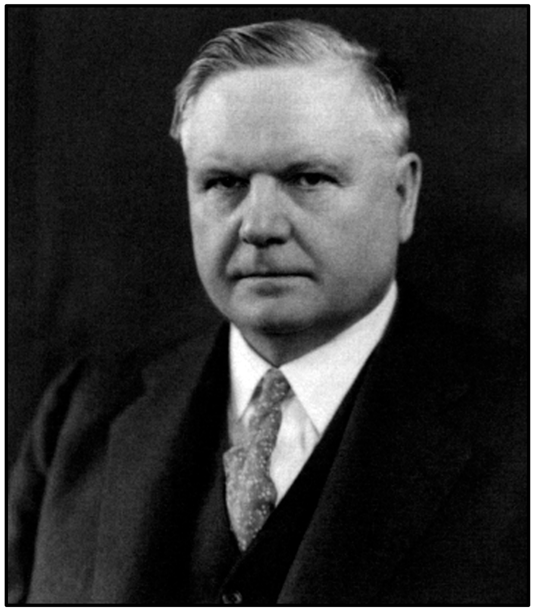


Figure 50. Cleve W. Van Dyke (1875-1945), founder of the town of Miami, Arizona (photo from Marin, 2015)

By early 1909, the Miami Stage Line provided regular service connecting the Miami, Live Oak, Keystone, and Cordova mine sites with Globe, where many of the workers resided (Sain, 1944).

Figure 51. Fitzpatrick's saloon and rooming house, circa 1909. Buildings on the hill are a part of Miami Copper's company town site. The headframe of the Miami No. 4 shaft is visible on the hill in the upper right (photo from Kelley's Studio, Miami, Arizona)

Before the town site survey was completed during the summer of 1909, Van Dyke sold the first lot to John Fitzpatrick, who built Miami's first business structure, a saloon located at the corner of Gibson Street and Keystone Avenue (Figure 51). A 1.25-mile canal was excavated along Bloody Tanks Wash in an effort to divert flood waters around the town site. Live Oak Street, Sullivan Street, Keystone Avenue, Miami Avenue, and Gibson Street were laid out and graded and five buildings were erected prior to the grand opening (Van Dyke, 1922).

On September 19, 1909, the Gila Valley, Globe and Northern Railroad had nearly completed its standard gauge branch line from Globe, when an injunction brought by Van Dyke temporarily halted construction just outside of Miami. This dispute involved the future name of the town. Van Dyke wanted it to be named Cordova, while the Miami Copper Company wanted the name to be Miami (Sain, 1944).

While Van Dyke was out of town on business, the railroad was completed to Miami Copper's mine site via an alternative route outside of Miami on September 24, 1909. By September 30, 1909, everything had been resolved and the injunction withdrawn. Van Dyke realized the success of his up-coming grand opening of the town site depended on having an operating railroad to Miami. The railroad resumed work to enter the Miami town site with the first train from Globe arriving in Miami on October 5, 1909 (Sain, 1944).

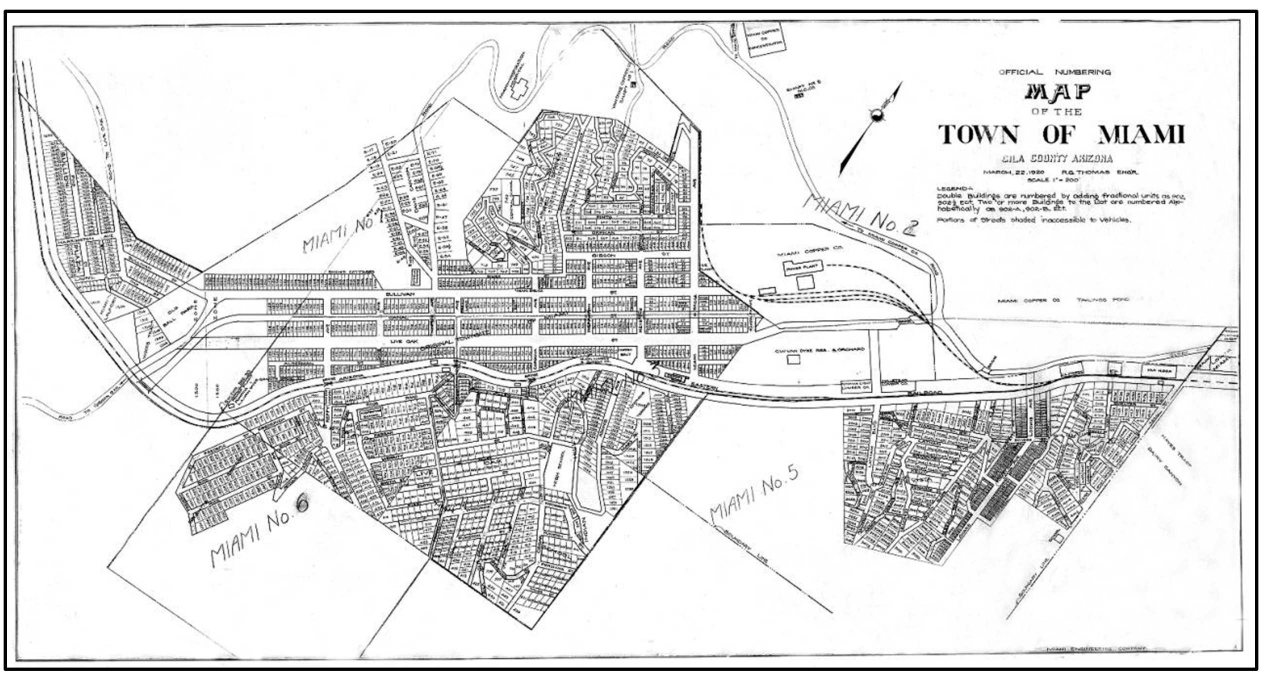


Figure 52. Miami town site map, circa 1920 (map from Gila County Recorder's Office, Arizona Memory Project)

By the end of September 1909, essentially all of the work of surveying commercial and residential lots and grading the streets for the new town of Miami was completed (Figure 52). However, Van Dyke's vigorous advertising campaign about the Miami town site sale in the Globe Silver Belt was met with disparaging advertisements from competing real estate interests. In spite of this negative publicity, Van Dyke's grand opening held on October 11, 1909 was a success with fifteen hundred people attending the festivities (Sain, 1944).

Miami was developed rapidly, but rather haphazardly until its incorporation in June 1914. One year after its formation, the 1910 census reported a population of 1,390. Over the next decade, construction was unable keep up with the needs of the area's rapidly growing workforce as Miami's population grew to 6,689. Miami's utilities were unable to meet demands for their services. Many workers had no place to sleep or eat due to an acute shortage of housing. Many slept in the open or on saloon floors. Several shifts of men would use the same beds. Workers often stood in line to get into a restaurant (Sain, 1944).

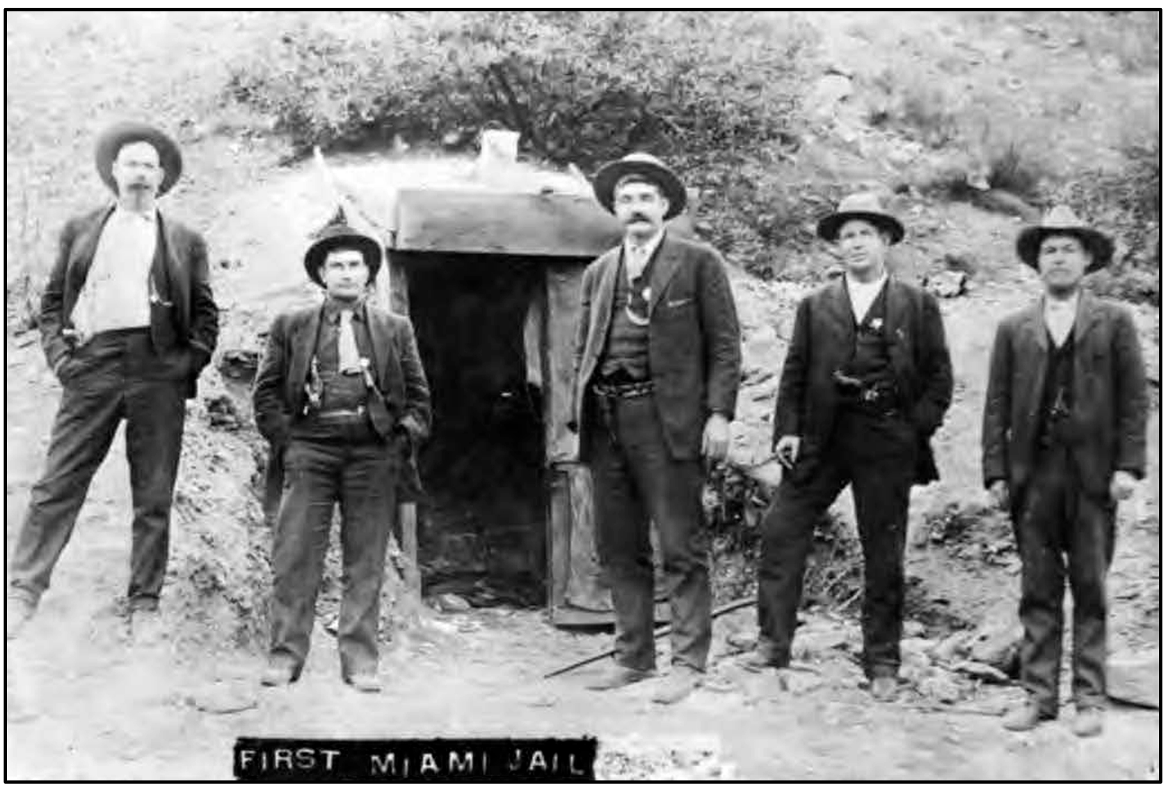


Figure 53. Miami's first jail, circa 1910, (photo from Kelley's Studio, Miami, Arizona)

During its first year, special law enforcement officers were employed by public subscription from the Miami's business community (Sain, 1944). So many arrests occurred at night, when it was inconvenient to transport the prisoners to jail in Globe, police officers resorted to holding detainees in an old mine tunnel or boxcar, which served as Miami's first jails (Figure 53).

Miami's business district included dry goods, grocery and general merchandise stores, hotels and boarding houses, restaurants, a bakery, blacksmith, livery, and dairies. The Western Union Telegraph Company established an office in Miami in November 1909. Saloons were more common than other types of business enterprises with nine establishments opened by the end of January 1910 (Sain, 1944).

Miami's first bank was located at John Fitzpatrick's saloon. On paydays, Fitzpatrick went to Globe to pick up several thousand dollars in silver and currency. On his return trip, he was accompanied by two guards, one preceding and the other following the buckboard, both armed with Winchesters. On the seat of the buckboard, Fitzpatrick carried a sawed-off shotgun. Armed guards stood near the teller's window when the miners cashed their paychecks. Miami's first real bank was established by the Gila Valley Bank and Trust Company in early 1910 (Sain, 1944).

During the early days it was difficult to get water, which had to be hauled by wagon from wells located outside of town. Miami's first public utility was the Granite Springs Water Company, Inc. The Granite Springs Water Company, Ida A. Van Dyke Telephone Company and the Miami Electric and Power Company, established in October 1911, were controlled by Cleve Van Dyke. Electricity was not available until 1912, when it was supplied to the business district. Cleve Van Dyke also bought the Arizona Silver Belt in 1913 and moved the paper from Globe to Miami (Sain, 1944), where it remained until 1976, when it was returned to Globe.

Developed three decades after nearby Globe, Miami only had to overcome a few problems experienced by its predecessor. The days of the Wild West had passed and the arrival of the railroad had resolved issues related to its remote location. While the lively night life of the mining community continued to present similar difficulties as before, most of Miami's challenges involved establishing and maintaining the political and business empires of those in power.

This often involved two factions, those who supported Cleve Van Dyke and those who did not. Cleve Van Dyke owned the Miami town site and controlled the utilities that served the community. Van Dyke and his friends also homesteaded most of the suitable land adjoining the town. This was a source of annoyance to others, including the management of the district's major copper producers, who often found themselves at odds with the Van Dyke faction on many issues that were important to the community (Sain, 1944).

Transportation services for the Globe-Miami area during the early 1900s were provided by stage lines and Arizona Eastern Railroad, which succeeded the Gila Valley, Globe and Northern Railroad in February 1910. The cost to travel from Globe to Phoenix on the Globe-Kelvin Stage Line during 1912 was $11.90. The trip via auto-stage took eight hours. By 1916, the Globe-Phoenix stage route to Phoenix was over the Apache Trail via Roosevelt Dam. These six and eight-cylinder seven passenger cars provided daily service for $10 one-way and $18 for the round trip. During the decade, 1910 to 1920, auto stages gradually replaced businesses employing horse-drawn stages. The Superior-Miami highway was completed in April 1922 at a cost of $1 million (Sain, 1944).

The Arizona Eastern Railroad provided transportation services to eastern destinations. In addition to the regular passenger service that passed through Globe to Safford and Bowie, a motor coach also made several trips daily between Globe and Miami (Sain, 1944).

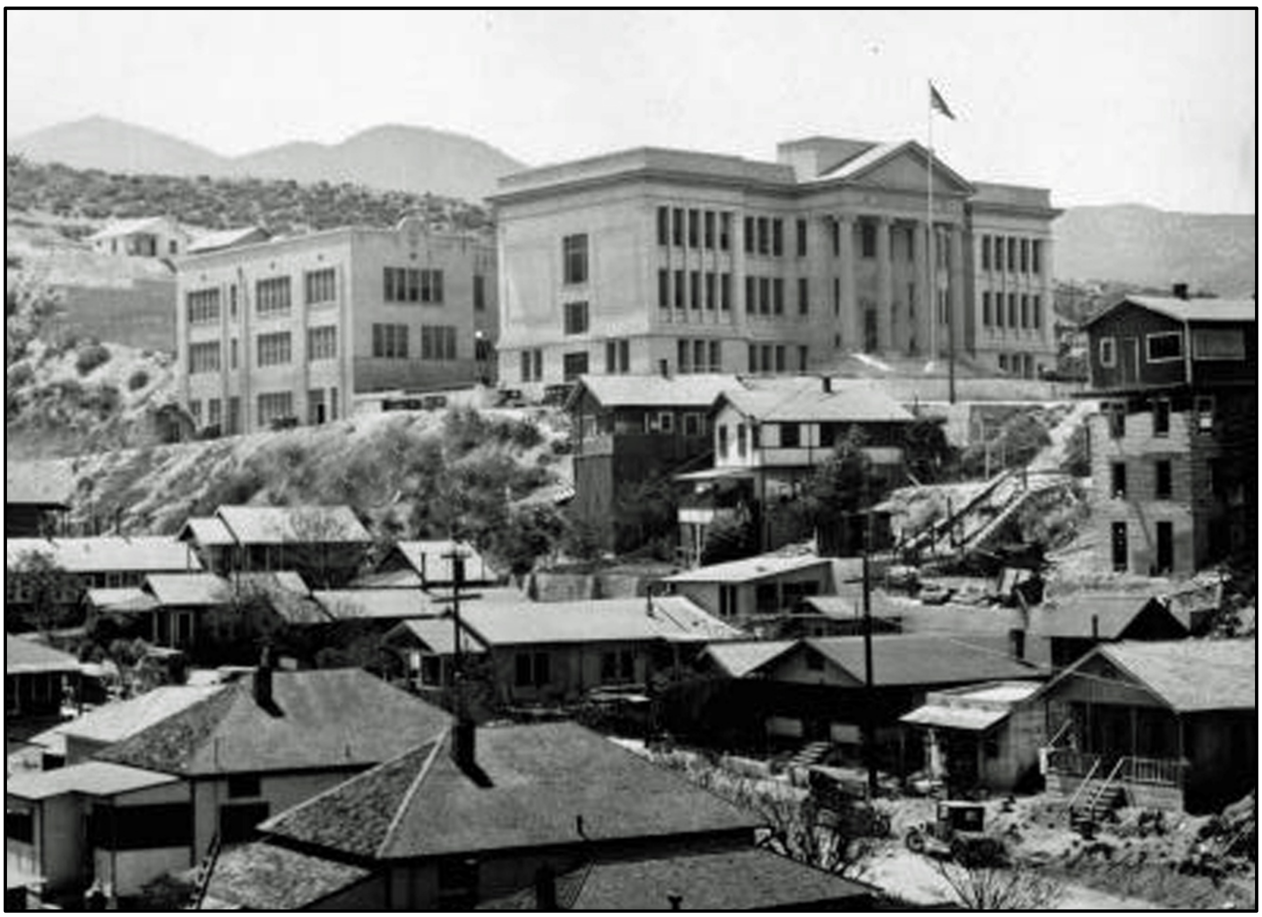


Figure 54. Miami high school (circa late 1930s) (photo from Kelley's Studio, Miami, Arizona)

Miami's first school was held in a one-room, wooden frame building located near the Miami mine during 1909. The school system expanded rapidly with school districts established in Lower Miami, Inspiration and Upper Miami during 1910. Miami's first high school (Figure 54) was opened in 1916 on a lot that had been donated by the Miami Copper Company with an additional gift of free light and water for ten years (Sain, 1944).

Medical services for the community were initially provided by Dr. John C. Bacon, who was hired by the Miami Copper Company in 1910. His clinic initially consisted of a tent with wood-planked side walls. Named for the two mining companies, the Miami-Inspiration Hospital was completed in early 1913 on a hill overlooking the town of Miami (Figure 55). This facility provided all aspects of medical care to the mine workers and their dependents until its closure in the mid-1960s.

In November 1914, Arizona passed its own state-wide ban on alcohol, five years before the 18th Amendment. This had a profound impact on Miami's business community, which had 26 saloons prior to its passage. After its passage there was a marked increase in billiard and pool hall establishments. The 1916 Miami business directory listed 16 billiard halls and 13 soft drink emporiums, compared to four and nine, respectively, prior to its passage (Sain, 1944).

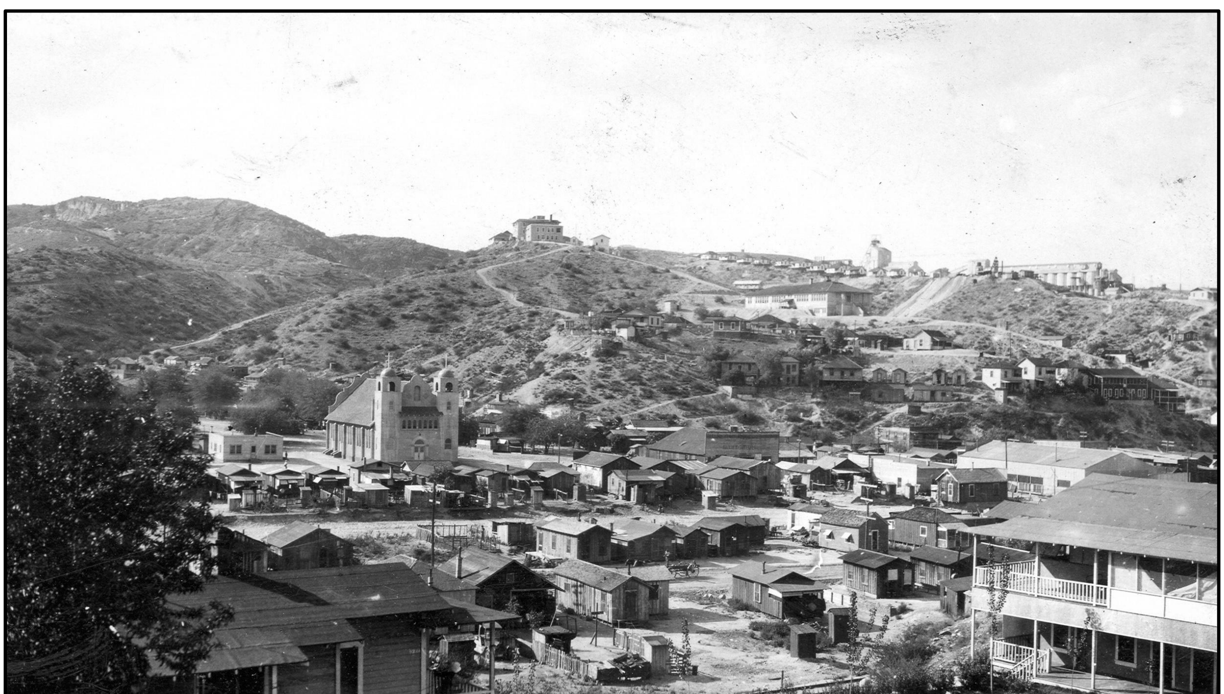


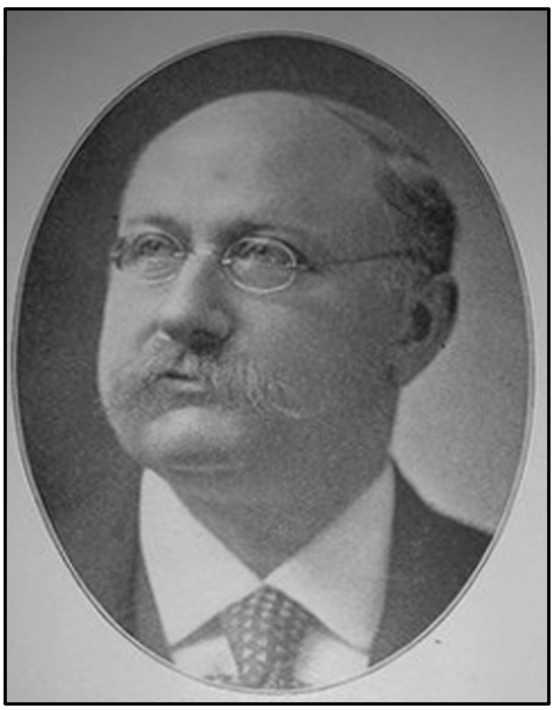
Figure 55. Downtown Miami, looking north toward the mining area. Large building at top of the hill in the center of the photo was the Miami-Inspiration hospital, circa 1920 (photo from the U. S. Geological Survey)

Over the decade 1910 to 1920, the population of Upper Miami grew as workers were added to mines' growing workforce. Neighboring communities of Lower Miami, Claypool, Grover Canyon, Cobre Valley, Midland City, and Bullion Plaza were developed to accommodate this growth.

4.14 Miami Mine (1907-2013)

In January 1906, Adolph Lewisohn (Figure 56, left) organized the General Development Company for the purpose of purchasing and developing promising mining properties, especially those having a potential for low-grade copper deposits (Parsons, 1933).

During the fall of 1906, Fred C. Alsdorf, a well-known mining engineer, was commissioned to examine the Keystone property (Figure 49) for the General Development Company. During the course of his examination, he learned about the Oaks-Newman claim group (Parsons, 1933).



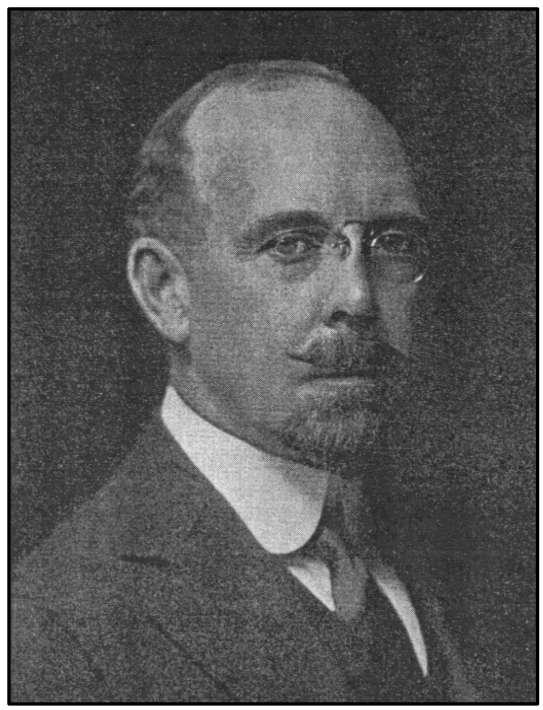


Figure 56. Adolph Lewisohn (1849-1938), prominent New York merchant and industrialist and J. Parke Channing (1863-1942), a consulting engineer employed by the General Development Company (photos from Mining Foundation of the Southwest)

In November 1906, Alsdorf brought this opportunity to J. Parke Channing (Figure 56, right), who had been visiting Globe after examining the Ray property for General Development. After examining the Oaks-Newman property, they met with John B.

Newman at the Old Dominion Hotel. After lengthy negotiations, an agreement was reached at 2:00 AM on the following morning.

Channing negotiated an option to acquire the Oaks-Newman claim group for a cash payment of $150,000 and a 5% interest in any company that might be formed to develop and operate the property. This option was free, with the first cash payment of $50,000 due in six months (Parsons, 1933).

4.14.1 John B. (Black Jack) Newman

One of the more interesting characters in Globe-Miami's history was John B. Newman (Figure 57). Born in Chorna, Austro-Hungary in 1862, his father was Polish and his mother Turkish (Parsons, 1933). Newman immigrated to New York around 1880, where he lived briefly before working in the coal mines of Pennsylvania, copper mines near Lake Superior and on the Texas and Pacific Railroad before making his way to Morenci, Arizona in 1884, where he briefly worked at the Longfellow mine. He arrived in Globe in 1885, afoot and shoeless after his burro died leaving him to walk 60 miles across the San Carlos Apache Reservation (Anonymous, 2021).

Figure 57. John Barry "Black Jack" Newman (1862-1928), the successful prospector who located the Oaks-Newman claim group (photo from Jewish Museum of the American West)

On his first day of work at the Old Dominion mine, the shift boss was unable to spell his Polish name. He entered “new man” in his pocket time book as a temporary expedient, but forgot to change it, so the name went on the payroll as Newman. With Jack being a handy name for a miner and Black referring to his swarthy complexion, he became known as Black Jack Newman (Parsons, 1933).

Unlike many miners, he was prudent and searched for opportunities to invest his money. Unable to read or write, he hired an attorney to do all of the paperwork, and then hired two other attorneys to check the work of the first (Rollins, 1956).

Within a year or two, he held interests in several silver and copper properties and owned his own home. He also prospected, staked and developed mining claims, either leasing them to other miners in return for a percentage of the returns or by selling them for a profit (Anonymous, 2021).

Believing one of his partners was cheating him, Newman shot him in the arm. Newman was arrested, tried and convicted of assault with the intent to kill, and sentenced to ten years in the Yuma Territorial Prison. After serving a year of his sentence, he was pardoned in June 1890 by Territorial Governor Lewis Wolfley, due to extenuating circumstances. Following his release from prison, he returned to Globe and resumed prospecting (Anonymous, 2021).

Newman served in Company B of the Arizona Territorial First Regiment during the Spanish American War (Merwin, 2013). After returning from the war, he located 13 mining claims around 1903 that would become the nucleus of Miami Copper’s future holdings (Parsons, 1933).

4.14.2 Exploration and Discovery of Miami Deposit

J. Parke Channing placed Fred Alsdorf in charge of the exploration program and work commenced on two exploration shafts in December 1906. The 210-foot, three-compartment No. 1 shaft (Captain shaft) was collared in an area where the surface outcrops of Pinal Schist were strongly stained by copper oxide minerals. The No. 1 shaft encountered disseminated chalcocite mineralization at a depth of 100 feet and mineralized granite with pyrite and chalcopyrite at 170 feet. Exploration drifts were driven on the 150 and 200-foot levels (Rickard, 1932).

On the 150-foot level, granite was cut by the drift driven in the northwest direction, while leached Pinal Schist was encountered within 100 feet in the opposite direction. On the 200-foot level, a drift was driven 70 feet southeast, encountering mineralized granite with sub-economic concentrations of pyrite and chalcopyrite. No ore was encountered (Rickard, 1932).

The three-compartment No. 2 shaft (Redrock shaft) was sunk approximately 850 feet east of the first shaft (Peterson, 1962). It was collared in an area of strong leached cap that was well silicified and showed residual iron, suggesting the presence of an enriched zone at depth (Rickard, 1932).

By the time the No. 2 shaft had reached a depth of 200 feet, early results of this effort were not encouraging. With little time left before the first option payment was due, the General Development Company sent Alsdorf a telegram, ordering him to suspend all operations. When Alsdorf relayed this message to Black Jack Newman, Newman calmly tore the telegram into small pieces, saying “we got no damn telegram.” On Newman’s promise to pay the wages of the miners, Alsdorf reluctantly agreed to continue sinking the No. 2 shaft. On April 13, 1907, the No. 2 shaft encountered enriched chalcocite ore, assaying 3% copper at a depth of 220 feet (Parsons, 1933).

By the end of May 1907, drifts had been driven 50 feet from all four points of the compass on the 270-foot level, confirming the presence of a major ore body and warranting the first option payment in June (Rickard, 1932). By March 1908, the No. 2 shaft was deepened to a depth of 720 feet, with continuous ore extending to a depth of 710 feet (Calkins, 1912). Ore reserves totaled 2 million tons, averaging 3% copper (Rickard, 1932).

4.14.3 Development of the Miami Deposit

The General Development Company organized the Miami Copper Company in November 1907 to develop its discovery at Miami, Arizona (Figure 49). At the outset, total capitalization was $3 million, consisting of 600,000 shares with a par value of $5 per share. Of these, 300,000 shares were assigned to General Development Company in exchange for its exploration costs and an undeveloped mine (Stevens, 1908). Up until incorporation, the General Development Company had made the first cash installment of $50,000 to Black Jack Newman and spent $100,000 on exploration and development of the property. The General Development Company also provided the funds for the second cash payment of $100,000 and transferred 30,000 shares of its 300,000-share allotment to Newman, in accordance with the original purchase-option agreement (Parsons, 1933). The remaining 300,000 shares were offered for sale to the public to help finance the development of the Miami property. With the success of the development program, the total capitalization was increased from $3 million to $4 million in August, 1910 (Stevens, 1911).

During 1908, Miami Copper erected a small experimental pilot plant to conduct bulk metallurgical testing on ores encountered during the development program. This facility included one Nissen stamp mill, two Johnson vanners and five Wilfley tables. A survey was also performed to establish the route for extending the Gila Valley, Globe and

Northern Railroad from Globe to Miami (Burgin, 1976). The decision to proceed with the development of the Miami project was made in January 1909. Grading on the future mill site commenced in April 1909. The Gila Valley, Globe and Northern Railroad completed the standard gauge branch line from Globe to the Miami mine site in September 1909 (Burgin, 1976).

Figure 58. Panorama of Miami Copper's company town site, looking southwest (circa 1909). The No. 3 shaft is at the far right, while the No. 2 shaft located at left center of photo (photo from Library of Congress)

During the early development of the Miami property, Miami Copper established a small town in the area between the No. 2 and No. 3 shafts, which included a company-owned store, boarding house, bunkhouse, and approximately 150 two to six-room frame dwellings, all lighted by electricity (Figure 58). A large office building was also erected at a cost of $15,000. A recreation hall on the summit overlooking Miami Flat provided reading material, pool tables and games for its workers and their families (Stevens, 1911). Most of these structures were subsequently relocated or abandoned due to subsidence resulting from underground mining activities shown in Figure 59.

Figure 59. Dramatic effects of subsidence resulting from underground mining operations at Miami (photo from Parsons, 1933). When mining ceased in 1959, the zone of surface subsidence measured 3,400 feet north-south by 2,600 feet east-west and was more than 400 feet deep (Burgin, 1976)

An extensive campaign of churn drilling and underground development under direction of J. Parke Channing began in early 1910. By the end of 1910, 32 churn drill holes with an average depth of 600 feet had been completed at a cost of $1.25 per foot. Laid out on a 200-foot grid, almost all of these holes encountered ore grade mineralization (2 to 2.5 % copper), ranging from 110 to 210 feet in thickness and showed commercial ore to at least 70 feet below the deepest underground workings in the mine (Stevens, 1911).

As of December 31, 1910, there were four shafts. The 210-foot three-compartment No. 1 shaft, 720-foot three-compartment No. 2 shaft and 422-foot three-compartment No. 3 shaft were sunk during the exploration and development of the ore body. The 720-foot, five-compartment No. 4 production shaft was sunk outside the proven ore zone to protect it from damage once mining commenced. The operation had 78,388 feet of underground workings on nine levels, extending from 220 to 570 feet below the collar of the No. 2 shaft. Proven ore reserves were 18 million tons, averaging 2.58% copper (Stevens, 1911).

Surface facilities supporting the Miami operation included a central 2,000-kilowatt power plant that provided compressed air and electricity for the mine. A pumping plant supplied one million gallons of water per day from the Old Dominion mine. Additional water supplies were obtained from three 10-inch wells, each producing 500,000 gallons per day, located at the lower end of Miami Wash. Water was transported to the mill site via a 25,000-foot 14-inch diameter pipeline from Pinal Creek (Burgin, 1976).

4.14.4 Commercial Operations (1911-1959)

The first section of the 3,000-short ton per day Miami concentrator was commissioned on March 15, 1911, with its initial concentrates being shipped to the Cananea smelter in Sonora, Mexico on April 4, 1911 (Peterson, 1962). Exploration and development costs as of December 31, 1911 totaled almost $10 million (Burgin, 1976). All six sections of the concentrator were in full operation by February 23, 1912.

The sulfide ores at Miami were initially treated by a gravity concentrator, which employed a crushing and grinding circuit to reduce the ore that was passed through a classifier separating it into coarse (i.e., sands) and fines (i.e., slimes) fractions. A series of Deister tables were employed to recover a copper concentrate product. As a result of unacceptable losses of copper in the final tails, considerable research was done to improve recoveries. Experiments using early flotation cells were so successful, Callow pneumatic flotation cells were installed to treat the slimes fraction of the ores in July 1915. In response to the wartime demand for copper, the capacity of the concentrator was increased to approximately 6,000-tons per day in December 1916. By January 1919, gravity recovery methods were abandoned entirely when flotation cells were installed to treat the sands fraction of the ores (Hunt, 1932).

Initial mining operations at Miami focused on extracting the high-grade portion of the ore body, which occurred from start-up until September 1925. During this period, a square-set stoping method was employed to initially extract the peaks of ore that extended above the Main Miami ore body into the overlying barren leached cap (Figure 60). The remainder of the high-grade ores was extracted by top slicing, shrinkage stoping with sublevel caving and undercut caving methods (Hardwick, 1965).

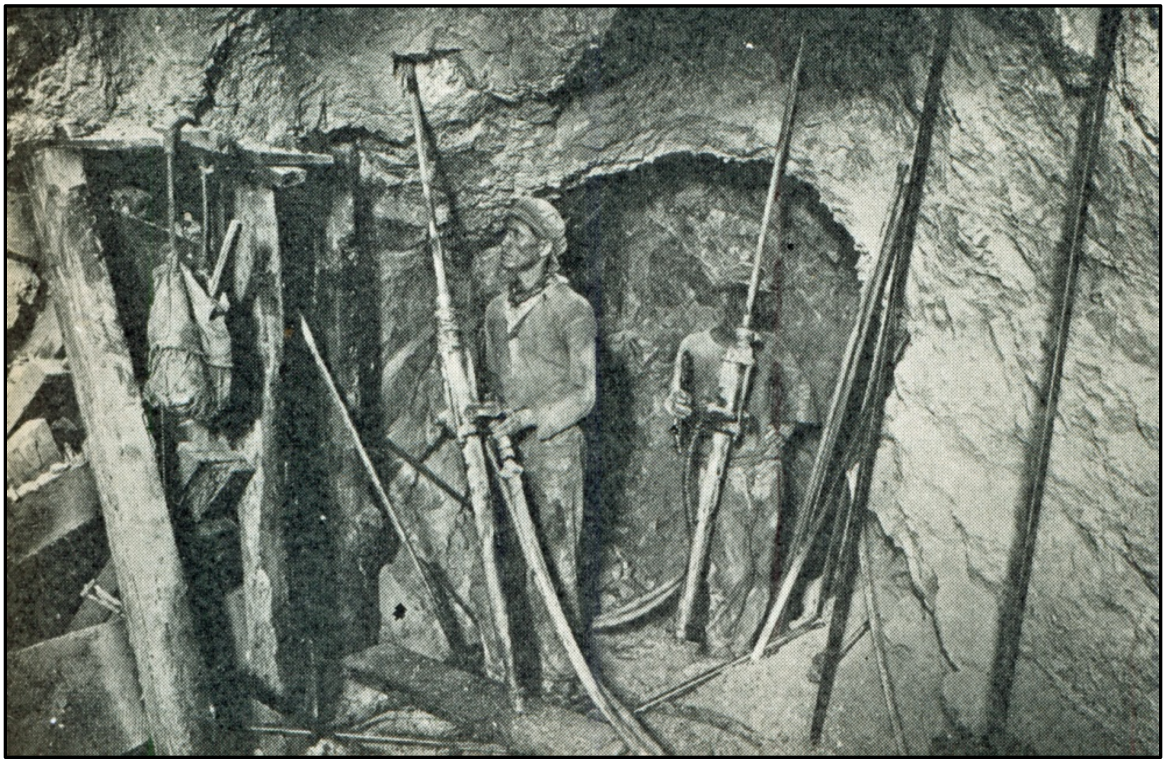


Figure 60. One-man pneumatic drills at Miami (photo by Parsons, 1933)

On April 17, 1913, a 250 to 300-foot thick section of overlying capping of the Northwest ore body, located approximately 300 feet west of the No. 2 shaft unexpectedly collapsed, resulting in destruction of the underlying underground mine workings down to the 370-foot level. In the past, the capping had always gradually settled as the ore had been mined from the underlying shrinkage stopes without any serious problems. However, on this occasion approximately three million tons of overlying capping suddenly gave away, breaking through to the surface. Although no fatalities directly resulted from the falling rock, five miners were killed and others were injured from the air blast that traveled through adjacent drifts (Anonymous, 1913).

During the first two years of operation, Miami Copper's concentrates were shipped to Cananea Consolidated Copper's smelter in Sonora Mexico. However, unstable political conditions resulting from the Mexican Revolution eventually made this option no longer viable. Beginning in April 1913, Miami Copper's concentrates were shipped to the

International Smelting and Refining Company smelter in Tooele, Utah. With the completion of International's new smelter in Miami in July 1915, Miami Copper's concentrates were treated locally (Richard, 1987).

Concerns that the No. 4 production shaft was too close to the subsidence zone created by the underground mining operation resulted in a decision to sink a new production shaft. In November 1917 the four-compartment, concrete-lined No. 5 shaft was collared 1,500 feet southeast of the No. 4 shaft, well outside of the zone of subsidence. It was completed to a depth of 963 feet in October 1919 (Willis, 1922d). The No. 4 shaft was abandoned in June, 1921, making the No. 5 shaft the main production shaft. Unlike many of Arizona's copper producers, Miami Copper was able to weather the downturn of the copper market during 1921 without having to suspend operations.

The first exploration effort to examine the down-dropped, hanging wall of the Miami fault occurred between 1920 and 1927. The No. 5 shaft was deepened to 1,800 feet. From a drift on the 1800-foot level, a winze was sunk to the 2600-foot level. An underground diamond drilling program (1923-1925) from a drift on the 2600-foot level discovered the Miami East deposit, but failed to delineate sufficient ore to warrant development (Burgin, 1976). A second underground diamond drilling program from the 1,800-foot level (1926-1927), also failed to encounter ore grade mineralization (Anzalone, 1981). Following completion of this program, the 1,800- and 2,600-foot levels were abandoned, and the shaft backfilled (Anzalone, 1981).

By the end of December 1923, 20.5 million tons of high-grade sulfide ore averaging 2.01% copper had been mined and treated (unpublished Bureau of Mines data). Remaining high-grade sulfide ore reserves stood at 5.1 million tons, averaging 2.08% copper and mixed sulfide-oxide reserves were 6 million tons, averaging 2.00%. A low-grade sulfide resource of 36 million tons, averaging 1.06% copper was also delineated (Heikes, 1927).

Unwilling to suspend operations when the high-grade sulfide reserves were exhausted, the management of the Miami Copper Company made plans to extract and treat this low-grade sulfide resource. This required several modifications to the mining and milling infrastructure. First, the lower grade ores required a finer grind to produce a satisfactory concentrate for smelting, necessitating major modifications to the milling circuit. Reduction of unit operating and overhead costs to increase both the mine and mill production capacities to at least 10,000-tons per day required a minimum capital expenditure of $1.5 million for additional equipment for the mine, concentrator and power plant. An additional $1.5 million in mine development costs (driving haulage ways, drifts and raises) were required before a daily output of 10,000 short tons could be achieved from the low-grade ore body (Parsons, 1933).

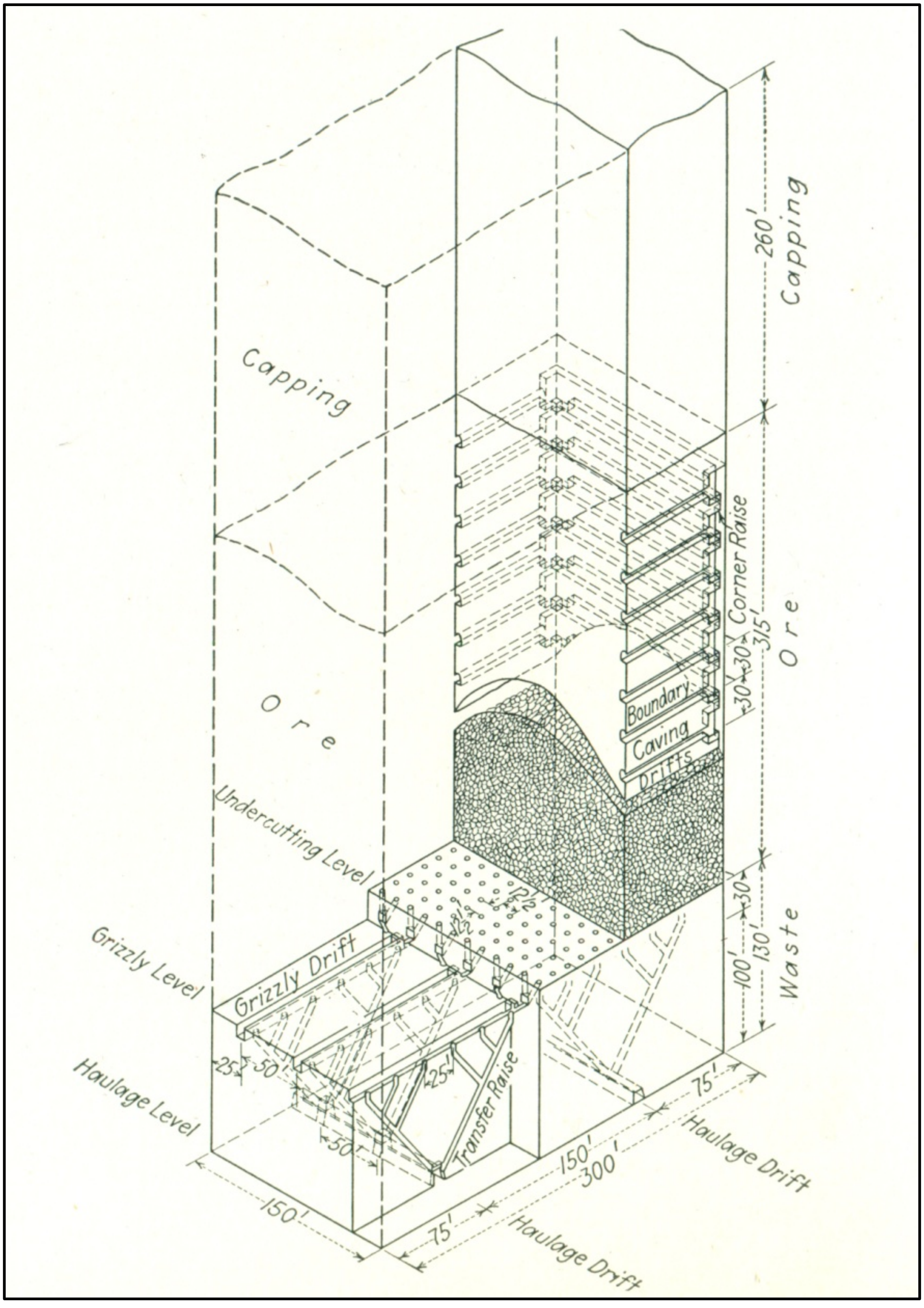


Figure 61. Schematic diagram of block-caving method employed at Miami (photo from Parsons, 1933)

As of October 1, 1925, Miami Copper increased its milling capacity to 10,000-tons per day and was successfully extracting the low-grade sulfide ore body by block caving method methods. Individual stopes or blocks measured 150 by 300 feet and had a minimum height of 300 feet (Figure 61). Alternate blocks were initially extracted with the adjacent blocks or pillars being left in place. The pillar blocks were caved a year or so later, after the debris filling the initial blocks had consolidated (Hardwick, 1965).

Broken ore from above the undercutting level was drawn by gravity through finger raises to the grizzly level, located 30 feet below the undercutting level, where it was passed through a grizzly, which consisted of 45-lb. rails spaced 12 inches apart (Parsons, 1933). The sized ore was directed through a transfer raise to a loading station on the 720-foot haulage level (100 feet below the grizzly level), where it was loaded into trains, consisting of two 6-ton trolley locomotives (Figure 62) designed for tandem operation by a single motorman, and 30 saddle-back 86-cubic foot (3.73 tons) ore cars.

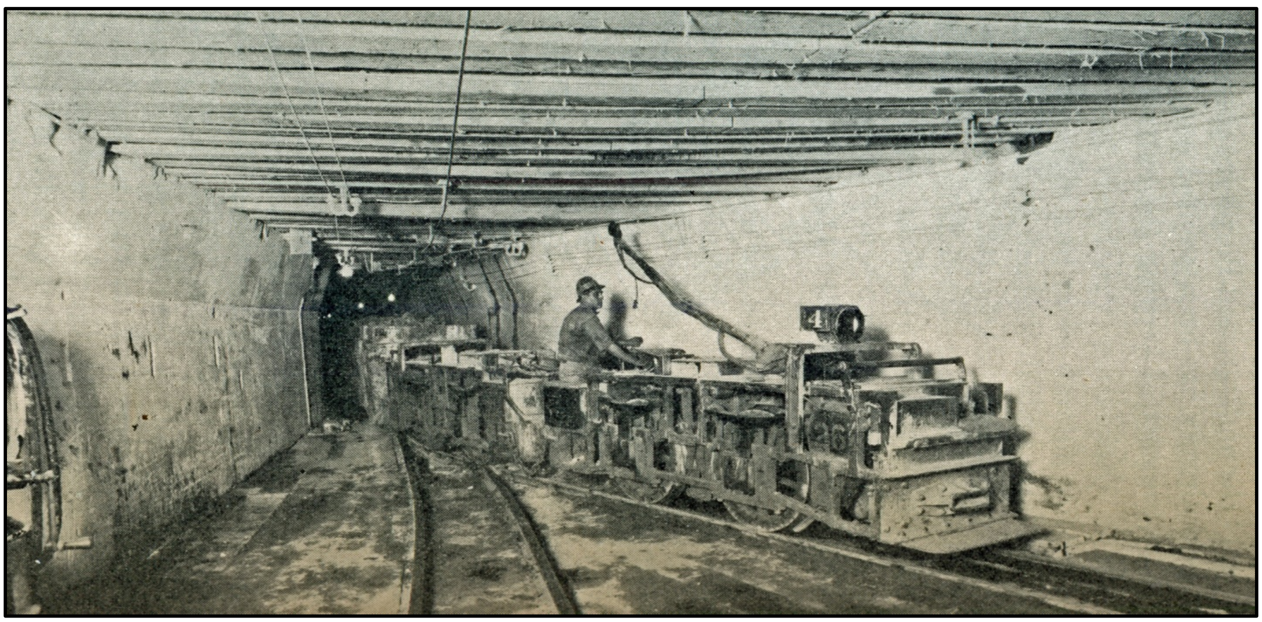


Figure 62. Electric trolley locomotive hauling ore at Miami underground mine (photo from Parsons, 1933)

Equipped with hand-operated door latches, the ore cars were unloaded as the trains passed slowly over an 800-ton ore pocket that was located adjacent to the No. 5 production shaft (Hardwick, 1965). All train traffic was in one direction with the empty trains returning to the mine via an alternate route.

From the ore pocket, ore was loaded into two 10.5-ton skips running in balance and hoisted to the surface by a single electrically operated hoist (Figure 63). A sustained production record for a single shaft was probably established at Miami during 1930, when 6,124,993 short tons of ore (17,141 short tons per day) were hoisted over 357.3 operating days (Parsons, 1933).

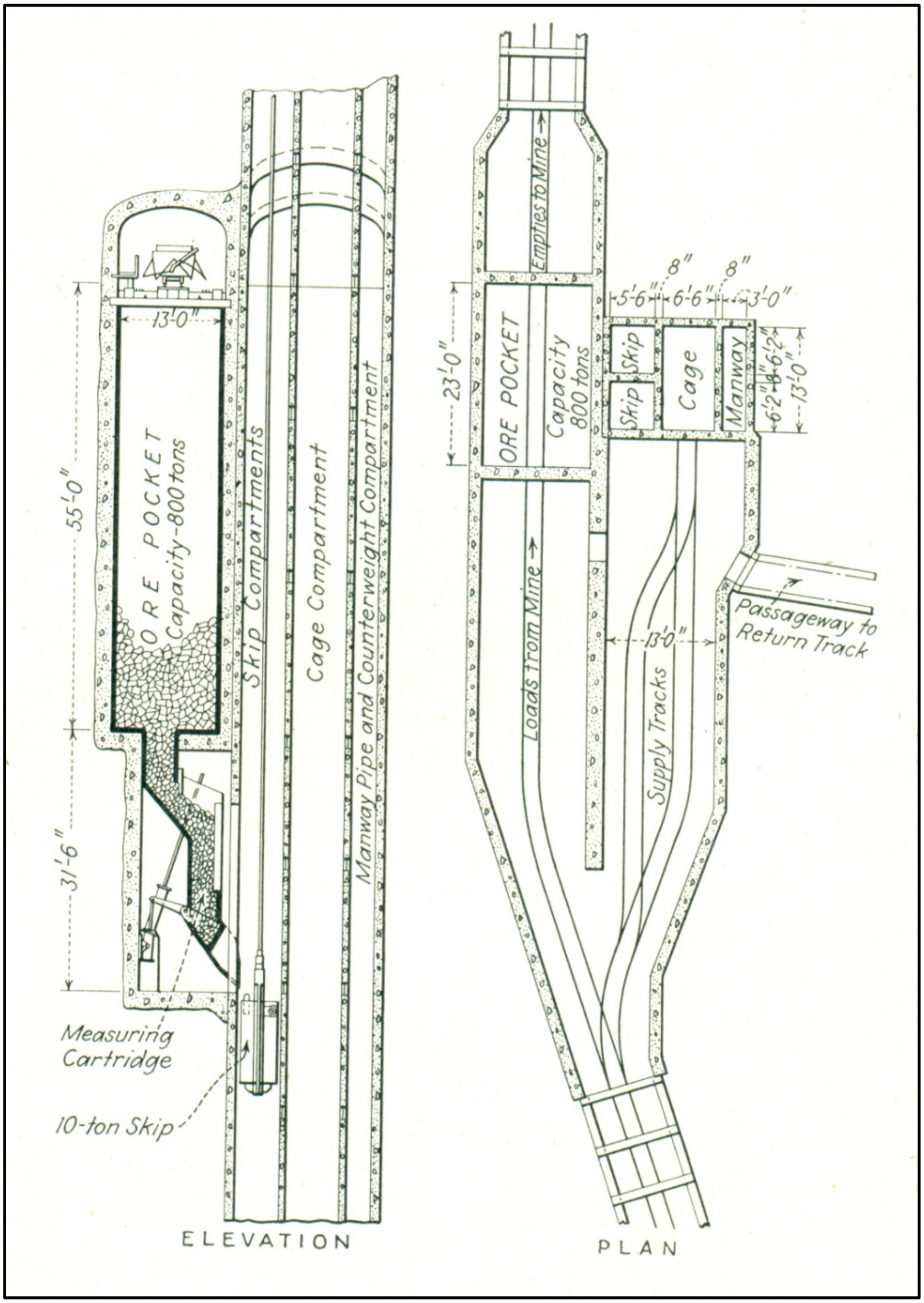


Figure 63. Schematic diagram showing underground ore pocket and skip-loading equipment (photo from Parsons, 1933)

Over the next couple of years, an ongoing exploration program increased Miami Copper's low-grade sulfide ore reserve to 99.6 million short tons, averaging 0.88% copper (December 1927), allowing them to increase the mill production capacity to 17,000-tons per day in September 1929 (Figure 64). With increased production, a new tailings impoundment was commissioned in July 1928 at Solitude Gulch, located approximately 3.5 miles southeast of the Miami concentrator (Gerry, 1931). By 1932, this facility was receiving all of the tailings from the milling operation.

In June 1931, a 250-ton per day experimental pilot plant was commissioned to test the leach-precipitation-flotation (L-P-F) process for treating mixed oxide-sulfide ores at Miami. Successful results of this research, resulted in a decision to build a 3,000-ton per day L-P-F plant, which was completed a cost of $313,100 in August 1932 (Burgin, 1976).

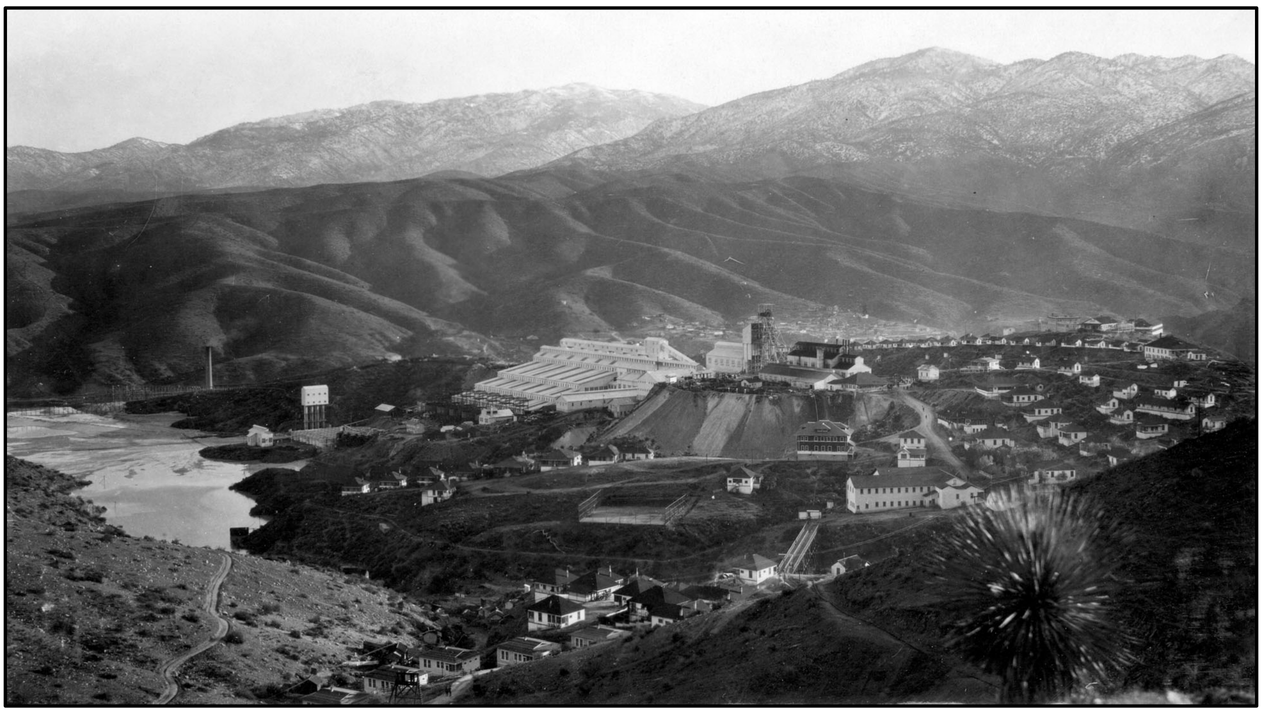


Figure 64. Miami concentrator, No. 4 shaft and company town, circa 1919, looking south (photo from U. S. Geological Survey)

However, low copper prices of the Great Depression resulted in a temporary suspension of operations at Miami on May 15, 1932, before the L-P-F plant could be commissioned. During the shutdown, broken sulfide ores in the stopes became oxidized. When limited production resumed in July 1934, mixed oxide-sulfide ore were treated by the L-P-F circuit, which was expanded to 6,000 tons per day in 1936. Production of sulfide ores resumed in early 1937. A molybdenum recovery circuit was added to the facility in August 1938 (Burgin, 1976).

Water shortages that began during 1937 were partially alleviated by drilling additional water wells and installing a 180-foot dewatering tank in 1939. In spite of these efforts, milling operations were gradually reduced to 72% of capacity by July 1940. A solution to this problem was found in May 1940, when Miami Copper purchased the assets of the Old Dominion Company for $100,000 (Haak, 1999). Following $190,000 of renovations to the Old Dominion mine, it was supplying water to Miami Copper's operation by August 1940 (Burgin, 1976).

By 1941, ore reserves above the 720-foot haulage level had been depleted. Thereafter, the 1000-foot level served as the main haulage level for the mine (Hardwick, 1965).

In-place solution mining operations at Miami Copper underground mine began in December 1941, extracting copper from a broken and fragmented zone located above an inactive portion of the underground block-caving operation, where nearly 75% of the leachable copper was present as chalcocite (Carstensen and Neira, 1997).

Production of mixed oxide-sulfide ores at the L-P-F plant was suspended in May 1943, after treating nearly 9.6 million tons of ore averaging 1.44% copper, of which 0.86% was oxide copper and 0.58% was sulfide copper (Burgin, 1976).

4.14.5 Efforts to Stimulate Production during World War II

In an attempt to stimulate domestic production of critical minerals at the outset of World War II and avoid the high prices experienced during World War I, the U. S. government instituted a premium price program for copper and other metals in January 1942. Under this program, substantial premiums were paid over established ceiling prices set by the Metals Reserve Company to mining operations for production in excess of quotas that were based on their past production history (Pehrson, 1943). During the war the ceiling price of copper was 11.8 cents per pound until June 1946, when it was raised to 14.4 cents per pound. In November 1946, the ceiling prices of copper were discontinued, with the market price of copper rising to 17.5 cents per pound (Burgin, 1976).

Efforts to delineate an ore body in the eastern down-faulted hanging wall of the Miami fault resumed in 1949 with a churn drilling program from the surface. It failed to find sufficient ore and was discontinued during 1950 (Burgin, 1976).

4.14.6 Post-World War II Government Assistance Programs

During the nearly three decades that followed World War II (1945-1973), the United States experienced unparalleled economic growth fueled by pent-up consumer demand that followed years of hardship during Great Depression and the war (Moffatt, 2020). The increasing demand for copper and changes in U. S. government minerals policy during this period helped to stimulate exploration and development of the America's copper resources as well as expand the production capacity of existing mining operations.

Prior to World War II, there was little stockpiling of strategic and critical minerals like copper. In response to shortages experienced during the war, the U. S. Congress passed the Strategic and Critical Materials Stock Piling Act in 1946 with a goal of reducing U. S. dependence on foreign sources for supplies of strategic and critical minerals during a national emergency. However, few stockpile objectives had been met by the start of the Korean War in June 1950. In September 1950, the U. S. Congress passed the Defense Production Act to rectify this situation. The goals of this assistance program were achieved by long-term market guarantees and changes in the tax code (i.e., accelerated tax amortization and increased depletion allowance) (Morgan, 1955).

By December 1951, Miami Copper's block caving operation at Miami had reduced its remaining ore reserves to 12 million tons, only sufficient to last for three years of normal operations. However, a large resource of 23 million tons, averaging slightly more than 0.5% copper, was present below the mined-out stopes of the high-grade mixed oxide-sulfide zone of the Captain ore body (Peterson, 1962).

In February 1953, Miami Copper secured a contract with the Defense Materials Procurement Administration under which the General Services Administration would purchase 230 million pounds of copper produced from this resource at a guaranteed price of 27.35 cents per pound (subject to escalations) and would option the molybdenum concentrates (Peterson, 1962). The U. S. Government also had an option to purchase an additional 120 million pounds of copper from the remaining high-grade reserves. The contract for the sale of copper from the low-grade portion of the mine was terminated in August 1955 (Burgin, 1976). The contract for the sale of copper from the high-grade portion of the mine was completed in early 1956.

Miami Copper began mining low-grade ores from the underground operation in March 1954. Dilution of the mixed oxide-sulfide ore by the overlying oxide cap increased the oxide to sulfide ratio of the mill feed (assayed 0.4% sulfide copper and 0.5% oxide copper) to a greater extent than was anticipated. While malachite, azurite and cuprite contained in the mixed ore were recovered by flotation methods, the dominant copper oxide, chrysocolla, could not be recovered. In an effort to improve copper recovery and lower operating costs, selective mining was introduced and mining schedules modified to eliminate 3.5 million tons of non-sulfide material from the ore reserves. The copper remaining in this unmined resource was later recovered by in-place solution mining methods (Burgin, 1976).

During 1956, research suggested copper recoveries could be improved by treating the mixed ores in the L-P-F circuit, which had been previously used from 1934 to 1943. This process involved the initial recovery of the sulfide concentrates by flotation followed by leaching the remaining oxides with acid, precipitation of copper on shredded iron and the recovery of the copper by flotation of the copper precipitates (Bean, 1960). The renovated L-P-F circuit was commissioned in April 1957 and operated until the end of March 1958, when low copper prices resulted in its suspension (Burgin, 1976).

A new precipitation plant was completed in late 1958. Along with additional sump capacity established on the 1000-foot level, pumps and other infrastructure were also installed to ready the underground mine for full scale in-place solution mining operations once conventional mining operations ceased. All conventional mining and milling operations at Miami were suspended on July 1, 1959 (Burgin, 1976).

In February 1960, the Board of Directors of the Miami Copper Company approved a plan to liquidate the remaining assets of the company. The Tennessee Corporation purchased the assets of the Miami Copper Company in June 1960, except for a royalty interest in its remaining copper reserves, which was sold to institutional investors for $15 million (Kerns et al., 1961). The Tennessee Corporation was subsequently acquired by the Cities Service Company through a merger in June 1963 (Burgin, 1976).

4.14.7 In-place Solution Mining Operations

Full scale in-place solution mining operations commenced upon completion of conventional block caving operations in July 1959. During 1969, Miami Copper mined approximately 1.35 million tons of low-grade ore assaying 0.78% copper along its property boundary adjacent to Inspiration Consolidated Copper's holdings. This ore was dumped into the subsidence zone created by the Miami Copper block caving operation (Burgin, 1976). In late 1974, an agreement was reached which allowed Inspiration Consolidated Copper to extend the Joe Bush pit onto Miami Copper's property (Ahlness and Pojar, 1983).

A dilute sulfuric acid-ferric sulfate solution (0.5% H_2SO_4) was applied using perforated pipes laid out over the surface above the ore body and by a series of shallow injection wells that introduced solutions below the Gila Conglomerate east of the Miami fault (Fletcher, 1985). The copper-bearing solutions were recovered from sumps located on the 1000-foot level of the underground mine and pumped to the surface, where the copper was initially recovered by precipitation onto tin cans or scrap iron (Figure 65).

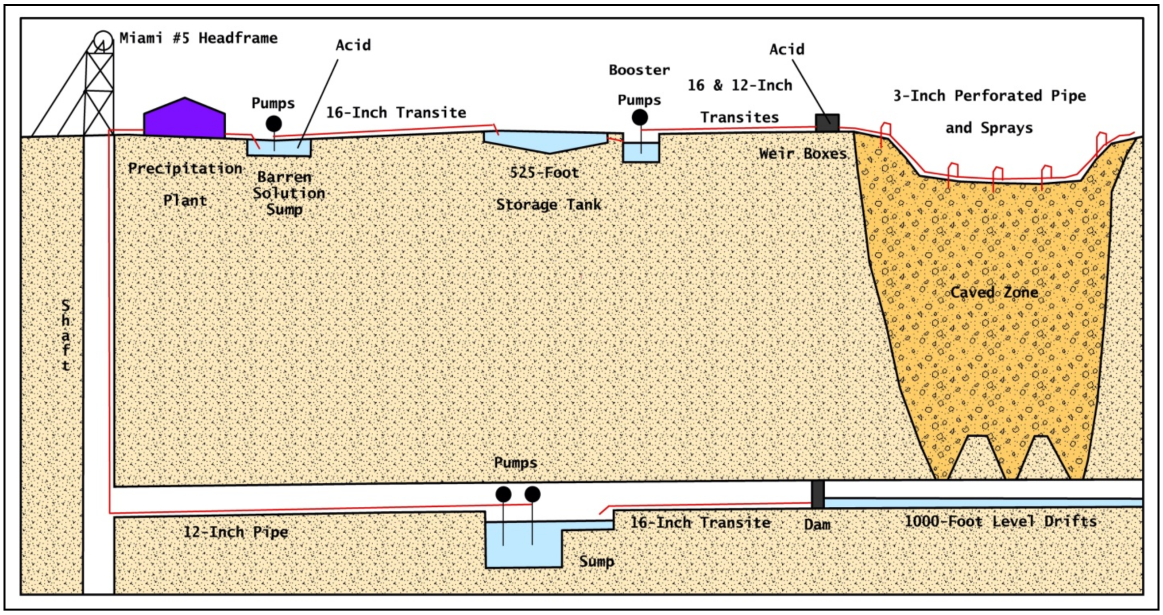


Figure 65. Schematic cross section of Miami in-place leaching operation (modified from Fletcher, 1971)

4.14.8 Miami East

In April 1969, a surface diamond drilling program encountered a high-grade copper zone within the down-dropped, eastern hanging wall of the Miami fault, which was a part of the Miami East deposit (Figure 6) that was discovered during the early 1920s. Boyles Brothers Drilling Company was awarded a contract to deepen the No. 5 shaft, which was completed to a depth of 3,550 feet in March 1973. Exploration drifts were established on the 2,900 and 3,300-foot levels from which an underground exploration drilling program was conducted (Burgin, 1976).

Two ventilation shafts (No. 11 and No. 12) were collared in January 1973. The No. 11 shaft was sunk to a depth of 3,359 feet and was connected with the underground workings in October 1975. The No. 12 shaft was terminated at a depth of 2,100 feet, when the project was placed on stand-by in early 1976 (W. Hawes, pers. comm).

The Miami East exploration program consisted of 16 surface diamond drill holes, averaging 3,773 feet in depth and 39 underground diamond drill holes, averaging 500 feet in length. It delineated a 5.976 million ton ore body assaying 3.14% copper (1.40% copper cutoff), which was hosted by a tabular-shaped body of diabase that dipped to the southeast at approximately 40^{o} (Newmont Mining Corporation, 1986) (Figure 66). This ore body lies within a much larger mineral resource of 100 million tons that assays 1.44% copper (0.60% copper cutoff), which is primarily hosted by the Pinal Schist (Magma Copper Company 1995).

Initial studies considered mining the much larger resource by block caving methods. However anticipated surface damage resulting from subsidence precluded this alternative due to its proximity to the town of Miami, the Inspiration smelter, the highway and river drainage (Anzalone, 1981). Geotechnical studies concluded the smaller high-grade ore body hosted by the diabase could by safely extracted by cut-and-fill mining methods (Burgin, 1976).

In September 1975, Cities Service announced the scheduled start-up of mining activities at Miami East had been postponed. On-going development activities were gradually reduced until early 1976, when it was placed on stand-by until economic conditions warranted resumption of development (Miller, 1976).

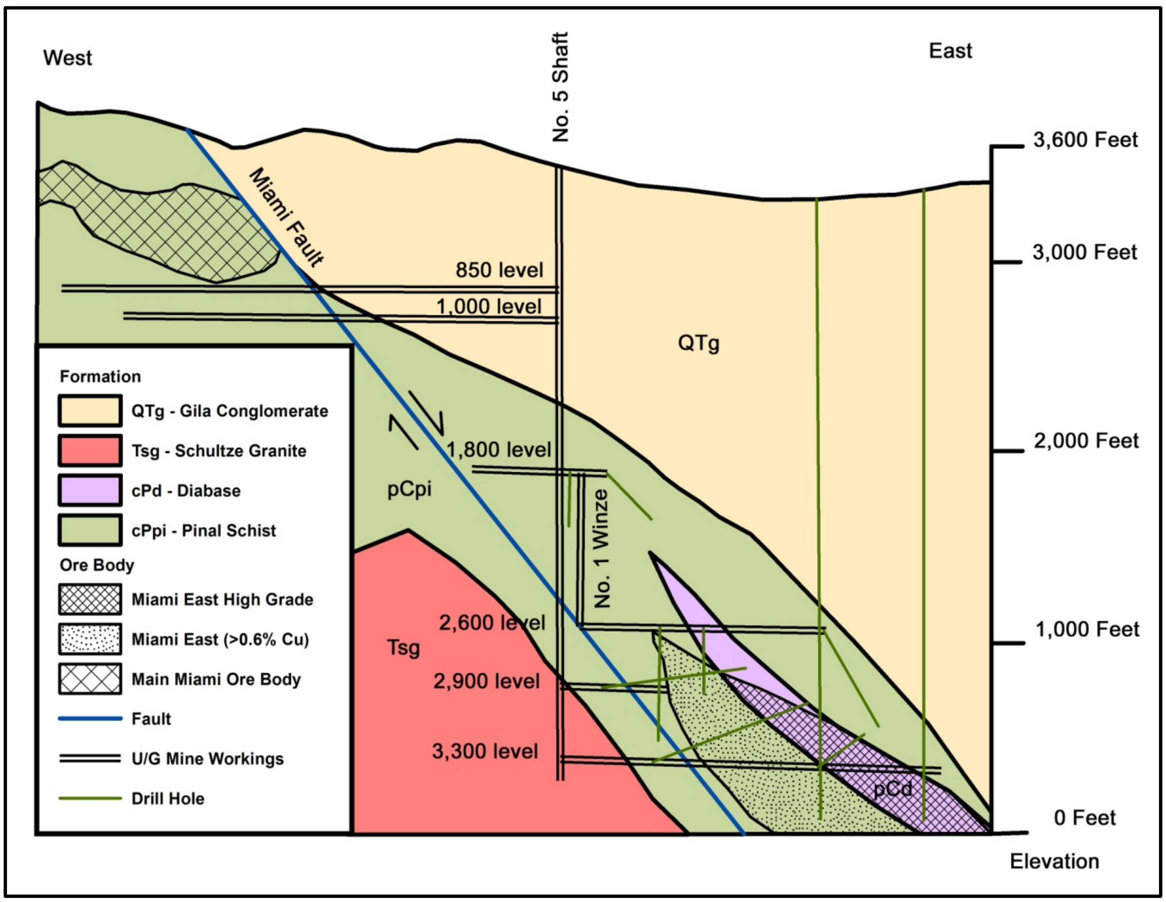


Figure 66. Schematic cross section of Miami East copper deposit, showing its relationship to Main Miami ore body in the footwall of the Miami fault (modified from Anzalone, 1981)

The precipitation circuit that was employed by the in-place solution mining operation was replaced by a solvent extraction-electrowinning facility in May 1976 (Figure 67) (Ahlness and Pojar, 1983).

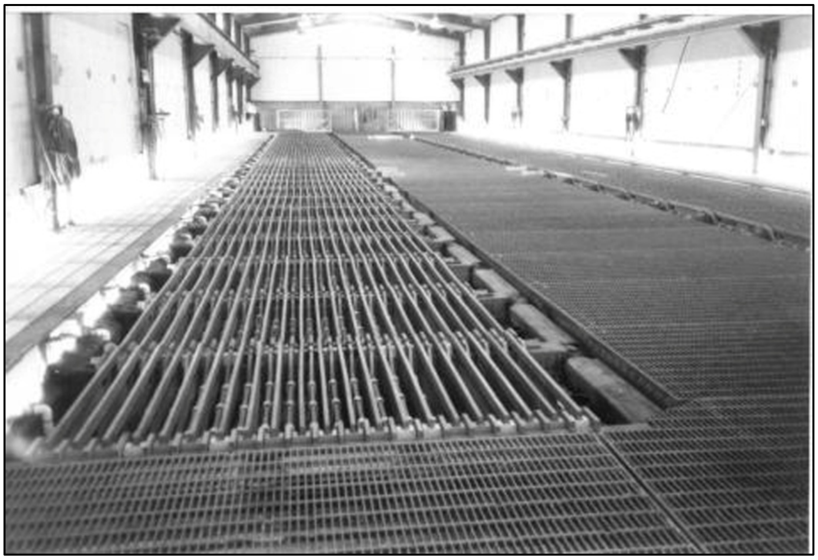


Figure 67. Electrowinning tankhouse at Miami, circa 1990s (photo from the Arizona Geological Survey)

With an increase in the price of copper to $0.94 per pound, development of Miami East resumed in September 1979. By mid-January, 1982, a corkscrew-shaped, 13-foot by 13-foot haulage ramp had been completed, connecting the 2900 and 3300-foot levels. All development at Miami East ceased in late June 1982 (Burgin, 1984), pending improvement in the copper price, which had declined from a high of $1.33 per pound in February 1980 (Butterman, 1981) to $0.70 per pound in June 1982 (Jolly and Edelstein, 1983).

The Cities Service Company became a wholly-owned subsidiary of Occidental Petroleum Corporation in December 1982 and sold the property to the Pinto Valley Corporation, a wholly-owned subsidiary of the Newmont Mining Corporation, in March 1983 (Hicks, 1985). In March 1987, Newmont reorganized its domestic copper assets to form a new public company, the Magma Copper Company (Beard, 1989a).

4.14.9 Miami Tailings Recovery Project (1989-2001)

Reprocessing mill tailings from Miami Copper's No. 2 tailings impoundment was initially considered as early as 1956, when a study on treating the tails through the concentrator's existing L-P-F circuit showed this proposal to be unfeasible (McWaters, 1990).

Tailings contained in the No. 2 tailings impoundment were derived from the Miami Copper's early operations from 1911 until 1932, when the recovery processes were less efficient. This site was estimated to contain 38 million tons of tailings, containing 0.331% copper - approximately 55% oxide and 45% sulfide (McWaters, 1990).

Records showed annual copper values contained within the tails decreased from 0.723% copper in 1911 to 0.114% copper in 1932. The tails consisted of slurry, containing 80% solids by weight of which 64% of the pore space was filled with an acidic solution that contained dissolved copper. Percolation of copper-bearing acidic solution downward through the tailing pile over time resulted in the enrichment of lower layers of the impoundment (McWaters, 1990).

After conducting laboratory leaching tests on the upper 50 feet of the Miami No. 2 tailings impoundment during 1967, Cities Service considered several scenarios to process this resource involving the L-P-F plant and the Solitude tailing impoundment between 1970 and 1979. However, unable to compete with their Pinto Valley project, these proposals were never approved (McWaters, 1990).

In 1980, a new approach was considered. It involved an agitated leach, solvent extraction-electrowinning of the acid soluble copper and a flotation circuit to recover the sulfide copper. However, studies concluded acid leaching could only recover 57% of the total copper contained within the tailings. Additional recovery by oxidation or flotation was not feasible (McWaters, 1990). Depressed copper prices during the early 1980s forestalled any decision to proceed with the project.

By early 1986, Pinto Valley Corporation had revised plans to treat the tailings in the Miami No. 2 tailings impoundment. Under this plan the tailings would be reclaimed by hydraulic mining techniques (Figure 68) and leached and washed in two reconditioned thickeners. The leached tails would be pumped to the inactive Copper Cities pit (Figure 69), while the overflow from the first thickener would report to an expanded SX-EW plant for copper recovery (McWaters, 1990).

Figure 68. Hydraulic mining at the Miami No. 2 tailings impoundment, circa 1990s, (photo from Arizona Geological Survey)

Figure 69. Tailings disposal in the inactive Copper Cities pit, circa 1990s (photo from Arizona Geological Survey)

After completing metallurgical, environmental and feasibility studies, the tailings leach project was approved in April 1987. Following the procurement of the ground water protection permit from the Arizona Department of Environmental Quality and right-of-way easements from Inspiration Consolidated Copper Company and the Bureau of Land Management, construction began in January 1988. In April 1989, Magma Copper commissioned the tailings retreatment plant at a total cost of $22.4 million (Magma Copper Company, 1991).

Broken Hill Proprietary Company Ltd. acquired the Miami project through its merger with the Magma Copper Company in early January 1996 and formed BHP Copper, Inc. to manage its assets (Broken Hill Proprietary Company Ltd., 1996).

Table 12. Historic production from the Miami property (Source: modified from U. S. Bureau of Mines data)

Treatment Method	Period	Ore Treated Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
Mill & DSO	1910-1960	152,382,123	2,275,214,492	0	0	9,742,831	34,971	2,431,021
Solution	1941-2013	0	693,103,089	0	0	0	0	0
Tailings	1989-2001	0	125,630,394	0	0	0	0	0
Total	1910-2013	152,382,123	3,093,947,975	0	0	9,742,831	34,971	2,431,021

The tailings retreatment plant was closed in July 2001 after treating approximately 38.1 million tons of mill tailings from the No. 2 tailings impoundment. Approximately 125.6 million pounds of copper were recovered during the tailings retreatment project. The in-place solution mining operation continued to produce small amounts of cathode copper until August 2013, when production was suspended for economic reasons.

Over its 102-year life, the Miami Copper project produced nearly 3.1 billion pounds of copper, 9.7 million pounds of molybdenum, 35,000 ounces of gold, and 2.4 million ounces of silver (Table 12). The in-place solution mining operation and tailing retreatment project accounted for approximately 22.4% and 4.1% of the total copper production, respectively.

4.15 Inspiration Mine (1904-Present)

Bud Woodson and Bill Beard sold their mining claims located north of the Keystone property to John D. Coplen, who persuaded Kansas City interests to organize the Inspiration Mining Company in 1904 (Sain, 1944). Early exploration efforts included the Woodson and Mercer adits driven from a ravine that opens into Webster Gulch, approximately 1,300 feet southeast of its confluence with Willow Spring Gulch. Low-grade chalcocite ore was discovered at a depth of 130 feet, resulting in intermittent shipments to the Old Dominion smelter (Ransome, 1919). Although Inspiration Mining's initial attempt to treat this ore in a 50-ton per day concentrator during 1906 was a financial failure, this venture confirmed the presence of a large, low-grade, disseminated chalcocite resource at the site (Peterson, 1962).

Figure 70. Henry Krumb (1875-1958), mining consultant (photo from National Mining Hall of Fame and Museum)

By September 1908, the potential for finding a major copper resource at Inspiration Mining's property became known by the mining community. The United States Smelting and Refining Company, Miami Copper Company and Wernher, Beit & Company were keenly interested in acquiring an option on the property. However, each wanted easy terms, and to that end each belittled Inspiration's value during negotiations (Parsons, 1933).

Henry Krumb, a respected mining consultant, who had no authority to represent anyone, was also convinced of the property's potential (Figure 70). In making his proposal at a meeting of directors of the Inspiration Mining Company, he spoke about other porphyry copper projects. He discussed tonnages of ore developed, mining and processing methods, costs of production, profits expected to be made, and how mining companies were financed (Parsons, 1933).

He told the directors of Inspiration Mining their property had the potential to earn $100 million, but required an initial investment of $15 million to develop and place it in production. He advised them to option the property with experienced professionals, who could finance and manage the project, but urged them to retain a substantial interest in the property (Parsons, 1933).

Figure 71. William Boyce Thompson (1869-1930), prominent mining entrepreneur, who founded the Shannon Copper Company in 1899, Inspiration Copper Company in 1908, Magma Copper Company in 1910, and the Newmont Mining Corporation in 1916 (photo form Mining Foundation of the Southwest)

Impressed with the soundness of his advice and his experience with Utah Copper Company, Nevada Consolidated Copper Company and Ray Consolidated Copper Company, the directors of Inspiration Mining decided to give Krumb an opportunity see what he could do. After an initial attempt to interest Charles Hayden failed, Krumb succeeded in getting George E. Gunn and William Boyce Thompson (Figure 71) to back the project (Parsons, 1933).

4.15.1 Exploration and Development (1908-1915)

Inspiration Copper Company was incorporated under the laws of Maine in December 1908 with capitalization of $10 million at $10 per share (Stevens, 1911). Under the terms of this agreement, Inspiration Mining received $25,000 in cash to satisfy an outstanding debt and 270,000 shares of the new company (Parsons, 1933).

Inspiration Copper acquired the adjoining Taylor and Black Copper properties in February 1909 and July 1909, respectively (Sain, 1944). Henry Krumb was appointed consulting engineer for the project. He laid out a plan for a systematic churn drilling program, which began in May 1909. Drilling was performed on 200-foot centers, with in-fill drilling done in critical areas (Stevens, 1911).

A 50-ton per day test mill was erected near the Joe Bush shaft in November 1910 and operated until August 1911. By early 1911, this exploration effort had completed 27,500 feet of underground workings and 81 churn drill holes, delineating 21.2 million tons of ore, assaying 2% copper (Stevens, 1911).

By 1911, both the Live Oak Development Company and Inspiration Copper Company had developed substantial reserves at their respective properties and were planning how to proceed (Figure 49). It was obvious both projects would benefit through the erection of a single large concentrator to treat ores from both properties. After a series of negotiations, it was decided to proceed with the merger of the two companies (Parsons, 1933).

The Live Oak Development Company and Inspiration Copper Company were merged in December 1911 to form the Inspiration Consolidated Copper Company. Inspiration Consolidated Copper had a total capitalization of $30 million at $20 per share (Weed, 1916). By virtue of its underlying interest in the Live Oak Development Company, Anaconda Copper controlled one-third of the outstanding shares of the Inspiration Consolidated Copper Company, giving it effective control of the newly formed company (Parsons, 1957).

As of December 31, 1911, its reserves totaled 45.3 million tons, averaging 2.00% copper; consisting of 30.3 million tons, assaying 1.95% copper on the Inspiration property and 15 million tons, averaging 2.11% copper on the Live Oak holdings (Peterson, 1962). Plans to develop Inspiration Consolidated Copper's property began to take shape during the spring of 1912. A contract was signed with the Salt River Valley Water Users Association for electrical power from newly completed Roosevelt Dam and construction of an electrical transmission line was completed to the mine site in 1914 (Tenney, 1927-1929).

To ensure a sufficient water supply, water rights were initially purchased at Wheatfields (Figure 24), located approximately 12 miles north of the mill site along Pinal Creek and 1,000 feet lower in elevation. However, before developing this supply, it was decided to examine an area near the confluence of Bloody Tanks Wash and Russell Gulch, where six water wells were drilled (Burch, 1917).

After considering potential sites for its planned concentrator, Inspiration Consolidated Copper purchased the Black Warrior town site for $175,000 in May 1912 (Weed, 1922). Twin main hoisting shafts (Figure 72) were collared in along the northern bank of Webster Gulch in June 1912 and sunk to a depth of 585 feet (Ransome, 1919).

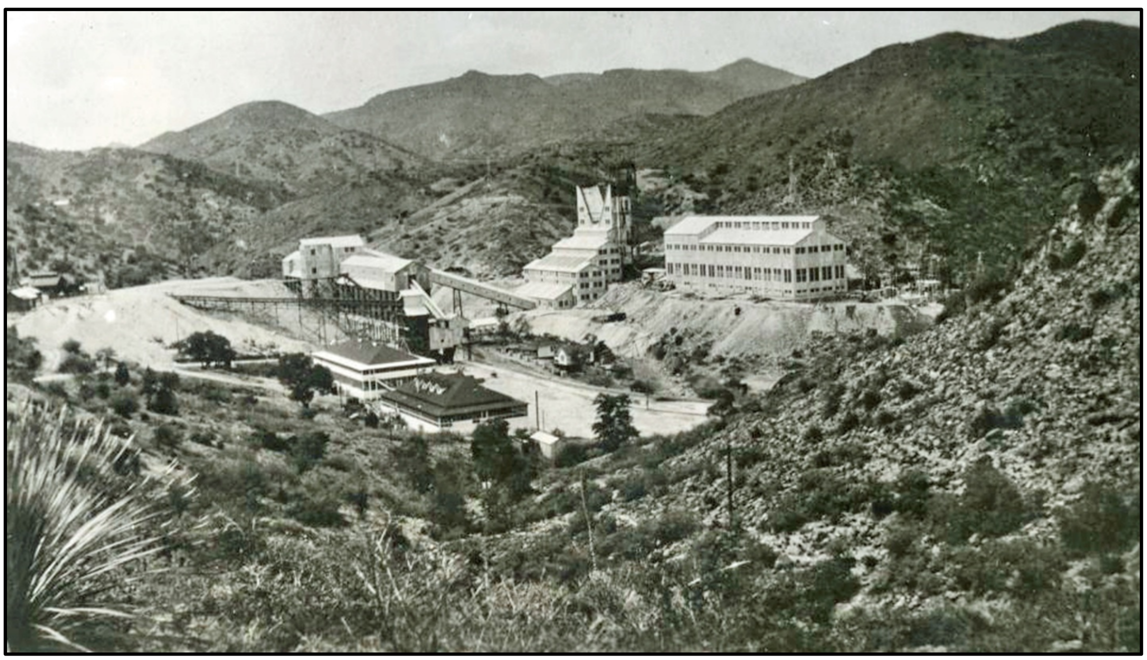


Figure 72. Inspiration Consolidated Copper's twin 585-foot main production shafts and crushing facility along Webster Gulch, circa 1916 (photo from University of Arizona Library Special Collections)

Original plans to employ a 7,500-ton per day gravity concentrator were reconsidered in early 1912, when management learned of remarkable advances in concentration being obtained from flotation methods by Minerals Separation Ltd. (Burch, 1917). Large metallurgical samples of ore were shipped to London, England for testing by Minerals

Separation Ltd. Results of these tests were received in November 1912. They showed much better results could be obtained using flotation than were expected from the existing gravity technology. A 600-ton experimental flotation concentrator was erected at the site in January 1913 to work out the details of incorporating it into the larger commercial facility (Parsons, 1933).

During 1914, a 4.5-mile standard gauge railroad was completed, connecting the mine and concentrator site with the Arizona Eastern Railroad. On the south side of Inspiration Ridge, a spur connecting the Inspiration adit in Live Oak Gulch with the main rail line in Miami was also completed (Ransome, 1919).

One major obstacle that needed to be overcome in developing Inspiration Consolidated Copper's holdings was the New Keystone property, which separated Inspiration from Live Oak (Figure 49). In an effort to consolidate its holdings in the district, Inspiration Consolidated Copper Company entered negotiations to purchase the New Keystone property in May 1912. Unable to reach an agreement, Inspiration started to drive an underground drift to connect its Inspiration and Live Oak holdings through the intervening New Keystone ground. This action forced the New Keystone Copper Company to file a lawsuit to halt this development. This lawsuit was settled in December 1914, in favor of the New Keystone Copper Company (Tenney, 1927-1929).

In January 1915, the assets of the New Keystone Copper Company were purchased by the Inspiration Consolidated Copper Company for $795,940, payable in 39,797 shares of stock at $20 per share (9 shares of New Keystone for 1 share of Inspiration) (Weed, 1916).

After several years of exploration and development, the first section of a 14,400-ton per day flotation concentrator was commissioned in June 1915. The final section of the concentrator became operational in February 1916 (Weed, 1916). The total capital investment in developing the mine and metallurgical plant was $20.5 million (Wisner, 1974). In response to the wartime demand for copper, two additional sections were commissioned at the concentrator during 1917, increasing its capacity to 18,000-tons per day (Weed, 1918).

4.15.2 Mining and Processing

Inspiration's treatment plant was the first large-scale concentrator in the United States to employ flotation as the primary method to process copper ores (Parsons, 1933). Using the most advanced techniques for concentrating copper ores at the time, it employed a single-stage grinding circuit of Marcy ball mills (Figure 73) to reduce the crushed ore from 2-inches to 48-mesh and flotation as the primary method of concentration. Tables were employed to recovery coarse particles of oxide copper minerals remaining in the pulp that had passed through the flotation circuit (Parsons, 1933). Flotation methods enabled copper operations to recover at least 80% of the copper contained in the ore compared to 65 to 70% with gravity methods that were in the use at the time (Parsons, 1957).

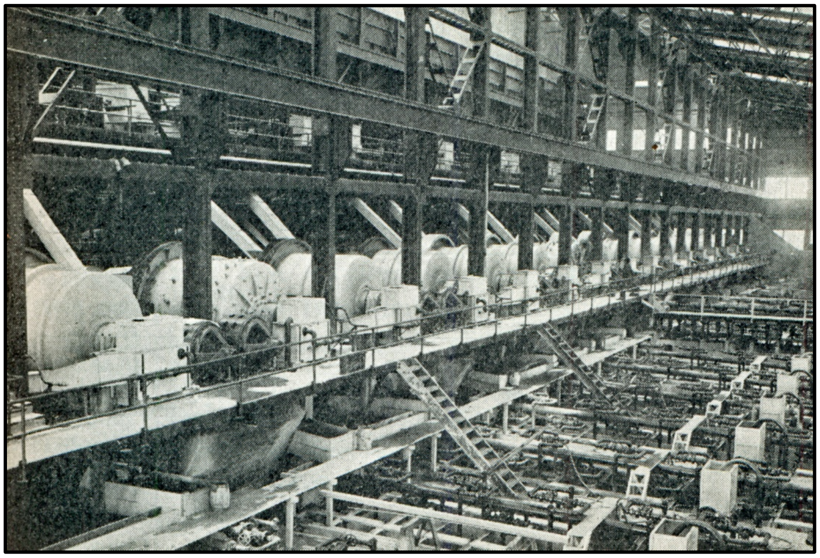


Figure 73. Ball mills and flotation machines at Inspiration concentrator (photo from Burch, 1917)

Figure 74. Subsidence above the Joe Bush ore zone, circa 1919 (photo from U. S. Geological Survey)

The ores at Inspiration were extracted by a block-caving method that was similar to one used at the Ohio Copper mine at Bingham Canyon, Utah (Parsons, 1933). Like Miami, this resulted in subsidence at the surface as the ores were mined (Figure 74). During the early days, Inspiration Consolidated Copper was severely criticized by many mining professionals who toured the operation due to the great amount of dilution of the ore as mined and the loss of ore during the mining process. However, extraction of ores by block-caving has stood the test of time because it was more profitable than more labor-intensive mining methods that curtail output in terms of both tons of ore and pounds of copper (Parsons, 1933).

4.15.3 Company Town

The original mining camp of Inspiration sprang up in the vicinity of the Woodson and Mercer adits along Webster Gulch around 1905. Most of these structures consisted of tent houses or primitive shacks. Soon after the start-up of operations in 1915, Inspiration Consolidated Copper Company established a planned community (Figure 75) for its workers along a ridge line east of the main production shafts and on Moonshine Hill (Figure 47).

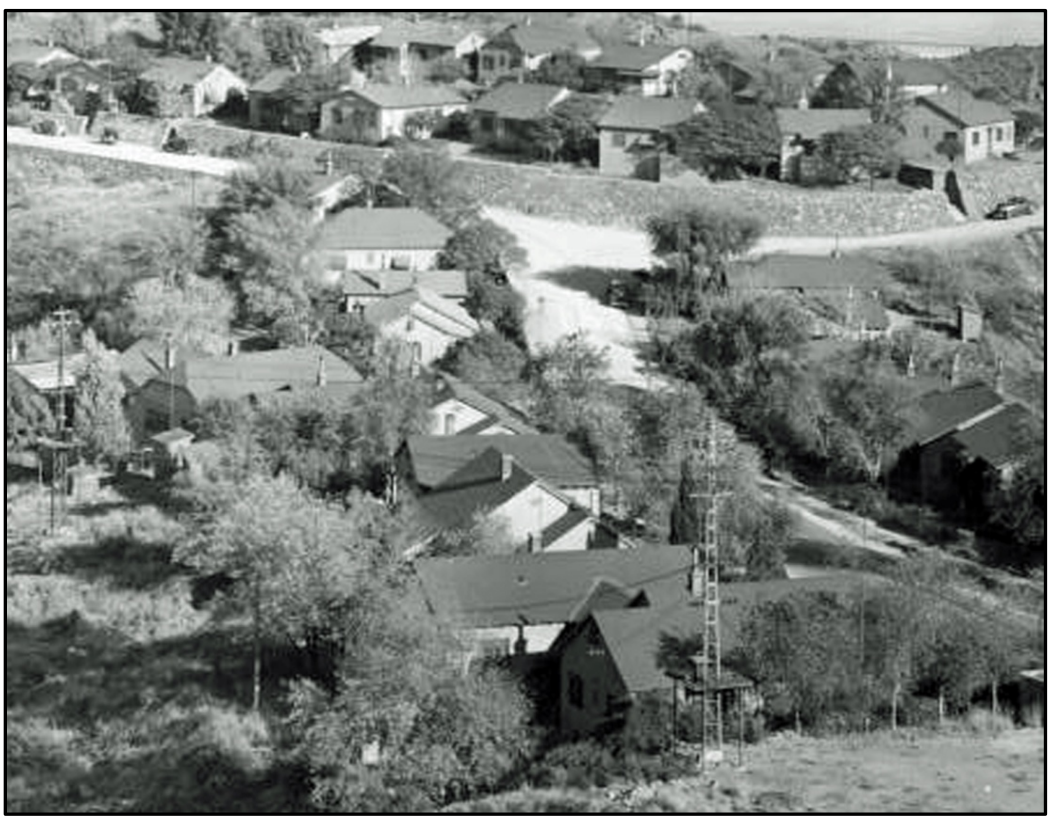


Figure 75. Inspiration company town (1916-1984), circa 1920s (photo from Arizona Geological Survey)

A company town in the truest sense, Inspiration was located on property entirely owned by the Inspiration Consolidated Copper Company. Every lot, residence, structure, street, and utilities were owned by the company. This community was characterized by well landscaped lots and tree lined streets. The buildings were of wood frame stucco construction in the Southwestern style. Mine workers paid reasonable rents and utility rates. At its peak, between 350 and 400 people resided in this community, which had 89 houses, three duplex apartments, Benjamin Franklin elementary school, the Warrior company store/service station, and a telephone office. Day to day security, maintenance, utilities, sewer, and garbage collection were all provided by the company. The Gila County Sheriff's office provided law enforcement. Established in 1917, the Inspiration post office operated continuously until its closure in 1983.

4.15.4 Labor Unrest and Post-War Decline

Like the Globe area, mining operations at Miami also experienced labor difficulties during World War I (July 1914 to November 1918). In December 1916, unions representing the miners in the Miami area (Industrial Workers of the World (IWW) and Western Federation of Miners (WFM)) requested a meeting with the managers of the mines. The mine operators refused to deal directly with the unions and directed their views to their employees. The unions did not press their demands at that time (Sain, 1944).

On June 28, 1917, the Western Federation of Miner's Union issued the following demands (Sain, 1944):

1. Recognition of Union Grievance Committee.
2. Representatives of the unions to be allowed on company property at any time for the purpose of organization.
3. Reinstatement of workers discharged for cause other than incompetence.
4. Equal representation on the Board of Control of the Hospital.

On June 30, 1917, the Industrial Workers of the World issued the following demands (Sain, 1944):

1. Two workers to operate all piston and Leyner drills.
2. Two workers to work together in all raises.
3. No blasting in stopes, drifts or raises during shift.
4. Abolition of rustling card system (i.e., a system requiring a company-issued card before a miner could get work).

5. Abolition of contract bonus system.
6. Abolition of the sliding wage scale.
7. Water sprays to be used on all machines.
8. No discrimination against any union members.
9. Representatives in the control of the hospital.
10. Minimum daily wage of $6.00 for all underground workers and $5.50 for surface workers.

When the mining companies made no reply to the unions' demands, except directly to their employees, the IWW called its members out on strike at 3:00 PM on July 1, 1917, and members of the Western Federation of Miners went on strike at 7 AM on the following morning (Sain, 1944).

On the first day of the strike, two hundred IWW members blocked the regular passenger train from entering Miami to search for strike breakers. Three hundred others prevented strike breakers from getting off the train, when it arrived in Miami. On the same day, a large mob attacked a non-striking mechanic coming off shift. In response to the violence, all of the mining companies suspended operations and U. S. troops were dispatched to Miami to restore order (Sain, 1944).

A short time later, Federal mediators began discussions with the mine operators and strike leaders. On August 11, the representatives of the mining companies agreed not to discriminate against members of the Western Federation of Miners if the strike was called off, but refused to take back the IWW members. Although Miami Copper and Inspiration Consolidated Copper resumed operations on August 22 and August 23, respectively, the unions were still on strike as late as September 26, 1917. Over the next month, workers gradually returned to work (Sain, 1944).

The 1917 strike's most notable impact was on the ethnic diversity of the workforce. Prior to the strike, the workforce was characterized by mixture of many nationalities. After the strike, the majority of workers were of Mexican ethnicity (Sain, 1944).

Depressed copper prices resulted in the temporary suspension of all mining and milling operations at Inspiration from the end of March 1921 until mid-February 1922 (Peterson, 1962).

Inspiration Consolidated Copper Company acquired the Montgomery claim group of the Black Warrior property and the Porphyry Consolidated Copper property in January 1920 and 1921, respectively (Weed, 1922). Southwestern Miami Development Company's holdings, located immediately southwest of the Live Oak property, were acquired by the Inspiration Consolidated Copper Company in May 1929 (Peterson, 1962).

4.15.5 Metallurgical Advances at Inspiration (1916-1932)

From the beginning, the ores at Inspiration were known to contain significant amounts of oxide copper minerals that could not be recovered by conventional flotation methods. Experimental work designed to find the best way to treat the mixed oxide-sulfide ores began in 1916. One plan developed during 1919 proposed to 1) crush the ore to 3-mesh, 2) leach the oxide copper with sulfuric acid and precipitate it onto scrap iron as cement copper, 3) wash the leach residue and neutralize it with lime, and 4) grind the leach residue to 48-mesh and recover the sulfide copper using conventional flotation technology. A 35-ton pilot plant confirmed the technical soundness of this process, but it was not profitable at the prevailing copper price of less than 15 cents per pound (Parsons, 1933).

During the early 1920s, metallurgical research under the direction of Louis D. Ricketts demonstrated that 85% of the copper contained within Inspiration's mixed oxide-sulfide (chalcocite, chrysocolla, malachite and azurite) ores could be recovered by a single leach solution, containing sulfuric acid and ferric sulphate (Parsons, 1957).

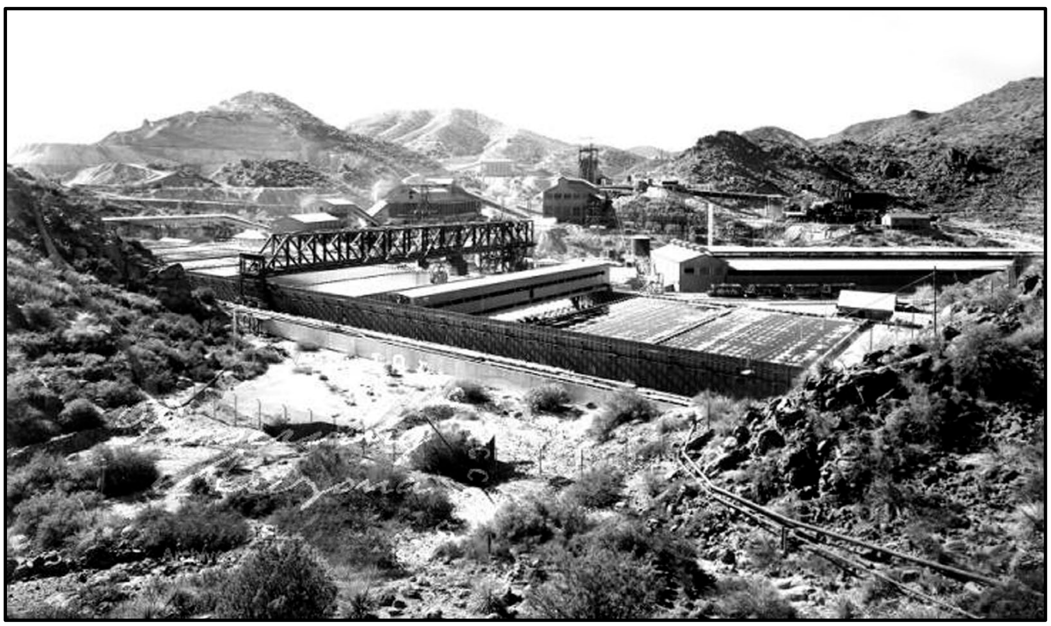


Figure 76. Vat leach plant and tank house (in foreground) with main production shafts (center background) and Thornton pit (left background) at Inspiration Mine along Webster Gulch, circa 1950, (photo from Arizona State University Library)

Construction of a 9,000-ton per day vat leach plant (Figure 76) began in September 1924 and was placed into operation in November 1926 at a cost of $6 million (Peterson, 1962). Leaching of the soluble copper minerals worked so well, the sulfide concentrator was permanently closed in June 1930, after which all of the ore was processed by the vat leach facility (Parsons, 1933).

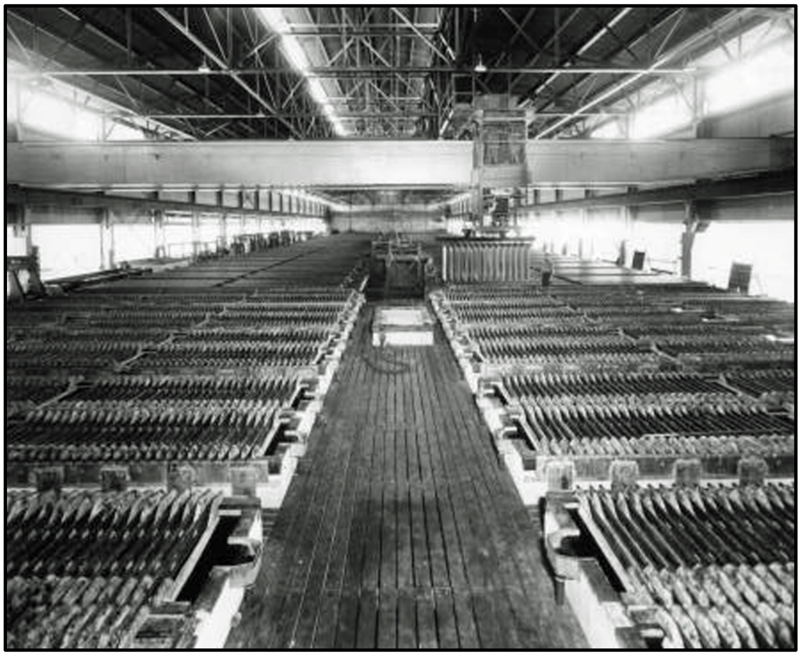


Figure 77. Inspiration Consolidated Copper's electrolytic tank house, circa 1960s (photo from the Arizona Geological Survey)

This facility recovered the dissolved copper from the pregnant leach solution at a tank house (Figure 77), where the copper was electrolytically plated onto cathodes, producing a marketable refined copper product. Early results from this facility showed the percentage extraction in successive leaching cycles was erratic. This issue was resolved in May 1930, when approximately 8% of the finest material was treated separately in a slimes circuit (one section of the concentrator), where flotation was used to recover the sulfide copper. This step was followed by agitated leaching with sulfuric acid to dissolve the oxide copper. This pregnant leach solution was passed through launders, where the copper was precipitated onto scrap iron. Concentrates from the flotation circuit and the copper precipitates were sent to the smelter (Parsons, 1957).

4.15.6 Coping with the Great Depression (1932-1941)

When copper prices fell to 5.5 cents per pound at the height of the Great Depression, Inspiration Consolidated Copper temporarily suspended all mining and leaching operations in May 1932. Since start-up in 1915, the Inspiration operation produced 1.3 billion pounds of copper at an average cost of 10.5 cents per pound. While Inspiration Consolidated Copper operation had never been one of the low-cost copper producers among the world's largest copper operations, its shareholders received $54 million in dividends in seventeen years on an original investment of approximately $16 million. As of December 31, 1932, Inspiration Consolidated Copper had ore reserves of 69 million tons, averaging 1.37% copper (Parsons, 1957).

By September 1935, the price of copper rose to 8.5 cents per pound, allowing limited operations to resume at Inspiration (Gerry and Luff, 1938). The copper price rose to 15.8 cents per pound in February 1937, allowing Inspiration Consolidated Copper to expand production, employing the "Dual Process" (Parsons, 1957).

The mixed oxide-sulfide ores were initially treated in the main leach plant only using a dilute sulfuric acid without ferric sulfate. Copper from the oxide minerals was selectively dissolved and recovered as a refined cathode product in the tank house. The sulfide copper minerals in the residues from the vat leaching circuit reported to the "old" flotation concentrator, which recovered a copper concentrate product that was shipped to smelter. The "Dual Process" enabled larger tonnages to be processed because of the shorter leach cycles of the acid-soluble oxide minerals. By December 1937, the price of copper declined to 10 cents per pound, making this procedure uneconomic, compelling Inspiration Consolidated Copper to revert to ferric sulfate leaching (Parsons, 1957).

4.15.7 Efforts to Meet the Wartime Demand for Copper

As explained earlier (4.14.5), the U. S. Government instituted a premium price program designed to stimulate domestic production of critical minerals at the outset of World War II, which was designed to avoid the high prices experienced during World War I. During this period (1942-1946), Inspiration Consolidated Copper received approximately $7.5 million in payments under this government run program. These subsidies nearly equaled its reported operating profit for this period (Parsons, 1957).

In July 1942, Inspiration Consolidated Copper resumed operations at the old concentrator to meet wartime demands for the red metal. During this period, substantial tonnages of mixed oxide-sulfide ores were treated by a "leach-float" process. The ground ore reported to an agitation leach circuit, where the oxide copper minerals were dissolved with sulfuric acid. The dissolved copper was precipitated in the pulp as cement copper, which was recovered with the sulfide copper minerals as a flotation concentrate and shipped to International Smelting and Refining Company's Miami smelter. Discontinued in August 1944, this process recovered approximately 80 million pounds of copper (Parsons, 1957).

Like many copper domestic copper operations during World War II, severe shortages of experienced underground personnel limited ore production at Inspiration. However, Inspiration Consolidated Copper's leach facility was able to process all of the ore that was mined (Parsons, 1957).

On October 1, 1944, Inspiration Consolidated Copper's electrolytic tank house was destroyed by a fire. However, the old concentrator that had been mothballed in 1930 was once again pressed into service, employing the “Dual Process”, which enabled production to continue with few disruptions or restrictions. During this emergency, copper was precipitated onto scrap iron (Parsons, 1957). A new electrolytic tank house was commissioned in late May 1945 (Needham and Luff, 1947).

4.15.8 Transition to Open Pit Mining

Prior to the World War II, the costs of mining by block-caving methods at Inspiration were comparable to or less than the costs for some open pit mining operations (e.g., Ajo, Bingham Canyon, Chino, Robinson). However, by the end of the war, conditions had completely changed. The costs of underground mining had significantly increased for both labor and supplies. Furthermore, the difficulty of finding competent underground miners severely impacted development schedules (Weed, 1950).

Operating costs at Inspiration were also negatively impacted by declining ore grades (1.37% copper in 1935 compared with 1.17% copper in 1945) and deteriorating ground conditions in the 35 year old mine. Over time the increasing sulfide to oxide ratios of the copper-bearing minerals within the mined ores further reduced the efficiency of the leaching operations (Parsons, 1957).

An end of Inspiration’s underground mining operation was in sight unless viable solutions could be found to resolve these challenges. After examining the considerable progress that had been made developing and manufacturing efficient electric shovels, large diesel-powered haul trucks, bulldozers, and other equipment, Inspiration’s engineering staff decided the time had come to transition the old block caving operation into an open pit mine. Advantages of open pit mining methods over underground operations included; 1) economy of skilled and semi-skilled labor and professional supervision; 2) less hazardous working conditions; and 3) dilution minimized by a high degree of selective mining (Parsons, 1957).

Inspiration’s first open pit mining project was located in the Live Oak area, where a relatively minor amount of pre-production stripping was required to expose approximately 20 million tons of good oxide ore. This oxide ore was blended with high sulfide ore from the underground operations, maintaining an acceptable oxide-sulfide ratio for the leaching operations (Parsons, 1957).

Preparations to convert the underground operation to an open pit operation began in March 1947. This included the construction of a $2 million primary crushing plant adjacent to the open pit. Stripping operations with electric shovels and haul trucks began in January 1948. Shipments of ore from the Live Oak pit to the leach plant began in April 1948, with the ore being trucked to the primary crusher. The coarsely crushed oxide ore was hauled by standard railroad cars to the secondary crushing plant located near the main production shafts, where it was blended with the underground sulfide ore before reporting to the leach plant (Parsons, 1957).

In deciding how to proceed with developing the Thornton pit above the underground workings of the Inspiration Division during the early 1950s, management of Inspiration Consolidated Copper faced two challenges. Approximately 60 million tons of overburden needed to be removed to access the ore zone. Furthermore, the Thornton ore body was situated on the south side of Inspiration Ridge, while the processing facility was located on the north side of the ridgeline. The cost of transporting the ore by truck over or around the Inspiration Ridge was high and would progressively increase as the Thornton pit became deeper (Parsons, 1957).

This problem was resolved by developing a “glory-hole caved block transfer system” on the 3,650-foot bench of the Thornton open pit (Figure 78), through which ore from the open pit was transferred to the main haulage way on the 600-foot level (3,350-foot elevation) of the underground mine. At that point, the ore was trammed to the two main production shafts and hoisted to the surface (Figure 79) (Parsons, 1957).

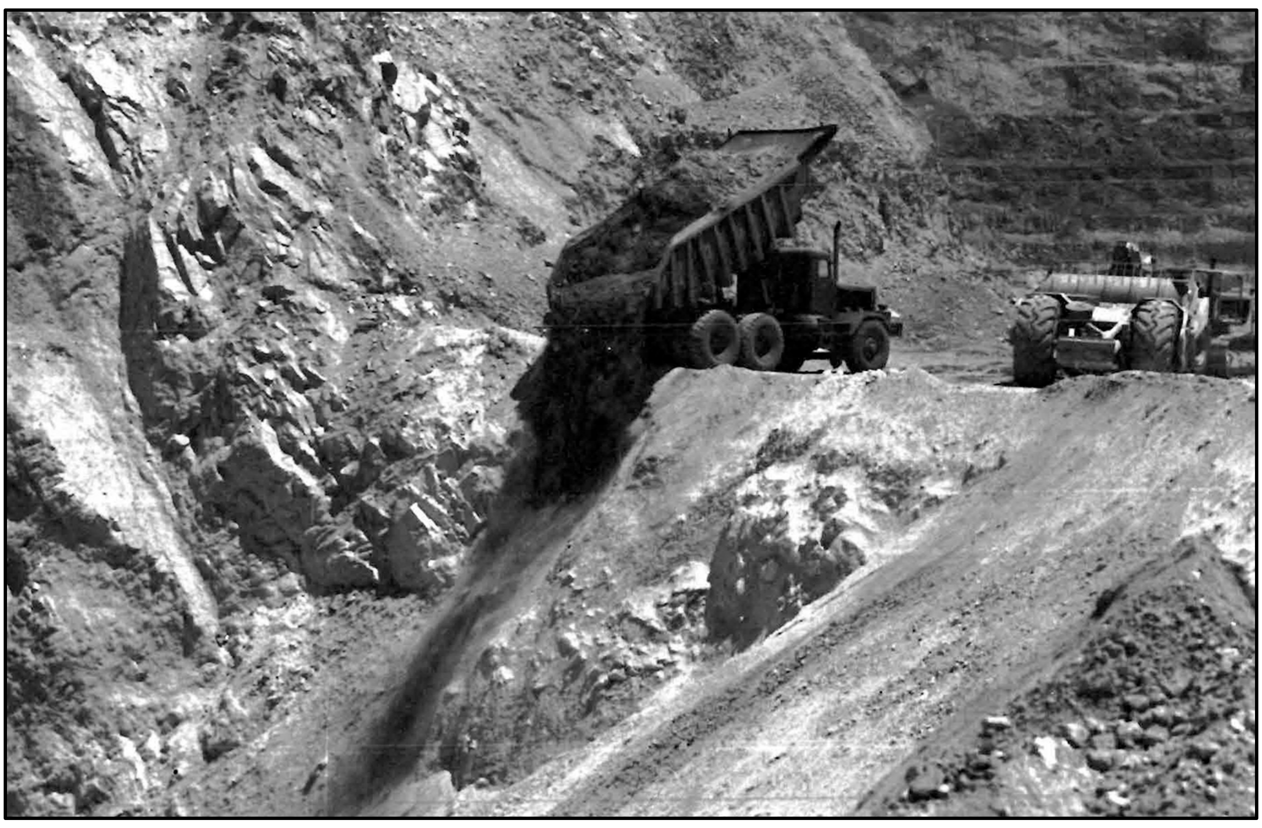


Figure 78. Haul truck dumping ore in a 65-foot by 100-foot glory hole caved block transfer in Thornton pit, circa 1950s (photo from Hardwick, 1963)

In August 1954, the underground block-caving operation was prematurely halted eighteen months earlier than scheduled due to flooding from a heavy rainstorm during the 1953 monsoon season. This event resulted in considerable damage in the lower levels of the mine making it impossible to profitably recover the remaining reserves by underground mining methods (Parsons, 1957).

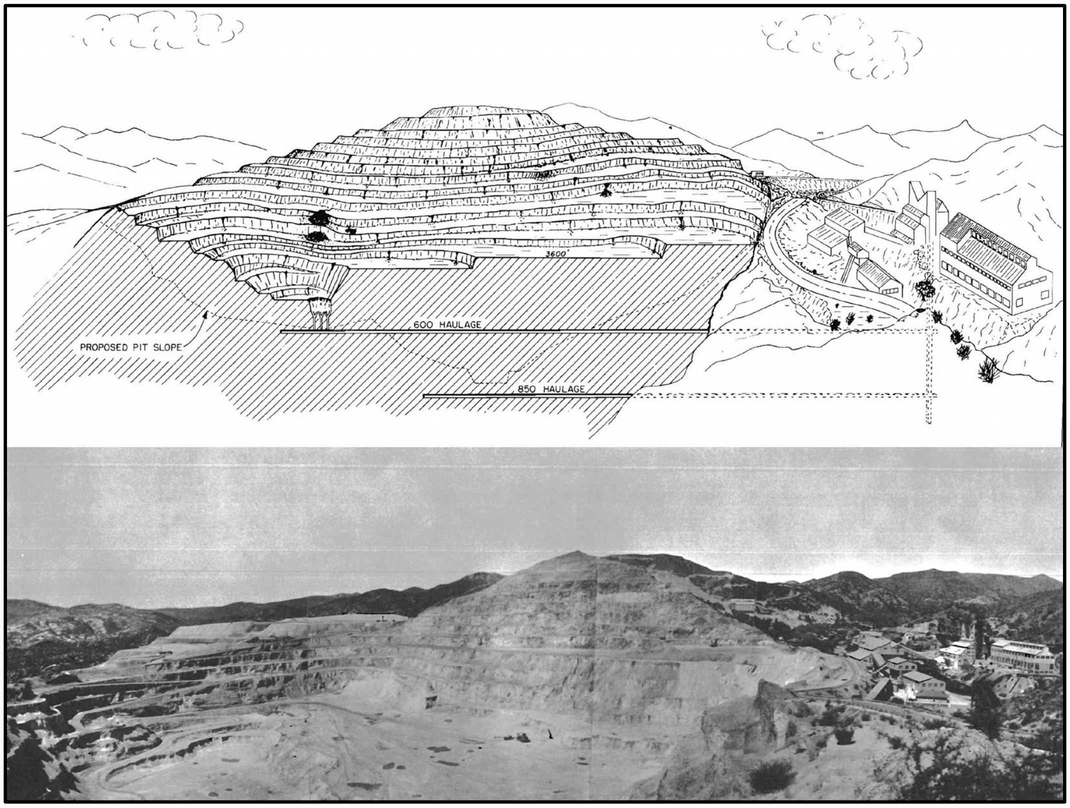


Figure 79. Schematic cross-section and actual view of the Thornton pit, showing glory-hole caved block transfer system, looking west, circa 1950s (cross-section and photo from Hardwick, 1963)

After approximately 14 million tons of ore was mined from the Thornton pit and deeper levels of the Live Oak pit between 1951 and 1961, all underground haulage was abandoned in favor of the more economical and flexible surface haulage systems (Anderson, 1963).

4.15.9 In-place Solution Mining and Dump Leaching Operations

Evidence of natural leaching in Inspiration's underground mine was initially recognized in 1939. This natural leaching was accelerated by unusually heavy precipitation during the winter of 1940-41. Launders filled with scrap iron were employed in an effort to combat the corrosive action mine waters had on underground equipment. By 1944, more than 200,000 lbs. of copper from these underground launders had been shipped to the smelter. Results of in-place leach testing over a 17-month period led to the development of plans to employ in-place solution mining operations in inactive portions of the underground mine (Rice, 1974).

Between 1950 and 1974, Inspiration Consolidated Copper conducted commercial in-place solution mining operations in selected areas above its underground mine that were not economic to mine by conventional open pit methods. One of these areas was the eastern portion of the Joe Bush pit, which due to its proximity to the Miami property boundary could not be mined by conventional open pit methods. Inspiration Consolidated Copper employed in-place solution mining methods to extract copper from this area from 1967 until 1974 (Ahlness and Pojar, 1983). In late 1974, Cities Service and Inspiration reached an agreement, which permitted Inspiration to mine and treat ore from the Miami Copper property on a royalty basis (Miller, 1976).

Leaching of waste dumps and low-grade stockpiles from open pit mining operations at Inspiration also began during 1950 (Ahlness and Pojar, 1983). The water supply for the leaching operations was derived from a process water pond (also known as Webster Lake) that formed behind the leach plant tailings impoundment in Lost Gulch. This water was acidic (pH - 2.5) and contained some ferric iron. It was pumped to a reservoir from which it flowed by gravity to the leach areas. Acid was added to solution raising its content to 4.5 grams per liter (Honeyman, 1954). Irrigation lines distributed dilute sulfuric acid solutions, which percolated downward through the broken rock into sumps located on the 850-foot level of the underground mining operation or to collection ponds located adjacent to the surface leach dumps. The resulting copper-bearing solutions were treated in launders, where the copper was precipitated onto scrap iron, while the spent solutions were returned to the process water pond. The copper precipitate was shipped to International Smelting and Refining Company's Miami smelter for further treatment (Hardwick, 1963).

4.15.10 Changing Metallurgy

By the early 1950s, open pit mining operations were encountering increasing amounts of chalcopyrite in the ores, which could not be recovered by the leach plant. In order to cope with this change in metallurgy, the old concentrator (Figure 80) was rehabilitated at a cost of $6 million and resumed production January 1957. This 17,500-ton per day facility employed the "Dual Process" where the ore was treated in two stages (Hardwick, 1963).

During the initial stage of treatment, the crushed ore was vat leached with sulfuric acid. The acid-soluble minerals were dissolved in the solution, which reported to an electrolytic tank house, where it was recovered as a refined cathode product. The leached residue was transported via rail to the concentrator, where the sulfide minerals were recovered by flotation. The final copper concentrate product was shipped to International Smelting and Refining Company's Miami smelter (Hardwick, 1963).

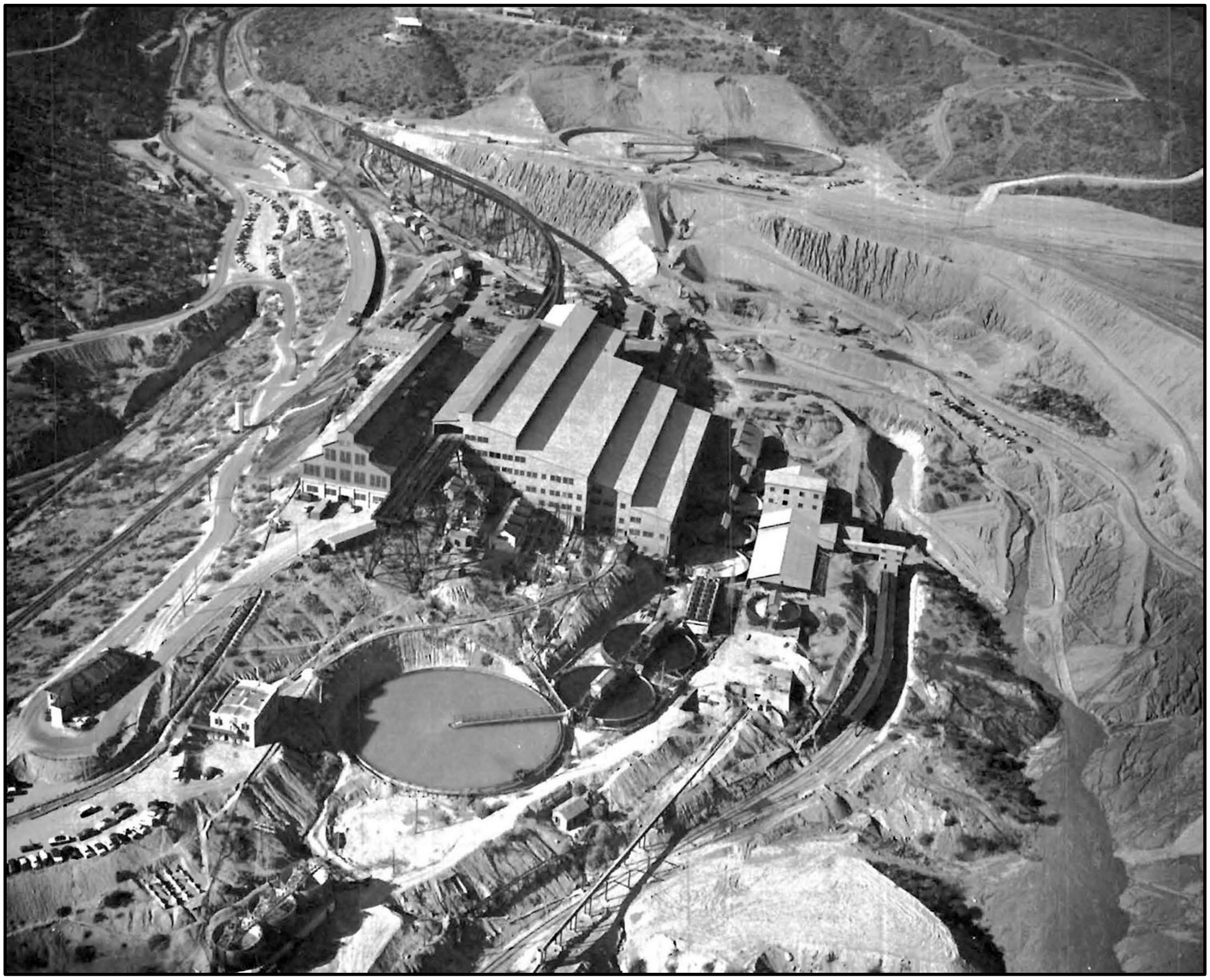


Figure 80. Inspiration concentrator, circa 1950s (photo from Hardwick, 1963)

As a result of a change in the process, excess capacity was present in the electrolytic tank house, allowing approximately 50% of the tank house to be converted into a refinery, where copper anodes from the smelter were refined to produce a marketable cathode product. A molybdenum recovery circuit was added to the concentrator in 1958 (Hardwick, 1963).

4.15.11 Upper and Lower Ox Hide

Initially staked in 1894, the Schulze copper property was intermittently explored by several mining firms between 1923 and 1962. During this period, 58 exploration drill holes were completed, revealing the presence of two deposits, known as Upper Ox Hide and Lower Ox Hide (Figure 6). Inspiration Consolidated Copper acquired a lease with an option to purchase the property from the Schulze family in 1964. After completing 21 diamond drill holes and 55 churn drill holes, Inspiration Consolidated Copper proceeded with the development of the property in early 1968 (Sorsen, 1974).

Table 13. Historic production from the Ox Hide property (Source: modified from U. S. Bureau of Mines data)

Mine	Period	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
Lower Ox Hide	1967-1982	13,426,493	39,010,202	0	0	0	0
Upper Ox Hide	1968-1974	14,077,250	50,894,729	0	0	0	0
Total	1967-1982	27,503,743	89,904,931	0	0	0	0

Mining operations began at the Upper Ox Hide deposit in July 1968 and produced its first copper in September 1968. These ores were dump leached with the copper recovered by precipitation methods. Mining operations were temporarily halted at Upper Ox Hide in late 1972 when excessive rainfall flooded the pit. Mining of the Lower Ox Hide pit began in January 1973 and continued until 1977. Residual copper recovery from the existing leach pads continued until 1982 (Table 13).

4.15.12 Ferric Cure Leaching Process

In an effort to improve copper recoveries (i.e., ~50%) from the Lower Ox Hide deposit in 1973, metallurgists at Inspiration developed the “Acid Cure” concept. Containing significant amounts of copper-bearing clays and manganese oxides, only 40 to 50% of the contained copper within these oxide ores was acid soluble. Laboratory tests showed that leaching with a concentrated acid solution followed by a cure or rest period followed by rinse within a weak acid solution significantly improved the recovery of the non-acid soluble copper in the ore (Fountain et al., 1983).

Inspiration initiated a two-year pilot test program to evaluate the “Acid Cure” on mixed oxide-chalcocite ores in 1976. Their prior experience with ferric sulfate vat leaching of these ores resulted in a decision to combine the “acid cure” and ferric sulfate leaching technology. The resulting procedure became known as the “Ferric Cure” process (Fountain et al., 1983).

Copper precipitate production from the dump leach operations was largely eliminated in October 1979 with the commissioning of a new $14 million solvent extraction-electrowinning facility that was capable of producing 100,000 lbs. of cathode copper per day (Niemuth, 1981).

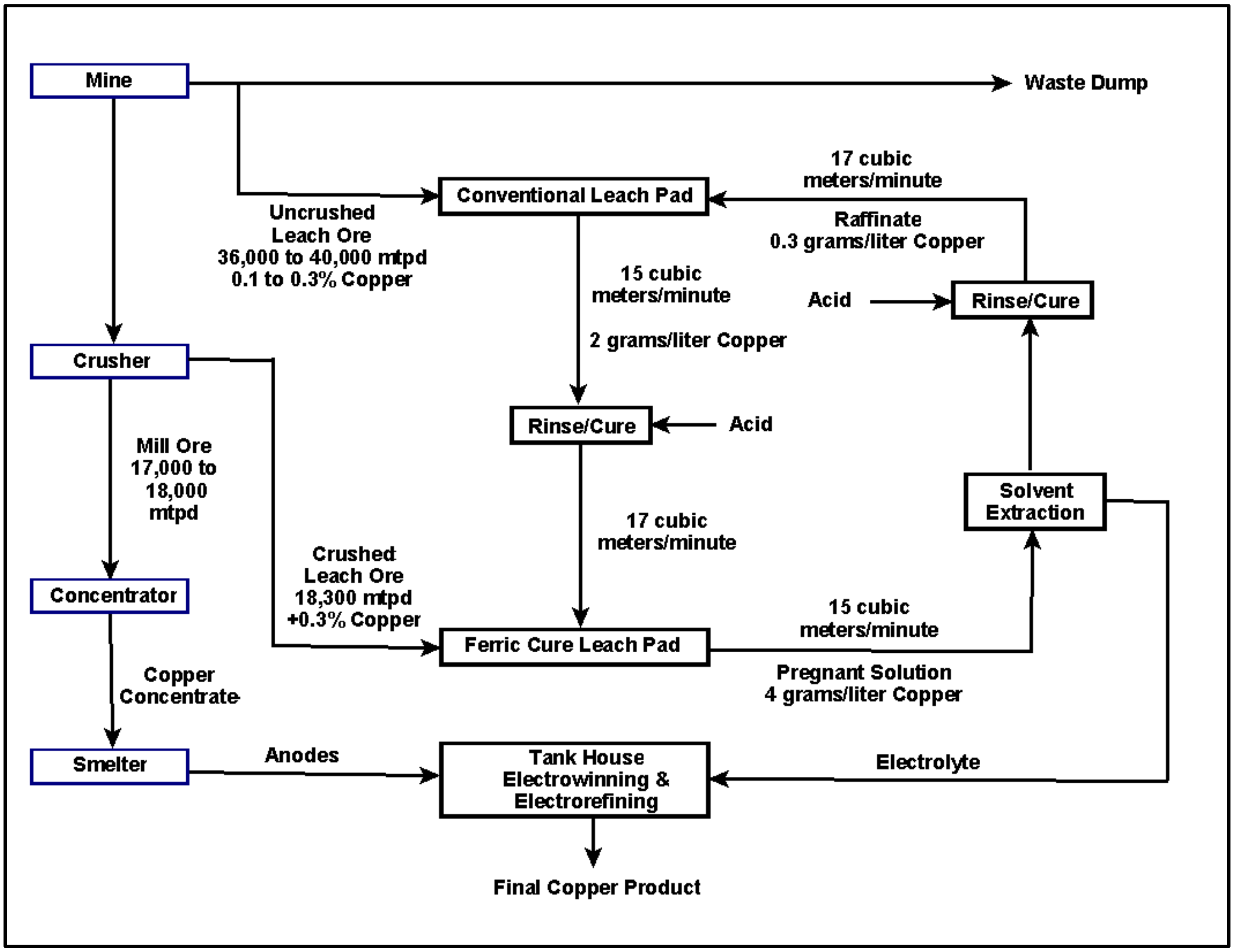


Figure 81. Process flow sheet for the Inspiration Consolidated Copper operation (modified from Fountain et al., 1983)

After several years of testing, Inspiration Consolidated Copper introduced its patented "Ferric Cure" leaching process in June 1980. Requiring an investment of $13.7 million, the new facilities included a new off solution collection reservoir, a new pump station to deliver solution to the solvent extraction plant, a rinse/cure station, and several miles of pipeline for solution distribution (Fountain et al., 1983).

During the early 1980s, the Inspiration mining operation treated mill (sulfide) ores at the concentrator and leach ores at its dump leach facility (Figure 81). The dump leach facility treated the high-grade (greater than 0.3% copper) crushed ores on ferric cure leach pads and its run-of-mine (i.e., uncrushed - 0.1 to 0.3% copper) ores on conventional leach pads (Fountain et al., 1983).

Higher grade leach ores (greater than 0.3% copper) were crushed to minus 4 inches and stacked in lifts of 30 feet on the ferric cure leach pads. Its surface was ripped prior to leaching to assure good percolation. The leach sequence began with the application of a strong sulfuric acid solution (200 grams per liter) for four days followed by a five day cure (i.e., rest) period, when no solutions were applied. This was followed by the second application of a strong sulfuric acid solution for three days followed by a ten day cure period. At that time, the ferric cure leach pad was rinsed for up to 120 days with the pregnant solutions from the conventional leach pads (i.e., uncrushed ores). The pregnant solutions from the ferric cure leach pad were treated at the solvent extraction plant, which produced a copper-bearing electrolyte that reported the tank house for electrowinning (Fountain et al., 1983).

As a result of the successful application of the “Ferric Cure” process, it was soon modified to treat the conventional leach pads. The “Low Grade Cure” consisted of a two day application of a moderately strong sulfuric acid solution (100 grams per liter) followed by a five day rest period prior to rinsing the conventional pad with raffinate from the solvent extraction plant (Fountain et al., 1983).

As a result of reorganization, Inspiration Consolidated Copper became a unit of its parent holding company, Inspiration Resources Corporation in July 1983 (Hicks, 1985).

Inspiration purchased the Bluebird project (Figure 6) from the Hecla Mining Company in July 1984, allowing it to expand its mining operations onto the neighboring property (Burgin, 1986). Under the terms of this agreement, Hecla Mining received gradually increasing annual advance royalty payments, increasing from $100,000 on execution of the agreement to $225,000 in the fifth and each subsequent anniversary until 1999. All minimum royalty payments were credited against a production royalty of 1.5 cents per pound contained copper in ore, assaying 0.15% copper or greater. Hecla also received a payment of $600,000 for the residual copper contained within the existing heap leach pads at Bluebird as of July 1984 (Hecla Mining Company, 1984).

A prolonged period of depressed copper prices resulted in the suspension of all milling operations at Inspiration in January 1986. Conversion to an all leach operation was made possible by the recent acquisition of Bluebird, which provided a short-term supply of high-grade oxide ores, while stripping operations readied other sources of leach ore for production (LaChapelle and Dyas, 1993). As a result of the closure of its concentrator, 91% of the concentrates and precipitates treated at its smelter during 1986 were from tolled or purchased material (Burgin, 1988).

By the early 1990s copper recovery operations at Inspiration had been simplified to only leaching run-of-mine (ROM) stockpiles using the ferric cure process. This process involved stacking uncrushed ores from the mining operation in 15-foot lifts. An irrigation system was employed to apply dilute sulfuric acid solutions to the pad, which leached the soluble copper as it percolated downward through the pad. The pregnant solution was collected in a pond and pumped to a solvent extraction-electrowinning plant, where the copper recovered as a marketable cathode product (LaChapelle and Dyas, 1993).

4.15.13 Later Years (1988-Present)

The Cyprus Minerals Company acquired the Inspiration mining operation through its purchase of the assets of Inspiration Consolidated Copper Company from the Inspiration Resources Corporation in July 1988 (Beard, 1989b). The Inspiration and Christmas mining projects were acquired during this transaction for $122 million (Cyprus Minerals Company, 1990). This acquisition allowed Cyprus Minerals to smelt its own ores, eliminating its dependence on short-term smelting contracts. Furthermore, the high value copper wire produced at Inspiration's rod plant enabled Cyprus Minerals to broaden its customer base (Greeley and Kissinger, 1990).

After its acquisition of Inspiration in July 1988, Cyprus made changes in the management of labor, improving efficiency of the operation. These changes included decertification of the unions, which allowed rigid work rules to be replaced with cross-training that permitted more flexible utilization of their labor force. Employee input in management decisions was also encouraged in an effort to cut operating costs (Barton et al., 2007).

In November 1993, the Cyprus Minerals Company and AMAX, Inc. merged to form the Cyprus AMAX Minerals Company (Cyprus AMAX Minerals Company, 1995). Phelps Dodge Corporation subsequently acquired the Inspiration property through its merger with the Cyprus AMAX in October 1999 (Phelps Dodge Corporation, 2000).

In June 2000, Phelps Dodge decided to temporarily suspend stripping operations in the higher cost portions of the mine. All mining and refinery operations were temporarily halted on January 15, 2002, pending improvement of the price of copper. Due to reduced production at Bagdad and Sierrita combined with reduced tolled concentrates, the Miami smelter partially curtailed operations in January 2003. The Miami smelter resumed full production during the spring of 2004. Miami's refinery was permanently closed in June 2005 (Phelps Dodge Corporation, 2006).

Freeport McMoRan Copper and Gold, Inc. (renamed Freeport-McMoRan, Inc. in 2014 with wholly-owned subsidiary Freeport-McMoRan Miami, Inc.) acquired the Inspiration property through its merger with the Phelps Dodge Corporation in March 2007 (Freeport-McMoRan Copper and Gold, Inc., 2008a). Limited mining operations at Inspiration resumed in late 2010 and continued for several years. Although mining operations were halted after depleting its remaining reserves in September 2015, residual copper production is expected to continue from the existing leach stockpiles through 2025 (Freeport-McMoRan, Inc., 2021).

Table 14. Historic production from the Inspiration property (excludes Upper and Lower Ox Hide) (Source: modified from U. S. Bureau of Mines data)

Period	Mill & DSO Short Tons	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
1899-1914	102,048	0	5,742,481	0	0	0	461
1915-1986	332,723,764	0	4,947,769,003	813,025	5,741,631	17,319	2,614,013
1950-2020	0	566,081,754	3,282,734,288	0	0	0	0
1899-2020	332,825,812	566,081,754	8,236,245,772	813,025	5,741,631	17,319	2,614,474

The key to the Inspiration operation's success as the district's largest copper producer has been the adoption of mining and metallurgical practices to the changing nature of the ores encountered over the life of the project. Historic production from milling and dump leaching operations at Inspiration totaled more than 8.2 billion pounds of copper (Table 14).

4.16 Bluebird Mine (1961-1984)

In 1961, Al Stovall leased the Bluebird property from the original locators (initially staked in 1900) and formed Stovall Company, which delineated a small ore body. Over the next two years, approximately 250,000 tons of ore were mined from which approximately one million pounds of copper was recovered at a small precipitate plant (Miller, 1967).

Callahan Mining Corporation acquired an option to purchase the property in August 1963 and completed approximately 4,800 feet of diamond drilling at the site before allowing its option to lapse in November 1963. Ranchers Exploration and Development Corporation acquired a 90-day option on the Bluebird property in January 1964 (Miller, 1967).

After commencing a 6,000-foot drilling program, it soon became evident the entire deposit consisted of oxide ore. After studying the economics of vat and heap leaching, the costs of mining and metallurgical factors, Ranchers exercised its option, purchasing the property for $1 million in March 1964 (Miller, 1967).

Ranchers' open pit operation at Bluebird (Figure 6) achieved production in October 1964. Its ores were stacked in 20-foot lifts on dedicated heap leach pads, where a dilute sulfuric acid solution was applied by a drip irrigation system. The leach solution dissolved copper as it percolated down through the heaps and passed through a series of launders, where the copper was precipitated onto scrap iron before being recycled to the heap leach pads. The copper precipitates were shipped to a smelter for further treatment (Miller, 1967).

In early 1965, Ranchers management's attention was drawn to several new technologies that would result in a higher value product than precipitate copper. The most promising of these was the solvent extraction process, where weak, impure solutions are upgraded and purified, creating an ideal solution that could be passed through an electrowinning circuit to produce a marketable copper cathode product (Miller, 1967).

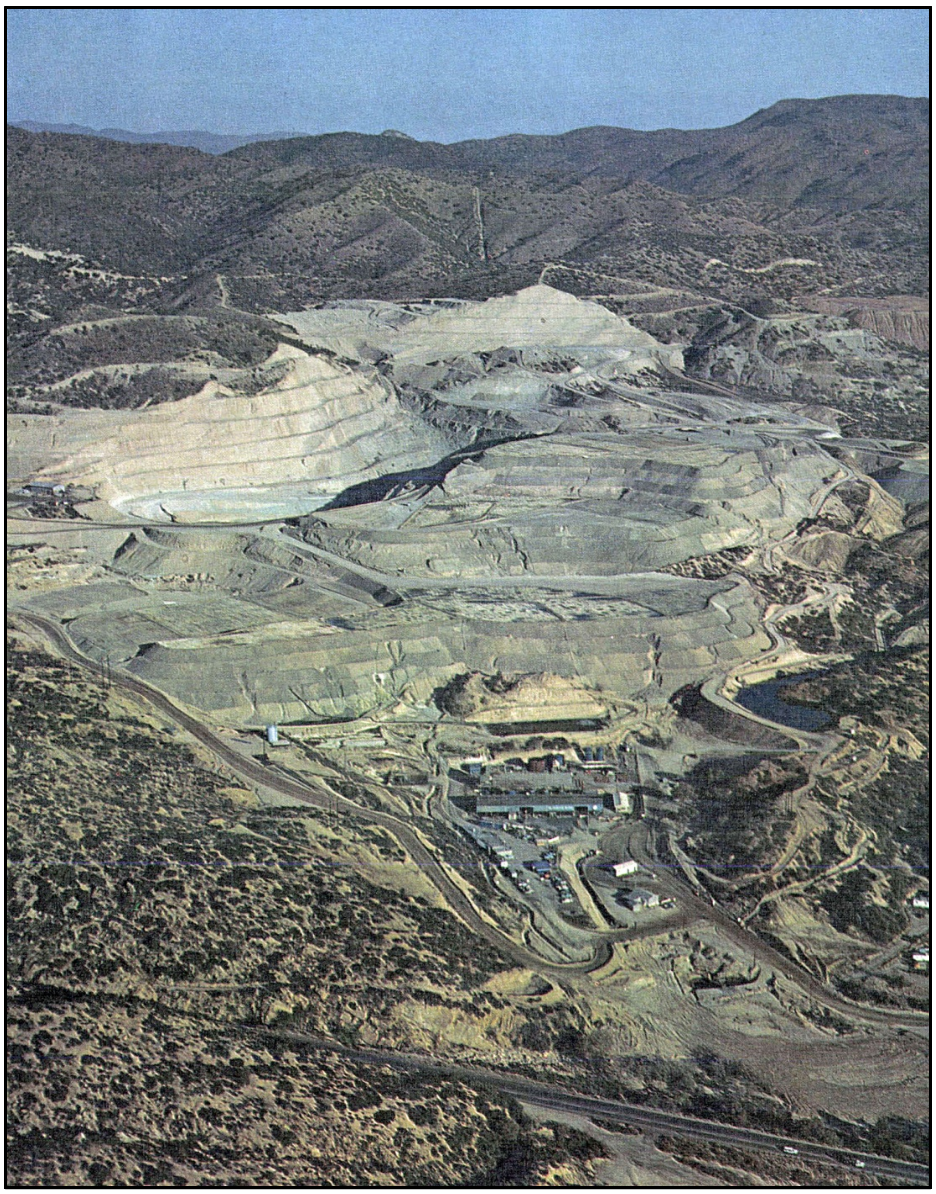


Figure 82. Bluebird mine with the solvent-extraction electrowinning plant in foreground, looking north, circa early 1970s (photo from Ranchers Exploration and Development Corporation, 1971)

Under the supervision of Hazen Research, a small solvent extraction-electrowinning pilot plant was operated at the Bluebird project from December 1965 until April 1966. A feasibility study conducted by A. H. Ross and Associates on data collected by this pilot plant showed a commercial scale facility was feasible (Miller, 1967). After carefully reviewing their options, the management of Ranchers Exploration and Development Corporation decided to proceed with the $2.7 million project. In March 1968, the Bluebird mine (Figure 82) became the first copper producer to commercially employ SX-EW technology to treat copper-bearing solutions from a heap leach operation (Cole 1969).

Although low copper prices forced Ranchers to temporarily suspend mining operations at Bluebird from October 1977 until February 1979, rinsing of the existing leach dumps continued to produce copper cathode during this period (Niemuth, 1981). Mining operations were again suspended from July 1981 until October 1982, when all production ceased (Hicks, 1984). Over the life of the Bluebird project (1962-1982), approximately 48.2 million tons of ore were mined, recovering 215 million pounds of copper (Table 15).

Table 15. Historic production from the Blue Bird property (Source: modified from U. S. Bureau of Mines data)

Period	Milled & DSO Short Tons	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1950-1954	72	0	3,745	0	0	0	0
1962-1982	0	48,215,493	215,062,700	0	0	0	0
1950-1982	72	48,215,493	215,066,445	0	0	0	0

The Hecla Mining Company subsequently acquired the Bluebird property through its merger with Ranchers Exploration and Development Corporation in March 1984 and sold the property to Inspiration Consolidated Copper Company in July 1984 (Burgin, 1986).

4.17 Miami Smelter, Refinery and Rod Plant (1915-Present)

By early 1913, significant production at Miami Copper combined with anticipated production from Inspiration Consolidated Copper's operation warranted construction of a large smelter in the Miami area. In late October 1913, the International Smelting and Refining Company purchased 32 acres of land from the Miami Copper Company for the new smelter site. Ground was broken in December 1913. As construction of the new smelter was underway, the Anaconda Copper Mining Company purchased the assets of the International Smelting and Refining Company in May 1914 and changed its name to the International Smelting Company. International Smelting's Miami smelter was commissioned in July 1915 at a total capital expenditure of $3 million (Rickard, 1987).

Designed to mainly treat concentrates from the Miami and Inspiration mining operations, International's Miami smelter was the third smelter in Arizona to be constructed without a blast furnace (Figure 83). It employed ten 22.5-foot diameter, oil-fired Wedge roasting furnaces, four oil-fired reverberatory furnaces (one with a 25-foot by 120-foot hearth and three with 21-foot by 120-foot hearths), and five 12-foot electrically operated Great Falls type converters (Weed, 1922). A Cottrell electrostatic precipitator significantly reduced dust losses in flues and stacks from the roasters and converters. This was the first Cottrell plant in Arizona to recover dust from a copper roasting operation (Rickard, 1987).

Figure 83. International Smelting and Refining's Miami smelter, circa 1940 (photo from Library of Congress)

Inspiration Consolidated Copper Company purchased the International Smelting and Refining Company's (renamed in 1934) Miami smelter from Anaconda Copper in April 1960. The purchase price was $1,135,000 (Hardwick, 1963).

In response to the Clean Air Act of 1970, the facility's original reverberatory furnaces and converters were replaced with an Elkem 51 MW electric furnace, Hoboken converters and an acid plant in 1973 at a total cost of $54 million (Greenspoon and Schroeder, 1976). This facility had an annual capacity to treat 450,000 tons of copper concentrates. Hoboken converters were chosen for their ability to control fugitive emissions, while the acid plant captured sulfur dioxide emissions from both the electric furnace and the convertors. Inspiration used the by-product acid production to recover copper from its dump leaching operations (Bhappu et al., 1993).

The 1973 decision to proceed with an electric furnace was driven by a long-term power contract with the Salt River Project and availability of precipitate copper. Anticipating a major increase in the cost of electric power when the long-term power contract expired in 1990, less costly alternative smelting technologies were examined. A decision was made to convert the facility to ISASMELT technology, which used natural gas. Approval to expand and modernize the Miami smelter was made in 1990. The new 650,000-ton capacity ISASMELT facility was commissioned in June 1992 at a cost of $92.5 million (Bhappu et al., 1993).

Inspiration commissioned a rod plant at Miami in 1966, the first of its kind to be located at a mine site. The original tank house refinery was replaced by a new copper refinery in October 1994 at a cost of $80 million. Having an annual capacity to produce 190,000 tons of high-grade copper cathode (Garvey et al., 1999), this facility operated until June 2005, when a reassessment of the company's operating capacity, flexibilities, efficiencies and costs resulted in a decision by Inspiration's successor, Phelps Dodge to permanently close its Miami refinery (Phelps Dodge Corporation, 2006).

After more than 100 years of operation, the Miami smelter continues to treat copper concentrates from Freeport-McMoRan's domestic mining operations, producing a blister copper product that is shipped to its El Paso copper refinery. Smelting operations at Miami also produce by-product sulfuric acid, which is used to recover copper at its North America leaching operations. Freeport-McMoRan's rod plant at Miami continues to produce copper rod, which is sold to wire and cable manufacturers (Freeport-McMoRan, Inc., 2021).

4.18 Porphyry Mountain – Castle Dome Mine (1881-1970)

The first recorded mining claim in the area near the future site of the Castle Dome mine was the Continental claim (Figure 6). Filed in 1881, this claim was located approximately 3,000 feet northeast of Porphyry Mountain. This activity was followed by the location of additional mining claims along the southern flank of Jewel Hill and along Gold Gulch, where terrace gravels cemented by copper carbonates were found (Peterson et al., 1951).

Initially attracting little attention, considerable work was done at the Continental mine by 1896. It was purchased by the Old Dominion Copper Mining and Smelting Company in 1899. By early 1902, workings consisted of three tunnels, developed on several levels with a few hundred feet of drifts and cross-cuts (Ransome, 1903). The Continental mine was intermittently operated by lessees from 1906 until 1941, producing 34,000 tons of ore, yielding 2 million pounds of copper, 3,600 ounces of gold and 134,000 ounces of silver (Peterson et al., 1951).

The Castle Dome Copper Company (reorganized as Castle Dome Mining Company in June 1909) was organized in April 1908 with a capitalization of $600,000 at $10 per share. It held 12 mining claims (240 acres) near the Continental mine (Stevens, 1908).

The Castle Dome Development Company was incorporated in December 1915 under the laws of Maine with a total capitalization of $3 million at $5 per share. At the time of its incorporation, it held eight patented mining claims on Porphyry Mountain and a 97% equity interest in the Inspiration Extension Copper Company, which owned 29 patented mining claims on Porphyry Mountain and 95 claims adjoining the western boundary of the Inspiration Consolidated Copper property in Webster Gulch (Peterson et al., 1951).

By 1922, Castle Dome Development had completed seven churn drill holes and eight tunnels with 4,500 feet of underground workings at Porphyry Mountain. Estimated reserves totaled ten million tons, averaging 1.4% copper (Weed, 1922).

In February 1924, the Pinto Valley Company acquired the assets of the Castle Dome Development Company through a merger, obtaining title to 37 patented mining claims on Porphyry Mountain. Over the next several years, systematic exploration efforts had delineated sufficient ore at Porphyry Mountain to conduct metallurgical tests to examine the feasibility of placing the property in production. A small pilot plant was established at the site during 1926. This facility tested bulk metallurgical samples obtained from the Indicator adit, located on the south slope of Porphyry Mountain (Peterson et al., 1951).

After completing a 1,085-foot diamond drill hole at Porphyry Mountain, the Pinto Valley Company reported an estimated ore reserve of 29 million tons, averaging 0.95% copper in 1929 (Peterson et al., 1951). Their proposed project planned to develop an underground block caving operation, which was similar to those used at Inspiration and Miami. Pinto Valley negotiated a contract with Inspiration Consolidated Copper in 1929 to treat 3,000 tons of Castle Dome ore per day at Inspiration's sulfide concentrator over a period of eight years. However, efforts to develop the deposit were subsequently abandoned, when deteriorating financial conditions resulting from the Great Depression made it impossible to raise sufficient capital required to proceed with the project (Peterson et al., 1951).

4.18.1 Castle Dome Copper Company, Inc. (1941-1970)

In May 1940, the Miami Copper Company purchased Old Dominion's holdings in the Miami-Globe area. This included mining claims of the Continental mine property, which had been held by Old Dominion since 1899. They began an exploration drilling program at the site in July 1940, discovering the eastern extension of the Castle Dome ore body.

During the fall of 1940, the Miami Copper Company acquired an option to purchase Pinto Valley’s claims at Porphyry Mountain. After a brief evaluation, Miami Copper exercised this option in November 1941. Castle Dome Copper Company, Inc., a wholly owned subsidiary of the Miami Copper Company, was formed to develop and operate the property (Burgin, 1976).

By the end of 1941, 61 drill holes were competed at Porphyry Mountain, delineating approximately 33 million tons of ore, averaging 0.75% copper (Parsons, 1957). Situated on the south slope of Porphyry Mountain (Figure 84), the Castle Dome deposit measured approximately 4,500 feet long by 500 feet wide with an average thickness of 225 feet. Although not extensive, supergene enrichment (chalcocite) at Castle Dome played an important role in the economic viability of the project.

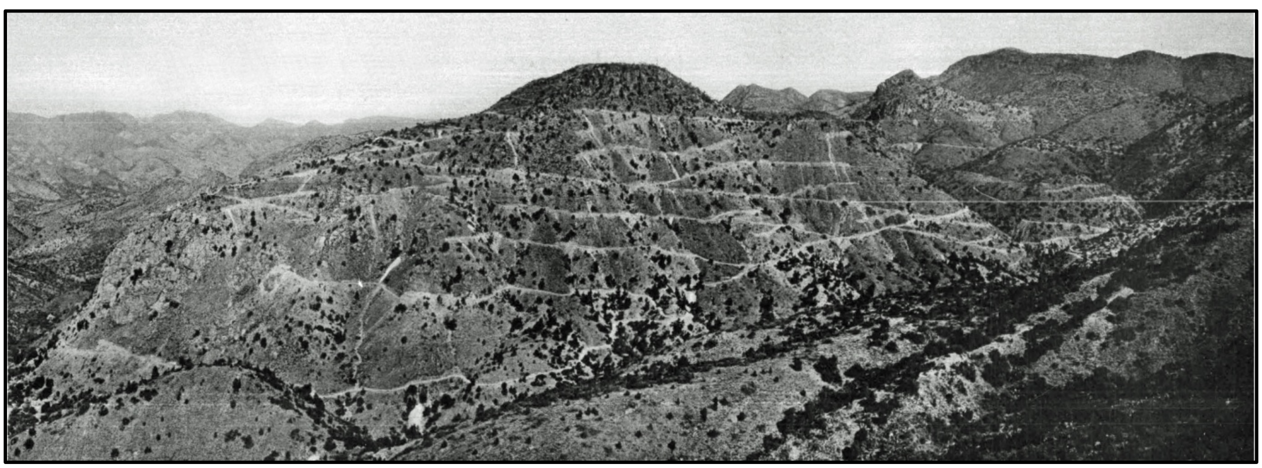


Figure 84. Porphyry Mountain view from the south prior to the commencement of mining in January 1942 (photo from Peterson et al., 1951)

By late 1941, there was an urgent need for copper as a result of World War II. Arrangements were made with the Defense Plant Corporation, a subsidiary of the Federal Government's Reconstruction Finance Corporation, to erect a 10,000-ton per day concentrator at the Castle Dome site. Under the terms of this agreement, the

Federal Government supplied $9 million for stripping the overburden and construction of the treatment facility. This plant was owned by the Defense Plant Corporation, who leased it to Castle Dome Copper Company, Inc. Miami Copper supplied the additional capital required to fund the project (Burgin, 1976).

Figure 85. Little Acres town site, looking east (circa 1950s) (photo from the Arizona Geological Survey)

During 1942, ten houses were built near the mine site and 32 houses constructed at Little Acres (Figure 85) southeast of Miami to house workers for the Castle Dome project. Copper Cities Transportation Company provided bus service to transport workers from Globe, Central Heights, Midlands City, Claypool, Lower Miami, and Upper Miami (Sain, 1944).

W. A. Bechtel Company commenced construction of the concentrator and removal of 14 million tons of waste overlying the ore body in January 1942. A 4.5-mile paved access road connected the mine with the main highway. Efforts to fast-track this project included recycling most of the structural steel and acquiring some of the heavy equipment from Phelps Dodge's recently dismantled Copper Queen concentrator in Bisbee. A 16-inch water line was laid over a distance of 11 miles from the Old Dominion mine at Globe to a 3.6-million gallon reservoir near the Castle Dome plant site. Power was provided by an 110,000-volt electrical transmission line via a connection with the Salt River Valley Water Users Association's hydroelectric generating station at Roosevelt Lake.

Castle Dome Copper took over mine excavation from the contractor in April 1943. The project was successfully commissioned on June 10, 1943. Due to the wartime demand for copper the concentrator capacity was increased from 10,000 to 12,000-tons per day in during the fall of 1944 (Burgin, 1976).

Castle Dome was the first project in the Globe-Miami area to employ large-scale open pit mining methods (Figure 6). The ore was mined on 40-foof benches. Major mining equipment included seven Bucyrus-Erie blast hole drills, three 5-cubic yard Marion electric shovels and fourteen 30-ton Knuckey haul trucks (Anonymous, 1946).

Figure 86. Castle Dome concentrator, circa early 1950s (photo from Arizona Geological Survey)

The Castle Dome concentrator (Figure 86) employed crushing, grinding and flotation circuits that produced a copper concentrate, which was shipped to the International smelter in Miami. The concentrator tailings were dewatered by two thickeners to produce a slurry that flowed via gravity to the disposal site located in Cottonwood Gulch. Women contributed to the war effort by working as mill operators at this facility helping the company avoid many of the staffing problems that resulted from labor shortages during World War II (Anonymous, 1946).

An exploration campaign conducted during 1944-1946 successfully delineated an additional 6,127,000 tons of ore, assaying 0.704% copper, located immediately southwest of the existing pit. The agreement under which the mill and other facilities were leased from the Reconstruction Finance Corporation was amended effective January 1, 1948, increasing the Federal Government's investment in the project from $9 million to $13.8 million. This permitted the development and mining of the recently discovered reserves beneath Red Hill (Burgin, 1976).

With the exhaustion of its reserves on December 6, 1953, all mining and milling operations ceased at Castle Dome (Figure 87). Over the ten-year life of the project, 41.4 million tons of ore were milled, recovering 517 million pounds of copper (Table 16).

Figure 87. Porphyry Mountain viewed from the south after mining commenced (photo from Peterson et al., 1951)

In 1954 Miami Copper purchased the concentrator and mining equipment from the Reconstruction Finance Corporation for $4 million and relocated it to their Copper Cities project (Parsons, 1957).

Table 16. Historic production from the Castle Dome property (Source: modified from U. S. Bureau of Mines data)

Period	Milled & DSO Short Tons	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1907-1929	738	0	116,244	0	0	0	2
1943-1953	41,442,617	0	517,232,217	0	0	9,385	583,067
1953-1973	32	48,000,000	67,115,822	0	0	0	0
1943-1973	41,443,387	48,000,000	584,464,283	0	0	9,385	583,069

Residual leaching of the existing waste dumps at Castle Dome began in 1953 with the copper recovered by precipitation methods. In June 1960, the Tennessee Corporation acquired the assets of the Miami Copper Company, including the Castle Dome property.

Cities Service subsequently acquired the property through its merger with the Tennessee Corporation in June 1963 (Scientific Applications International Corporation, 2008). An additional 67 million pounds of copper were recovered from the waste dumps prior to the suspension of residual leaching operations at Castle Dome in 1970 (Table 16).

4.19 Copper Cities Mine (1880-1982)

During the 1880s, prospectors worked small placer gold occurrences along Lost Gulch (Burgin, 1976). By the mid-1890s, the source of the placer gold had been discovered. Development of these small gold and silver lodes hosted by the Pinal Schist began in 1896. The Girard Mining Company (later reorganized as the Lost Gulch Mining Company) erected a ten-stamp mill at this site, but this venture soon failed due to the lack of an adequate water supply. Over the next several years, relatively high-grade gold ores were processed by crudely constructed arrastras (Peterson, 1962).

The Lost Gulch United Mines Company was organized in 1908 under the laws of Arizona with a capitalization of $2 million at $1 per share. They identified four fissure veins cutting intrusive rock, which averaged 3 to 4 feet in thickness. Delineated by 3,000 feet of underground workings, ore reserves were reported to be approximately 10,000 tons, assaying 1% copper, 5% zinc, 3 ounces per ton silver, and 0.35 ounce per ton gold. A ten-stamp amalgamation mill was erected in February 1910, but only processed 300 tons of ore before ceasing operations in May 1910 (Stevens, 1911).

Lost Gulch United Mines Company was succeeded by the Louis d'Or Gold Mining Company in July 1912 (Weed, 1916). Charles Hart, representing the Baldwin Syndicate, visited the area in 1916 (Hardwick and Stover, 1960). During the course of his examination, he recognized similarities between porphyry outcrops south of Sleeping Beauty Peak and leached outcrops in the Robinson mineral district nearly Ely, Nevada.

Based on Hart’s recommendations, the Louis d'Or Gold Mining Company was reorganized as the Louis d'Or Mining and Milling Company in November 1916 (Peterson, 1962). Controlled by the Baldwin Syndicate, it had $3 million of capitalization at $1 per share. Exploration from 1917 until 1922 confirmed the presence of a large disseminated copper resource, but its grade was too low to warrant production (Peterson, 1962). Louis d’Or Mining and Milling acquired the assets of Inspiration Miami Copper Company (77 claims) and Inspiration Miami Extension Copper Company (five claims) in 1923. However, by 1926 much of company’s capital had been used to acquire property, forcing it to issue notes to secure funding for development (Burgin, 1976).

In July 1928, the assets of the Louis d'Or Mining and Milling Company were sold at a bankruptcy sale. With the assistance of the Pinto Valley Company, these assets were purchased by a “note holders’ protective committee”, who organized the Porphyry Reserve Copper Company in early 1929 (Burgin, 1976). Porphyry Reserve Copper Company issued $500,000 in bonds to help finance its exploration efforts, which included 13 drill holes. Between 1929 and 1930, Porphyry Reserve Copper also recovered approximately 353,000 pounds of copper from a small exotic copper occurrence along Tinhorn Wash (Figure 6), where the stream gravels are cemented by copper carbonates and silicates (Peterson, 1962).

In 1934, Porphyry Reserve Copper defaulted on interest payments due on the bonds that had been issued in 1929, and allowed many of their unpatented mining claims to lapse after failing to perform the required annual assessment work. These claims were relocated by various individuals and were later consolidated by J. R. Heron of Globe. Bondholders eventually foreclosed on the small group of mining claims the company still retained. The Miami Copper Company purchased these claims at a sheriff’s sale in 1942 and later acquired many of the original claims from Heron and others (Burgin 1976).

4.19.1 Copper Cities Mining Company (1942-1982)

Copper Cities Mining Company, a wholly-owned subsidiary of Miami Copper, was formed to develop and operate the property (Figure 6). A churn drilling program commenced in August 1943, but was suspended in December 1943 after completing 20 drill holes due to manpower shortages during World War II. Exploration resumed in October 1946 and was completed in June 1948. Exploration drilling was done on a 250-foot rectilinear grid, with intermediate holes being completed along the outer fringe of the ore body. A total of 109 drill holes, averaging 600 feet in depth, delineated 33.8 million tons of ore, assaying 0.71% copper. Overburden was estimated to be 34.7 million tons, of which 20 million tons had to be stripped prior to commencing production (Gray, 1953).

Copper Cities Mining Company obtained a $7.5 million loan from the Reconstruction Finance Corporation in November 1950 (Burgin, 1976). Under the terms of this agreement, Copper Cities purchased the Castle Dome plant and equipment from the Reconstruction Finance Corporation for $4 million in January 1951 (Parsons, 1957). Stripping of overburden and site preparation began in May 1951 (Gray, 1953).

Under the Defense Production Act, Copper Cities Mining Company executed a purchase agreement with the General Services Administration in January 1952. Under the terms of this agreement, the U.S. Government agreed to purchase up to 170 million pounds of the first 192.5 million pounds of the copper produced at 23 cents per pound (subject to escalation if wages or other operation costs increased), if Copper Cities was unable to sell the copper mined for domestic use at a price equal to or greater than the contract price. Copper Cities Mining Company repaid its $7.5 million loan in September 1954, and no purchases of copper were made by the Federal Government (Burgin, 1976).

By the end of December 1953, 14.1 million tons of barren leached capping had been stripped from the ore body and concrete foundations for the concentrator, crushers and tailings thickeners were completed. Upon completion of mining operations at Castle Dome in December 1953, workers began to dismantle the Castle Dome mill facility. Within three months, 900 tons of steel and machinery had been relocated to the Copper Cities site, where a mill with a modified flow sheet was reassembled (Skillings, 1975). The Copper Cities concentrator was commissioned in August 1954 and achieved full production in November 1954. Total capital expenditures as of December 31, 1954, amounted to $13.7 million. A molybdenum flotation circuit was added to the concentrator in 1965, using much of the equipment from the recently closed Miami concentrator (Burgin, 1976).

Figure 88. Copper Cities pit viewed from the southeast, Sleeping Beauty Mountain is in the background, circa 2013 (photo by David Briggs)

Conventional open pit mining operations at Copper Cities were performed on 45-foot benches (Figure 88). Primary mining equipment included four blast hole drills, three 5-cubic yard electric shovels, eight 40-ton rear dump haul trucks, two 30-ton rear dump haul trucks, seven bulldozers, and one grader (Hardwick and Stover, 1960).

In June 1960, the Tennessee Corporation (merged with Cities Service in June 1963) acquired the assets of the Miami Copper Company, including the Copper Cities property (Scientific Applications International Corporation, 2008).

Dump leaching operations began at Copper Cities in December 1962 (Burgin, 1976). Dedicated leach dumps were located in a steep V-shaped ravine, having a maximum height of 300 feet. The presence of pyrite in the ore eliminated the need to add sulfuric acid to the leach solution, which consisted of water distributed over the pad by plastic pipes that were perforated at regular intervals. The pregnant solutions (0.175 to 0.19% copper) were collected in a sump at the base of the dump and flowed to launders, where the copper was precipitated onto shredded scrap iron. Copper precipitates were removed from the vats with a clam shell bucket, while the barren solutions were recycled to the dump leach pads. The final precipitate, averaging 82.5 to 82.7% copper, was dried prior to shipment to the smelter (Smith, 1963).

The Diamond H ore body was discovered in 1965 and placed in production in July 1970. Initial ore reserves at Diamond H totaled 11 million tons assaying between 0.5 to 0.6% copper (Burgin, 1976).

With the depletion of its ore reserves, all mining activities at Copper Cities were suspended in May 1975 and milling of stockpiled ores was completed in September 1975 (Greeley, 1978). The concentrator was subsequently dismantled and shipped to the Philippines. Residual leaching from existing dumps continued until June 1982, when low copper prices resulted in the suspension of the secondary recovery operations (Hicks, 1984).

Table 17. Historic production from the Copper Cities property (Source: modified from U. S. Bureau of Mines data)

Period	Mill & DSO Short Tons	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
1907-1942	5,873	0	420,942	0	0	0	978	2,459
1954-1975	77,369,399	0	807,776,919	0	0	1,481,640	18,373	1,313,022
1962-1966	0	NA	22,361,674	0	0	0	0	0
1967-1982	0	46,197,000	60,337,959	0	0	0	0	0
1907-1982	77,375,272	46,197,000	890,897,494	0	0	1,481,640	19,351	1,315,481

Over the life of the Copper Cities project nearly 808 million pounds of copper were recovered from 77.4 million tons of mill and direct smelting ores (DSO). Dump leaching operations recovered an additional 82.7 million pounds of copper between 1962 and 1982 (Table 17).

4.20 Porphyry Mountain - Pinto Valley Mine (1974-Present)

The Pinto Valley mine is located at Porphyry Mountain (Figure 6), where the Castle Dome operation mined a shallow chalcocite enriched zone between June 1943 and December 1953. An exploration program designed to test the underlying primary (chalcopyrite) sulfide mineralization at the site began during 1961 (Burgin, 1976). By 1969 158 drill holes, totaling 230,000 feet, had been completed on a rectangular grid with 400-foot centers, delineating an ore reserve of 350 million tons, averaging 0.44% copper (Skillings, 1975).

Parsons-Jurden Corporation of New York City was awarded a contract to perform conceptual engineering for the concentrator and a detailed feasibility study on the proposed project in December 1969. In conjunction with Fluor-Utah, Inc., Cities Service personnel formulated a mine plan, which was incorporated into the feasibility study that was completed in late 1971. Due to the long delivery time required for major mining equipment, tentative orders for shovels, haul trucks and blast hole drills were made in advance of receiving final approval for the project (Skillings, 1975).

Cities Service Board of Directors approved the Pinto Valley project in May 1972. Bechtel Corporation was awarded the general contract for construction of the concentrator and associated facilities. Initial mine development was started by John Mercer and Company with the removal of 2.25 million tons of waste from the top of Porphyry Mountain, using front end loaders and 30 and 50-ton haul trucks (Li and Carter, 1975). This work also included construction of haulage roads. Cities Service personnel took over pre-production stripping with larger equipment in August 1972, eventually removing another 51 million tons of waste from the top of the ore body, which was exposed on the 4,220-foot level in early 1974 (Skillings, 1975). Over a period of two years, approximately 500 feet of material was removed from the top of Porphyry Mountain.

The first ore was fed to the primary crusher in May 1974. The initial three grinding lines of the 40,000-ton per day concentrator were commissioned in July 1974 and the final three grinding lines began operation in November, 1974 (Li and Carter, 1975). Total capital expenditures for the project exceeded $100 million (Skillings, 1975).

The processing plant consisted of a three-stage crushing circuit, which reduced the ore to minus 3/8-inches. The crushed ore reported to a single-stage grinding circuit, consisting of six 18-foot diameter by 21-foot ball mills, which ground the ore to a 15% plus 65-mesh product before reporting to a flotation circuit that produced copper and molybdenum concentrate products. The final copper concentrates were delivered via 10.7-mile slurry pipeline to a filter plant located adjacent to Inspiration's Miami smelter (Li and Carter, 1975).

Figure 89. Pinto Valley pit, looking north (photo from U. S. Forest Service, 2019)

At start-up the mining fleet included two 15-cubic yd. 2100 P&H electric shovels, two 20-cubic yd. P&H 2300 electric shovels, a 12-cubic yd. Dart D-600B front end loader, and eighteen 150-ton Wabco haul trucks. Mining was conducted on 45-foot benches with the maximum pit slope of 42^{o} (Figure 89). Ultimate dimensions of the initial pit measured 6,000 feet long by 3,500 feet wide with a maximum depth of 1,450 feet (Li and Carter, 1975).

Designed to treat leach solutions from sulfide waste dumps, a SX-EW plant was added to the Pinto Valley processing facility in July 1981 (Niemuth, 1982). Cities Service suspended its mining and milling operations at Pinto Valley in late June 1982 due to the economic recession that negatively impacted the demand for copper and copper prices. However, the low-cost dump leaching operations continued to produce copper cathode. The Cities Service Company became a wholly-owned subsidiary of the Occidental

Petroleum Corporation in December 1982 (Scientific Applications International Corporation, 2008).

4.20.1 Magma Copper Company (1983-1995)

The Pinto Valley Corporation, a wholly-owned subsidiary of the Newmont Mining Corporation, purchased Cities Service's Miami holdings in March 1983 for $75 million. According to the terms of this agreement, Cities Service also received 20% of the cash flow from their former holdings up to a maximum of $30 million, after Newmont's investment, capital expenditures and cash losses were recovered (Newmont Mining Corporation, 1984).

Newmont resumed mining and milling operations at Pinto Valley in May 1984, shipping its copper concentrates to San Manuel for smelting (Newmont Mining Corporation, 1985). Over the years, the capacity of Pinto Valley's concentrator was incrementally increased from 40,000-tons per day at start-up to 62,500-tons per day in 1986. Newmont spun off its domestic copper assets (i.e., San Manuel, Superior, Pinto Valley, and Miami) in March 1987 to form a new public company, the Magma Copper Company (Beard, 1989a).

During late December 1992 and January 1993, unusually heavy rainfall over a seven week period (17 inches = 80% normal annual precipitation) caused many containment structures to overflow, including an overtopping of a tailings impoundment that discharged waste into Pinto Creek (Bingham and Baltzer, 2001).

4.20.2 BHP Copper, Inc. (1996-2013)

Broken Hill Proprietary Company Ltd. acquired the Pinto Valley property in January 1996 as a result of its merger with Magma Copper Company and created a local wholly-owned subsidiary, BHP Copper, Inc. to manage its U.S. holdings (Broken Hill Proprietary Company Ltd., 1996).

During the fall of 1996, BHP Copper began to dispose of mine waste rock on top of the inactive No. 1/2 tailings storage facility that had been decommissioned in late 1987. Saturated fine tailings within the impoundment were confined behind a tailings dam composed of the sand fraction of the mill tails, which had been constructed using an up-stream construction method. During the placement of the second 50-foot lift of waste rock in October 1997, bulging was observed along the dam face (Sotil et al., 2020,). At that time, the relatively thin zone of drained sandy material in the tailing dam face could no longer contain the liquefied fine tailings, resulting in the release of 370,000-cubic yards of tailings and waste rock that flowed downstream into Pinto Creek (U. S. Forest Service, 2019). This failure was directly attributed to the rapid loading resulting from the placement of mine waste rock over saturated tails (Adams et al., 2018). The majority of the clean-up and habitat restoration of the impacted area was completed by June 1999 at an estimated cost of $34 million (Broken Hill Proprietary Company Ltd., 1999).

All mining and milling operations at Pinto Valley were suspended on February 25, 1998 due to the decline in the price of copper. The concentrator was placed under care and maintenance and the mining equipment fleet was sold. However, all operating and environmental permits were maintained during the shutdown, as were the water and electrical systems. The SX-EW facility continued to produce minor amounts of cathode copper from residue leaching of the low-grade sulfide stockpiles over the next nine years (Capstone Mining Corporation, 2014).

Broken Hill Proprietary Company Ltd. and Billiton Ltd. merged in June 2001 to become BHP Billiton Ltd. (BHP Billiton PLC, 2001).

In April 2006, a feasibility study was completed, recommending the rehabilitation of the mill and flotation plant and resumption of mining operations. The re-start budget for this $140 million project included an extensive rebuild of the crushing circuit, major maintenance of the concentrator and the construction of new concentrate thickeners and a concentrate storage facility (Niemuth, 2007).

Following a decision to restart production in January 2007, BHP Copper resumed mining operations at Pinto Valley in June 2007, using the Washington Group as a contract miner. The refurbished concentrator was re-commissioned in October 2007. Copper concentrates were trucked to a trans-load facility at San Manuel from which they were shipped via rail to the port of Guaymas, Sonora for export to Asian smelters (Niemuth, 2007).

However, with the economic downturn during the fall of 2008, a decision was made to halt all mining and milling operations in January 2009 (Capstone Mining Corporation, 2014). The SX-EW facility continued to recover limited amounts of copper cathode from residual leaching of the existing low-grade stockpiles. In December 2012, BHP Copper upgraded and re-commissioned the mining and milling operations at a cost of $194 million (Capstone Mining Corporation, 2014).

4.20.3 Capstone Mining Corporation (2013-Present)

Capstone Mining Corporation acquired the Pinto Valley mine and associated railroad operations from BHP Copper, Inc. in October 2013 for $650 million and created a local wholly-owned subsidiary, Pinto Valley Mining Corporation (Capstone Mining Corporation, 2014). Since Capstone Mining's acquisition, Pinto Valley's annually copper production has been approximately 130 million pounds.

In early 2014, the Pinto Valley Mining Corporation extended the mine life of the project by eight years to 2026 and in early 2016 more than doubled its remaining mine life. The addition of low-grade ores to the run-of-mine leach dump was temporarily suspended during 2015. Residual leaching continued for several years as the leach dumps were converted to waste dumps (Capstone Mining Corporation, 2017).

Table 18. Historic production from the Pinto Valley property (Source: modified from U.S. Bureau of Mines data)

Period	Milled Ore Short Tons	Dump Leach Short Tons	Cu Lbs.	Mo Lbs.	Au Troy Oz.	Ag Troy Oz.
1974-2020	604,503,111	0	4,227,104,546	22,463,324	125,378	7,211,408
1974-2020	0	532,349,000	475,997,256	0	0	0
1974-2020	604,503,111	532,349,000	4,703,101,802	22,463,324	125,378	7,211,408

During the spring of 2019, the Pinto Valley Mining Corporation partnered with Jetti Resources to test a novel patented catalytic technology, designed to recover copper from primary sulfide ores that are too low grade to treat by existing conventional methods. Results of this one-year pilot program demonstrated that low-grade chalcopyrite stockpiles could be successfully leached using this catalytic technology. As a result of this successful test, Capstone Mining Corporation announced in July, 2020, that it will incorporate this new technology into its existing operation at Pinto Valley, significantly expanding its dump leaching activities to fully utilize its SX-EW plant's capacity (Capstone Mining Corporation, 2020).

Since 1974, the Pinto Valley project has produced 4.7 billion pounds of copper and nearly 22.5 million pounds of molybdenum (Table 18). At its current rate of production, proven and probable ore reserves as of December 31, 2020 (407 million tons, averaging 0.31% copper and 0.007% molybdenum) will sustain operations until 2039 (Capstone Mining Corporation, 2021).

4.21 Cactus-Carlota Mine (1896-Present)

The earliest reported mining activity in the Cactus-Carlota mine area (Figure 6) was performed by the Pinto Creek Mining and Smelting Company. Organized in December 1896, it controlled 36 mining claims, covering approximately 720 acres along Pinto Creek, where six fissure veins cutting the Schultze Granite assayed 3.5 to 6% copper, 8 ounces silver per ton and 0.1 to 0.3 ounces of gold per ton. After showing great persistence and making considerable expenditures, Pinto Creek Mining and Smelting suspended exploration activities when the mortgage on the property was foreclosed in 1910 or 1911 (Stevens, 1911).

Between 1906 and 1908, the Arizona National Copper Company, Pinto Creek Copper Mining Company and the Cactus Development Company were organized to explore several mining properties along Pinto Creek (Stevens, 1908).

All of this activity resulted in the development of Crowley City, named for Con Crowley, the prospector who located the Cactus mine in 1898. During 1910, this community had a population of 150 of which 100 were employed as miners. This mining camp had a large general merchandise store, post office and school (Anonymous, 1910).

Cactus Development consolidated holdings of Arizona National and Pinto Creek Copper under one management and was subsequently reorganized as the Cactus Copper Company in August 1909. They sank the 530-foot Hamilton shaft, the 560-foot Pinto shaft and completed underground development on several levels. However, this exploration effort failed to find sufficient ore of commercial content to warrant further development. Cactus Copper abandoned the property in October 1910 (Stevens, 1911).

The Carlota Copper Company acquired the Carlota property around 1920 and intermittently mined oxide copper ores from a shallow pit and underground workings from 1924 until 1957. The majority of this production occurred during World War II, but declined significantly in 1948. Beginning in 1958, smelters refused to process these ores due to its high alumina content. Three unsuccessful attempts were made to recover precipitate copper using vat and heap leaching methods between 1959 until 1964 (Mieritz, 1966).

The Homestake Production Company acquired a lease on the Carlota property in July 1968. They completed 25 diamond drill holes along the Kelly fault zone, delineating mineralization in the hanging wall of this structure, which is referred to as the Cactus Breccia. Homestake Production dropped the property during the early 1970s. The hanging wall of the Kelly fault was subsequently explored by an additional 14 drill holes completed by Sonesta Resources before abandoning its efforts in 1975 (U. S. Forest Service, 1997).

With the exception of approximately 30 rotary drill holes during the early 1920’s, little additional work occurred on the adjoining Cactus zone until the 1960s, when Cities Service conducted an extensive drilling program at the site. The Cactus zone was subsequently acquired by the Magma Copper Company in March 1983, who continued the evaluation of the site until 1988 (U. S. Forest Service, 1997).

The neighboring Eder-Ghost property was initially drilled by the Howe Sound Company during the mid-1950s. This property was subsequently acquired by a joint venture between the Inspiration Consolidated Copper Company and Anaconda Copper during the mid-1960s. They drilled 12 rotary drill holes and 32 diamond drill holes between 1968 and 1975, which defined the Eder North and Eder South deposits. Although Anaconda dropped out of the joint venture in 1974, Inspiration Consolidated Copper continued to hold the property until its merger with Cyprus Minerals in July 1988 (U. S. Forest Service, 1997).

4.21.1 Recent Exploration and Development (1989-2008)

Westmont Mining, Inc. acquired a six-month option to lease the Carlota property from Sherwood Owens in January 1989 (Figure 90). During this period, analysis of geological data and metallurgical testing suggested both in-situ and open pit/heap leaching methods were feasible. However, the in-situ leaching option was not deemed practical due to potential permitting difficulties. An initial preliminary feasibility study completed in June 1989 by Independent Mining Consultants of Tucson showed an ore reserve of 16.6 million tons, assaying 0.68% copper with a waste to ore ratio of 3.1 to 1. Metallurgical testing by Metcon Research demonstrated approximately 90% of the copper could be recovered by heap leach methods. A rough financial analysis showed a favorable internal rate of return (IRR) at a copper price of $1.00 per pound (Independent Mining Consultants, Inc., 2005).

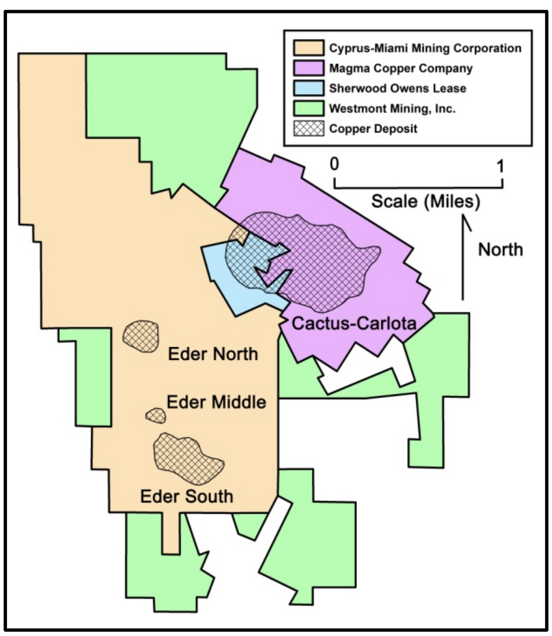


Figure 90. Schematic diagram showing property holdings in relationship to the ore deposits at Cactus-Carlota, circa 1990 (modified from Independent Mining Consultants, Inc., 2005)

Based on these results, Westmont Mining, Inc. acquired a 20-year lease on the property from Sherwood Owens in August 1989. Under the terms of this agreement, Westmont made a $10,000 payment on exercising the option in August 1989; a payment of $15,000 six months thereafter and continuing payments of $20,000 every six months prior to commencement of construction. No payments were due during construction. Upon commencing commercial operations, minimum monthly advance royalty payments of $3,000 would be credited toward a 5% Net Smelter Return Royalty on production with all payments after the commencement of commercial operations credited toward a purchase price of $3 million (Independent Mining Consultants, Inc., 2005).

However, it soon became apparent, adjacent holdings held by Magma Copper and Cyprus Miami would be required for the viable development of this property (Figure 90). In October 1990, Westmont purchased the Eder/Ghost claim group from Cyprus Miami Mining Corporation for $500,000 (Independent Mining Consultants, Inc., 2005).

Westmont acquired the Magma Copper's holdings through two lease agreements, dated March 1990 and June 1991. The initial lease agreement involved the Carlota deposit, while the June 1991 agreement dealt with the oxide portion of the Cactus deposit, located immediately east of the Carlota deposit. Each of these agreements required minimum annual advance royalty payments that were credited against a 5% Net Smelter Royalty once production began. In March 1993, these two lease agreements were superseded by a purchase agreement under which the Carlota Copper Company purchased 19 unpatented and 23 patented mining claims for $5 million (Independent Mining Consultants, Inc., 2005).

Cambior, Inc. acquired the Carlota project through its purchase of Westmont Mining, Inc. from Constain Minerals, Inc. in August 1991. Under the terms of this agreement, Cambior, Inc. acquired all of the shares of Westmont Mining for $10 million on closing and agreed to pay Costain Minerals an additional $5 million if and when the Carlota project achieved commercial production (Cambior, Inc., 1991).

Cambior submitted its first Plan of Operations to the U. S. Forest Service in February 1992. With the completion of a Preliminary Feasibility Study in March 1993, Cambior Board of Directors approved funding to complete the project's development through final engineering/design and permitting phases (Independent Mining Consultants, Inc., 2005).

In January 1995, the U.S. Forest Service published the Draft Environmental Impact Study and submitted it to the public for review. The Final Environmental Impact Study and Record of Decision were issued in July 1997. The Tonto National Forest Service supervisor approved Carlota's Plan of Operation in September 1998. However, lawsuits by environmental groups delayed development until September 1999, when a Summary

Judgment was rendered in favor of the U.S. Forest Service and Carlota Copper (Cambior, Inc., 2001).

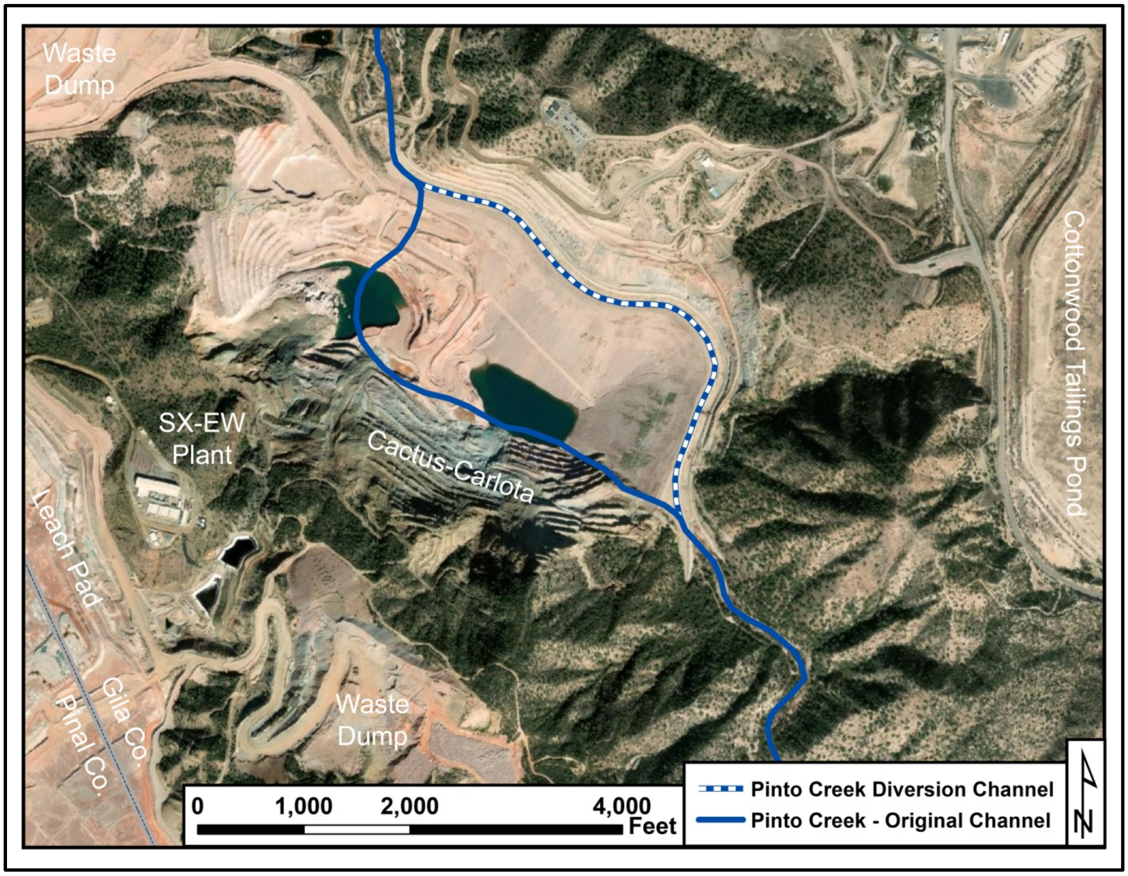


Figure 91. Aerial photo showing the Pinto Creek diversion channel around the Cactus-Carlota pit (photo from ESRI)

One of the more controversial aspects of the Cactus-Carlota project was the decision to divert Pinto Creek around the eastern and northern sides of the main pit (Figure 91). Measuring approximately 5,000 feet by 3,200 feet, the ultimate bottom of the main pit ranges from 2,850 to 2,950 feet above mean sea level (feet-amsl), which is approximately 500 to 600 feet below the pre-mining elevation of Pinto Creek. An area in the eastern and northern portions of the mined-out pit were backfilled to an elevation of 3,600 feet-amsl (about 80 feet above the Pinto Creek) to buttress the in-pit side of the diversion channel (U. S. Forest Service, 1997).

Although approval of the Carlota project was received in September 1999, Cambior postponed further development pending improved market conditions. The property remained on care and maintenance status until December 2005, when Quadra Mining Ltd. purchased the project for approximately $39.7 million. Over the 14-year period, 1991 through 2005, Cambior spent approximately $68 million on permitting and feasibility studies to ready the Carlota property for development (Quadra Mining Ltd., 2008).

4.21.2 Commercial Production (2008-Present)

The decision to proceed with the development of the Carlota open pit/heap leach operation was made in November 2006 (Figure 92). Construction of the mine and treatment facilities was completed in September 2008. Leaching of the ore commenced in October 2008 and the first cathode was produced from the SX-EW plant in December 2008 (Figure 93) (Quadra Mining Ltd., 2009).

Total construction, equipment and other project development costs as of December 31, 2008 were $220 million (Quadra Mining Ltd., 2009). The first shipment of cathode from the site was made in February 2009.

Quadra Mining Ltd. merged with FNX Mining Company, Inc. in May 2010 to form Quadra FNX Mining Ltd. (Quadra FNX Mining Ltd., 2011). KGHM acquired the Carlota project through its merger with Quadra FNX in March 2012 (KGHM Polska Miedź S.A., 2013).

Figure 92. Cactus-Carlota pit, looking northwest, 2013 (photo by David Briggs)

Figure 93. Pulling copper cathodes at electrowinning tank house at Carlota (photo from KGHM)

Table 19. Historic production from the Cactus-Carlota area (Source: modified from U. S. Bureau of Mines data)

Period	Ore Treated Short Tons	Dump Leach Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1941-1957	51,998	0	3,376,178	0	0	0	89
1957-1964	0	NA	17,800	0	0	0	0
2008-2020	0	42,430,000	201,800,000	0	0	0	0
1941-2020	51,998	42,430,000	205,193,978	0	0	0	89

Although active mining operations in the Cactus-Carlota pit were suspended in 2014, residual leaching of the existing heap leach pads continued over the next several years. During this period, sub-surface leaching techniques using injection wells were employed to achieve a more uniform recovery from the leach pads, increasing overall copper recovery (Rucker et al., 2017). Mining operations resumed at the Eder South deposit in May 2018. To date, historical production from the Carlota property totals approximately 205.2 million pounds of copper (Table 19).

4.22 Van Dyke Mine (1916-Present)

As mining activity increased at Live Oak, Keystone, Cordova, Miami, and Inspiration during the first decade of the 20th century, the demand for infrastructure to support the local workforce became increasingly imperative. At the time, much of these needs were provided by the community of Globe, along Pinal Creek, 6 miles to the east.

It was not long before real estate speculators recognized this business opportunity and began purchasing tracts of land to develop a community to serve the needs of the area's growing workforce. One of these speculators was Cleve W. Van Dyke, who purchased a large tract of land (now known as Upper Miami) along Bloody Tanks Wash from the Miami Land and Improvement Company in November 1908 (Sain, 1944).

Many of the old timers thought Van Dyke had gone mad for spending $25,000 to purchase a property that had a propensity to periodically flood (Sain, 1944). However, Van Dyke had a good head for business and was up to the challenge. He formed the Miami Townsite Company, which successfully sold and rented lots for residential and commercial use that became present-day downtown Miami. In nearly all of these transactions, Van Dyke retained the underlying mineral rights to the property with the new owner only holding title from the surface down to a depth of 40 feet. These deeds also contained a clause relieving any mine operator of liability for any surface damage might result from future underground mining operations (Lake, 2018).

4.22.1 Van Dyke Copper Company (1916-1968)

Van Dyke transferred the mineral rights of his holdings to the Van Dyke Copper Company (Figure 49), which was organized in August 1916 under the laws of Arizona with a capitalization of $5 million at $0.50 per share (Weed, 1922). Van Dyke Copper commenced a rotary drilling program during the fall of 1916, collaring their first drill hole in Gila Conglomerate, approximately 1,300 feet south of the Miami No. 4 shaft. This drill hole (V-1) encountered abundant copper carbonate and silicate mineralization assaying 6.58% copper along a structural zone from 1,169 to 1,212 feet. The first exploration hole was lost in the footwall of the fault after the bit twisted off at a depth of 1,219 feet (Bird et al., 2020). A second drill hole (V-2) collared approximately 2,600 feet east-southeast of V-1, also intersected 41 feet of mineralized breccia, assaying 4% copper, while a third hole (V-3), collared approximately 6,700 feet southeast of V-2 was abandoned in Gila Conglomerate at a depth of 1,400 feet (Peterson, 1962).

Exploration activities were halted in early 1918 due to U. S. participation in World War I (Rice, 1921). Follow the signing of the Armistice in November 1918, Van Dyke Copper resumed development work. The Van Dyke shaft (Figure 94) was collared approximately 200 feet south of drill hole V-1 in May 1919 (Peterson, 1962). By the spring of 1921, the shaft was completed to a depth of 1,692 feet and lateral workings developed on the 1,212-foot and 1,550-foot levels (Weed, 1922). It encountered the same mineralized zone as drill hole V-1 at a depth of 1,183 to 1,218 feet (Bird et al., 2020).

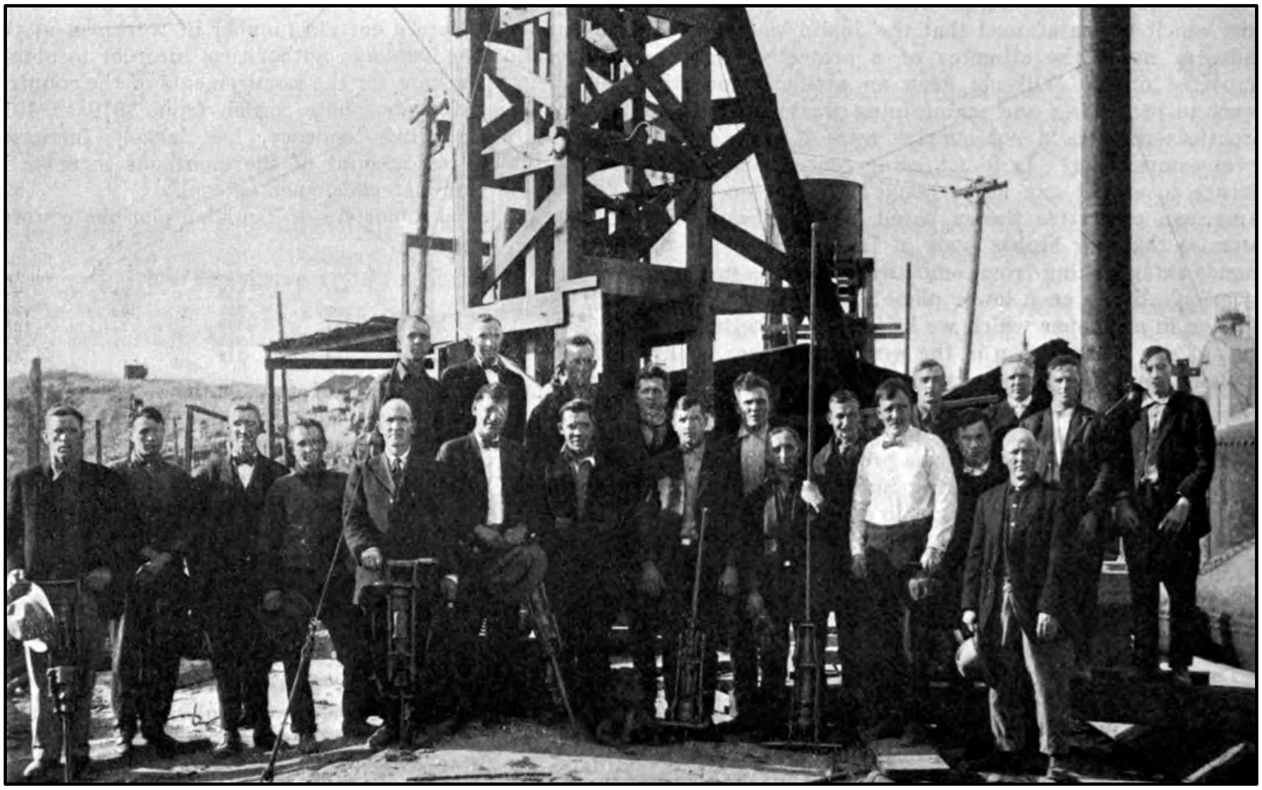


Figure 94. Shaft-sinking crew at the Van Dyke shaft, Miami, Arizona (photo from Rice, 1921)

With the collapse of the price of copper following World War I, underground exploration and development at Van Dyke was suspended in 1921. Van Dyke Copper resumed development in 1928 with the dewatering of the shaft, erection of a new headframe, installation of an electric hoist, and the development of underground drifts on the 1,212-foot, 1,312-foot and 1,412-foot levels (Bird et al. 2020). The first shipment of high-grade oxide copper ore was made during 1929. However, production was suspended in early 1932, when the collapse of the price of copper during the Great Depression made it impossible to sustain profitable mining operations (Peterson, 1962).

The Van Dyke mine was reopened with the assistance of the Federal Government in April 1943. Although ore grades averaged 5% copper difficulties in hoisting the ores from the 1,212-foot level and servicing the underground operations through the single small hoisting compartment of the shaft made the operation unprofitable. The mine was closed in June 1945 after producing 8,461 tons of ore (Peterson, 1962).

In 1947, the AMICO Mining Corporation was formed by the Anaconda Copper Mining Company, Miami Copper Company and the Inspiration Consolidated Copper Company to explore undeveloped lands in the Miami-Inspiration mineral district. These properties included claims held by the Van Dyke Copper Company and the Sho-Me Copper Company. After completing four deep drill holes (average depth – 3470 feet) to examine the Pinal Schist underlying the Gila Conglomerate (Reed, 1952), no ore was found and the company was dissolved in 1949 (Peterson, 1962).

The Freeport Sulfur Company acquired a lease on the Van Dyke property in 1964. They relinquished their lease after completing two drill holes, which failed to encounter sufficient mineralization to warrant additional work (Bird et al., 2020).

4.22.2 Occidental Minerals Corporation (1968-1980)

Occidental Minerals Corporation acquired a lease with an option to purchase properties held by the Van Dyke Copper Company and Sho-Me Copper Company in April 1968. After several years of exploration, Occidental joint ventured the property with AMAX during the early 1970s and Utah International around 1975. However, after completing additional drilling, AMAX exited the joint venture in late 1973 and Utah International terminated its interest in late 1975 or early 1976 (Bird et al., 2020).

By the end of 1975, Occidental Minerals and others had completed 51 diamond drill holes at Van Dyke, totaling 32,384 feet. This drilling program delineated a resource of 119.2 million tons, assaying 0.52% copper with a cut-off grade of 0.20% copper (Bird et al., 2020).

Lying in the down-thrown, eastern hanging wall of the Miami fault zone, the Van Dyke deposit is overlain by 600 to 2,000 feet of unmineralized Tertiary Gila Conglomerate. Below the Gila Conglomerate, a layer of hematitic clay (up to 150 feet) occurs along the unconformity separating the Gila Conglomerate from the underlying Pinal Schist, which displays characteristics of a “leached cap” that was formed by the oxidation and leaching of low-grade, weakly pyritized porphyry copper mineralization. Copper mineralization at Van Dyke consists primarily of copper oxides and silicates (i.e., azurite, malachite and chrysocolla), which are underlain by a weakly developed supergene (i.e., chalcocite) zone separating the oxide mineralization from weak primary sulfide (i.e., chalcopyrite) mineralization at depth (Bird et al., 2020).

The use of conventional mining methods to mine copper from Van Dyke was not considered economically viable due to the depth of the resource, its location and low tenor of the mineralization (Ahlness and Pojar, 1983).

In January 1976, Occidental Minerals began a two-phase test to evaluate the possibility of recovering copper from the Van Dyke deposit by in-situ leaching methods (Huff et al., 1988). The first test involved drilling one vertical injection well and one vertical recovery well from the surface, each being 1,000 feet deep, spaced 75 feet apart. The mineralized interval adjacent to the wells was hydraulically fractured prior to leaching. A weak sulfuric acid solution was pumped down the injection well; allowed to percolate through the fractured rock and leach the acid soluble copper mineralization before being recovered from the recovery well. The pregnant solutions produced from the test were transported via pipeline to a near-by SX-EW plant for processing (Ahlness and Pojar, 1983).

After successfully completing the first phase of testing, Occidental Minerals began a second phase of testing in October 1977 (Huff et al., 1988). The second test employed five 1,200-foot wells configured in a 5-spot pattern with 100-foot well spacings. All of the wells were hydraulically fractured adjacent to the mineralized test zone prior to leaching. A dilute sulfuric acid solution was injected in the center well and the copper-bearing pregnant solution recovered from the recovery wells at the four corners. After completing the test in early 1979, results proved the feasibility of surface in-situ leaching at Van Dyke (Ahlness and Pojar, 1983).

At this point Occidental Minerals applied for two special-use permits from the town of Miami to conduct further tests. However, the town council denied these requests. Occidental Minerals filed suit in Superior Court, claiming the denial of the permits was unconstitutional because it violated its right to use its property. The Superior Court agreed with Occidental Minerals, but the town of Miami appealed the case to the Court of Appeals in Tucson (Niemuth, 1981). In October 1980, Occidental Minerals abandoned its efforts at Van Dyke after spending more than $11 million on the project (Burgin, 1982).

4.22.3 Kocide Mining Corporation (1986-1989)

Kocide Mining Corporation acquired a lease on the Van Dyke property from the Van Dyke Copper Company, the Sho-Me Copper Company and the Miami Trust Company in 1986. In-situ leaching operations began in December 1988, injecting a dilute sulfuric acid solution into old underground mine workings at Van Dyke (Bird et al., 2020).

The pregnant solutions were recovered by a production well and treated at a cementation plant (Figure 95), where the copper was precipitated onto shredded detinned cans with the barren solutions being recycled to the underground mine. The copper precipitates were shipped to Kocide’s Casa Grande facility, where it was used to produce copper sulfate used in agricultural products (Beard, 1989b). After recovering approximately 720,000 pounds of copper (Table 20), all production was suspended in October 1989 due to metallurgical problems related to unacceptable amounts of iron that accumulated in the recycled leach solutions (Bird et al., 2020).

Figure 95. Kocide's precipitation plant at Van Dyke, circa late 1980s (photo from Arizona Geological Survey)

Table 20. Historic production from the Van Dyke property (source: modified from U. S. Bureau of Mines)

Period	Mill & DSO Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1929-1932	113,726	11,571,217	0	0	0	326
1943-1945	8,461	850,500	0	0	0	15
1976-1979	0	100,000	0	0	0	0
1988-1989	0	721,720	0	0	0	0
1929-1989	122,187	13,243,437	0	0	0	341

4.22.4 Arimetco International, Inc. (1990-1997)

Arimetco International, Inc. acquired Kocide's leasehold interest in the Van Dyke property in June 1990 and began to rehabilitate the Van Dyke shaft during the spring of 1992, in order to determine the best production method for this ore body. However, heavy rains during early 1993 destroyed a pumping station in Magma Copper's adjacent Miami mine, flooding its mine workings and damaging a bulkhead that separated the underground workings at Miami from the Van Dyke mine (Arimetco International, Inc. 1993). For safety reasons, Arimetco was forced to suspend shaft rehabilitation after reaching the 500-foot level because of potential flooding. After the suspension of development work in early 1993, the lack of funding limited activities at the site to monitoring well drilling, permitting and mine design (Arimetco International, Inc., 1996).

In January 1997, Arimetco International's operating subsidiary, Arimetco, Inc. declared bankruptcy (Chapter 11), due to significant cash flow problems resulting from low copper prices and production difficulties at their Yerington-MacArthur operation in Nevada. A subsequent ruling by the U. S. Bankruptcy Court directed Arimetco International to dispose of its mining assets, including its leasehold interest at Van Dyke.

4.22.5 Copper Fox Metals, Inc. (2012-Present)

In April 2010 Bell Copper Corporation acquired an option to purchase the Van Dyke property from Bennu Properties LLC, and Albert and Edith Fritz (Bennu-Fritz). After a two-year delay, Bennu-Fritz acquired clear title to the surface and sub-surface minerals at the Van Dyke property in April 2012 through a tax lien foreclosure process, allowing the transaction to proceed (Bird et al., 2020).

Figure 96. Diamond drilling in the parking lot adjacent to the Miami mayor and council building, circa 2014 (photo from Copper Fox Metals, Inc.)

In July 2012, Copper Fox Metals, Inc. entered a purchase agreement to acquire the Van Dyke property from the Bell Copper Corporation for Cdn $500,000. Bennu-Fritz received US $1.5 million for its underlying interest and retained a 2.5% NSR production royalty on future production. This transaction was completed in April 2013 (Bird et al., 2020).

After completing additional diamond drilling (Figure 96), metallurgical testing, environmental baseline and hydrological studies, and a mineral resource estimate, a Preliminary Economic Assessment (PEA) was published in November 2015 that suggested the Van Dyke project was a technically sound in-situ leach project. It recommended proceeding with a pre-feasibility study consisting of a 33,000-foot diamond drilling program to upgrade and expand the resource as well as a five-hole in-situ leach pilot test to investigate soluble copper recoveries, hydraulic connectivity, hydrology, and other geotechnical parameters (Bird et al., 2020).

In considering how to recover the copper from the Van Dyke deposit by in-situ methods, three options were analyzed; 1) directional drilling from the surface, 2) passive drainage from underground galleries, and 3) angled pumping from underground galleries (Gray et al., 2015).

Directional drilling of wells from the surface was considered the costliest of the three options due to depth and expense of each well and the number of wells required. There were also potential risks involving the maintenance of the wells as well as accessing the entire deposit. Passive draining from an underground tunnel was considered the least expensive option, but would likely result in poorer recoveries (Gray et al., 2015).

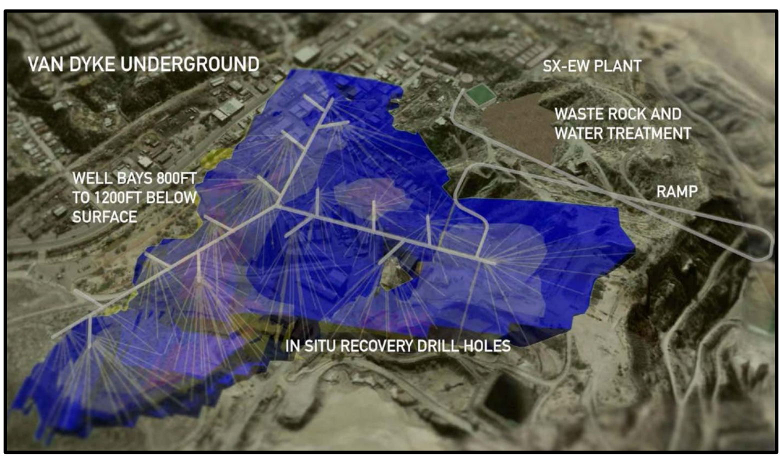


Figure 97. Proposed access and underground well field for Van Dyke in-situ leaching project (photo from Copper Fox Metals, Inc., 2017)

Angled pumping from underground galleries was considered the best option for in-situ leaching operations at Van Dyke. This option involves active pumping of injection and recovery wells located in underground galleries situated above the water saturated ore body (Figure 97). Under saturated conditions a hydraulic gradient is created allowing the leach solutions to thoroughly permeate the rock as they move from the injection well to the recovery well, ultimately increasing copper recovery (Gray et al., 2015).

Table 21. Resource estimate for the Van Dyke deposit effective January 9, 2020 (from Bird et al., 2020)

Class	Short Tons	Total Copper %	Acid Soluble Copper %
Indicated Resource	107,627,000	0.33	0.23
Inferred Resource	185,218,000	0.27	0.17

In 2017, Copper Fox Metals began the process of obtaining an Underground Injection Control Permit from the U.S. Environmental Protection Agency and the Aquifer Protection Permit from Arizona Department of Environmental Quality (Bird et al., 2021). An updated mineral resource estimate published in May 2020 is shown in Table 21.

4.23 Gibson Copper Mine

Sam L. Gibson and William M. Henderson located the Gibson claim group (Figure 6) in 1903 and commenced small scale mining operations with a total cash outlay of $90 and team of horses. After working their claims for several years, they organized the Gibson Copper Company in 1906 under the laws of Arizona with capitalization of $2.5 million at $25 per share. This influx of capital enabled them to sink a three-compartment shaft to a depth of 244 feet on the Pasquale vein and develop approximately 75,000 tons of ore (Stevens, 1906). An initial group of four mining claims was patented in September 1906.

As a result of its remote location and high transportation costs, this mining operation initially produced hand-sorted ores assaying 30 to 32% copper that were hauled by horse-drawn wagon over 18 miles of rough mountain roads to the railhead at Globe for shipment to a smelter in El Paso, Texas (Sain, 1944). By 1904, arrangements were made to treat their ores at the Old Dominion smelter, allowing them to reduce the cut-off grade for their ore shipments to 20% copper (Stevens, 1911).

The Gibson Copper Company continued operations until June 1910, when the Summit Copper Company acquired a lease with a four-year option to purchase the Gibson property for $442,375 by June 1914 (Stevens, 1911). Over the next seventeen months, Summit Copper deepened the main production shaft from 244 to 573 feet and completed about 4,000 feet of new drifts and cross-cuts. Intermittent ore shipments were made to the El Paso smelter, which averaged approximately 26% copper. However, Summit Copper’s development efforts failed to replace the high-grade ores extracted, resulting in the decision to abandon its option to purchase the property in January 1912 (Weed, 1916).

On return of the property, Gibson Copper Company resumed production until April 1913, when financial difficulties resulted in the suspension of operations. Over the next several years, lessees shipped 200 to 300 tons of direct smelting ore per month to the Old Dominion smelter.

The Gibson mine was developed on six levels accessed by a 600-foot inclined shaft that was sunk on the Summit vein to a vertical depth of 430 feet. A three-compartment 573-foot vertical shaft located approximately 125 feet northwest of the Pasquale vein outcrop intersected the Pasquale, Intermediate and Summit veins at depths of 125, 260 and 525 feet, respectively (Peterson, 1963). Approximately 26,000 feet of underground workings were present at the site. Considerable timbering was required to support the heavy and treacherous ground (Stevens, 1911).

Miners and their families resided in the nearby mining camp of Bellevue, which at its peak had 350 residents and daily stagecoach service to Globe (Eshraghi and Ford, 2015). This community included an engine-house, boiler-house, carpenter and machine shop, blacksmith shop, warehouse, office, assay lab, general store, schoolhouse, and a boarding house (Stevens, 1911). Its post office was opened in July 1906 and closed in April 1927.

In May 1917 the Gibson Consolidated Copper Company was incorporated in Delaware to acquire the assets of Gibson Copper Company and resumed shipments of direct smelting ores until December 1918, when production was temporarily suspended as a new flotation concentrator was readied for operation. A dam was constructed on Pinto Creek to impound six million gallons of water for the processing plant. The 150-ton per day concentrator was commissioned in August 1919. However falling copper prices forced Gibson Consolidated Copper to suspend operations in September 1920. Heavy rains in July 1923 resulted in the collapse of one of the main production shafts.

In August 1925, foreclosure proceedings were filed against Gibson Consolidated Copper for a $200,000 delinquent loan. The company's assets were sold at a sheriff's auction in July 1926 to satisfy judgment in favor of the plaintiff.

Over the next couple of decades there was little recorded production from the Gibson mine as ownership of the property passed to several owners. Ross Finley and Albert Stevens acquired eight patented mining claims in September 1942. In March 1963, Finley's widow and Albert Stevens leased their claims to Harlem Fountain and Reed Nix, who recovered a small amount of copper from two dump leach pads during 1964 and 1965.

Table 22. Historic production from the Gibson copper mine (source: U. S. Bureau of Mines)

Period	Mill & DSO Short Tons	Cu Lbs.	Pb Lbs.	Zn Lbs.	Au Troy Oz.	Ag Troy Oz.
1903-1969	55,750	17,201,360	0	0	129	14,775

Paul Kayser, the founder of El Paso Natural Gas Company, acquired control of the Gibson property in 1966 and formed Arizona Mining Properties, Inc. During the late 1960s, Arizona Mining Properties prepared the site for a pilot heap leach and in-place solution mining project, which commenced operations during the fall of 1969. Lessees and sub-lessees continued intermittent small scale heap leach and in-place solution mining operations at the site until the early 1990s (Eshraghi and Ford, 2015). Reported production from the Gibson mine is shown in Table 22.

Heap leach operations employed a small asphalt-lined heap leach pad with a series of single-lined solution ponds. Irrigation lines applied leach solutions for the in-place solution mining operations to an area overlying collapsed underground workings, allowing them to percolate downward by gravity to several adits, where the pregnant solutions were collected and combined with the copper-bearing solutions from the heap leach pads. Copper was recovered in a series of launders, where it was plated onto scrap iron that was shipped to area smelters (Eshraghi and Ford, 2015).

4.24 Copper Springs Prospect

The presence of copper adjacent to the southeastern lobe of the Schultze Granite has been known since the mid-1910s, when the Copper Springs Mining Company was formed to explore and develop a copper prospect along Copper Springs Canyon (Figure 6). A number of short tunnels at the site, aggregating approximately 1,400 feet in length, encountered leached cap and copper carbonates (Weed, 1922).

Exploration programs at the site included five churn drill holes during 1948, five or six widely spaced drill holes by Bear Creek Mining Company during the late 1950s, seven shallow drill holes by the Kerr-McGee Corporation in 1964 and several drill holes by the Cities Service Company during the late 1960s. These programs identified the presence of widespread sub-economic primary copper mineralization (averaging 0.14% copper) underlying a 40 to 50-foot thick zone of secondary (chalcocite) enrichment that assayed approximately 0.40% copper (Corn, 1990).

4.25 Azurite Prospect

Located along the northern range front of the Pinal Mountains, approximately 3.5 miles southeast of the Miami (Figure 6), the presence of copper at the Azurite mine has long intrigued prospectors.

Inspiration Consolidated Copper completed surface mapping, a geophysical survey (i.e., Induced Potential or IP survey) and a 16-hole diamond drilling program (3,624 feet) at the site during 1968, which identified a resource of 1.7 million tons, averaging 0.26% copper, in the small, fault bounded sliver of mineralized Pinal Schist that outcrops along the range front. Miami Copper Company and the Phelps Dodge Corporation each completed three deep exploration drill holes (up to 2,400 feet) in an unsuccessful search for concealed mineralization in the hanging wall of the range front fault (Gatchalian, 1975).

5 RECLAMATION ACTIVITIES

Initial release of contaminants from mine and processing sites along Pinal Creek occurred shortly after silver mining activities began in the Globe Hills during the mid-1870s (Anonymous, 2012). Although minor at first, impacts grew as widespread development of the region's copper resources at Miami during the early 20th century greatly expanded the area impacted by this activity. By the early 1940s, large scale mining operations and their accompanying environmental impacts had spread to the portions of the adjacent Pinto Creek watershed with the development of the Castle Dome mine at Porphyry Mountain.

Like many old mineral districts throughout the western United States, the mines in the Globe-Miami area operated nearly a century before legislation during the late 1960s and 1970s required steps to be taken to minimize their negative impacts on the environment. Since that time, copper producers in the Globe-Miami area have committed substantial resources to bring their operations into compliance with evolving federal, state and local environmental regulations (Bingham and Baltzer, 2001).

Today's mining practices and reclamation activities are designed to mitigate environmental impacts resulting from mining and processing the ores with a goal of restoring mined lands to a natural or semi-natural state once mining has been completed. Efforts have been made to improve the quality of the region's water and air, restore dormant habitats, and develop new landscapes to return the site to beneficial post-mining land use (Freeport-McMoRan, Inc., 2014).

5.1 Nature of the Challenge

During the course of mining and treatment of copper ores in the Globe-Miami area, oxidation of pyrite and to a lesser extent, other sulfide minerals within the mine wastes and tailings produces a weak sulfuric acid solution when combined with oxygen and water. Known as acid mine drainage, it commonly contains elevated levels of dissolved contaminants.

Direct exposure to these contaminants from consumption of contaminated surface water or groundwater or through the ingestion or inhalation of contaminated soil particles may pose a risk to public health and the environment. Major contaminants commonly identified include aluminum, arsenic, beryllium, cadmium, copper, cobalt, iron, manganese, nickel, sulfate, zinc, and sulfuric acid. Other contaminants may also include elevated levels of uranium, radium, fluoride, chromium, lead, mercury, and high levels of dissolved solids (Anonymous, 2012).

The two principal aquifers located within the Upper Pinal Creek Basin (Figure 10) include the Gila Conglomerate (QTg) and the shallow alluvial aquifer (Qal) (Neaville and Brown, 1994). The Gila Conglomerate (Figure 8) is the main source of water for domestic and industrial use. Its significant amount of calcium carbonate, which neutralizes acidic water and lower permeability, protects it from extensive contamination. Consequently, contamination resulting from metal-laden acid mine drainage is largely confined to the shallow alluvial aquifer (Figure 8) and surface waters extending from the upper portion of Bloody Tanks Wash and Russell Gulch, through Miami Wash to lower Pinal Creek, a distance of about 10 miles (Anonymous, 2012).

Groundwater contamination of the alluvial aquifer has been slowly moving downstream for at least 90 years. Initially being recognized in the Miami Wash area during the 1930s, it gradually expanded to the first public water wells during the late 1940s and eventually reached private water wells along Pinal Creek downstream from the mineral district during the 1970s (Anonymous, 2012).

Although the presence of contaminated groundwater had been long recognized in the mineral district, it was not studied until 1979 (Envirologic Systems, Inc., 1983). This research as well as later studies by the U.S. Geological Survey documented the release of contaminants and other hazardous materials from all of the major mining operations and treatment sites, including but not limited to process solution ponds, tailings impoundments, leach dumps, and waste dumps as well as from stormwater runoff (Eychaner, 1988, 1989, 1991; Eychaner and Stollenwerk, 1985, 1987; Haschenburger, 1989). Erosion of waste dumps and tailing impoundments has contaminated downstream drainages. Dust from wind-blown tailings and emissions from copper smelters have also contributed to the widespread pollution of the region (Anonymous, 2012).

5.2 Remediation and Reclamation

In July 1986, Inspiration Consolidated Copper Company was cited for violating the Clean Water Act of 1972 by the U. S. Environmental Protection Agency for discharging acidic process solutions from Webster Lake (a large process solution impoundment) into Miami Wash. They were also cited for the mixing of metal-contaminated groundwater and surface waters near the confluence of Miami Wash and Pinal Creek (Anonymous, 1999).

The Water Quality Assurance Revolving Fund (WQARF – Arizona's State Superfund Program) was created under the Environmental Quality Act of 1986 to support Arizona Department of Environmental Quality's efforts to identify, prioritize, assess, and resolve threats of contaminated soil and groundwater sites throughout the State.

Former and existing mining operations bordering Pinal Creek were placed on Arizona's WQARF Priority List by the Arizona Department of Environmental Quality in May 1989. A consortium known as the Pinal Creek Group, composed of the Cyprus Minerals Company and Magma Copper Company was formed in May 1990 to voluntarily conduct remedial investigations on how to proceed with the clean-up of the area and implement these reclamation efforts (Anonymous, 1999).

Reclamation efforts have employed several strategies designed to deal with groundwater contamination issues in the Globe-Miami area. Remedial pumping from water wells along Webster Gulch, Miami Wash (Kiser Basin) and other locations was designed to reduce the acidity of the acid-metal plume and impede the downstream movement of the leading edge of the plume. Contaminated water from this remedial pumping operation was directed to various impoundment sites, including the Diamond H pit, where it was stored for reuse by on-going mining operations (Anonymous, 1999).

The Pinal Creek Group began a water well testing and replacement program for the owners/users of private water wells in 1994 (Anonymous, 2012). This ongoing program offers free well testing for any privately owned wells that may have been contaminated and depending on the results, a free replacement well installed deep within the uncontaminated Gila Conglomerate.

Located approximately 5.8 miles north of the confluence of Miami Wash and Pinal Creek, the Lower Pinal Creek water treatment plant was commissioned in November 1999 to treat groundwater at the leading edge of the acid-metal plume (Figure 98). In January 2001, a groundwater barrier (i.e., soil-cement-bentonite slurry wall) was completed at this site to provide downstream containment of the plume. This permitted full scale groundwater extraction from just above the barrier for neutralization and metal removal at the Lower Pinal Creek water treatment plant (Anonymous, 2012).

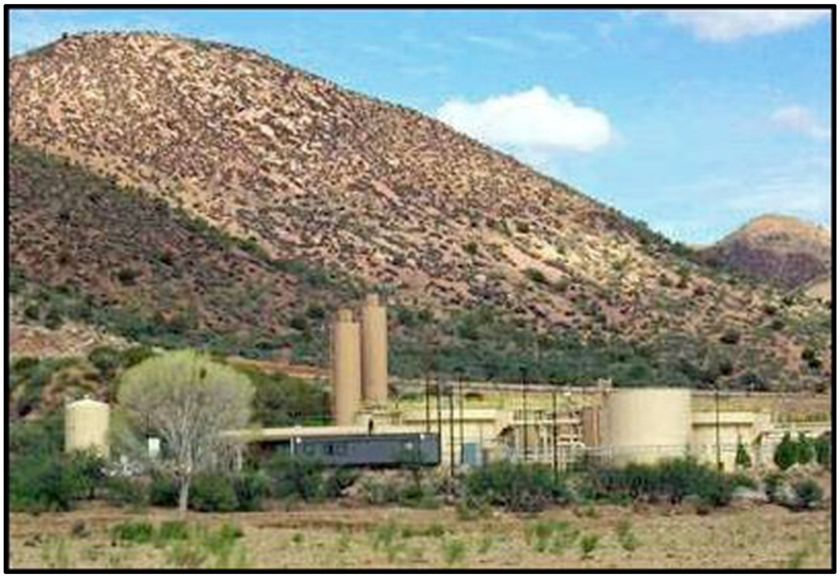


Figure 98. Lower Pinal Creek water treatment plant (photo from Arizona Department of Environmental Quality)

In May 2001, a second treatment plant was completed adjacent to the Diamond H pit to treat contaminated water pumped from Miami Wash. Threatened by a failure of the Diamond H pit wall during the summer of 2004, the Diamond H water treatment plant was subsequently relocated to a more secure site (Anonymous, 2012).

Figure 99. Cattle grazing on a reclaimed tailings impoundment at Inspiration, circa 2013 (photo by David Briggs)

Over the years, a number of heavily polluted sites that were sources for much of the contamination have been reclaimed. This included recontouring waste dumps, leach dumps and tailings impoundments to ensure drainage channels limited percolation. Stormwater was diverted around impacted areas into existing drainages. Reclaimed sites were covered with approximately 2 feet of topsoil and seeded with native grasses and shrubs to help stabilize slopes and promote revegetation and wildlife habitat. Cattle have been also employed to assist these efforts by adding natural organic components to the soil (Figure 99) (Jones, 1991).

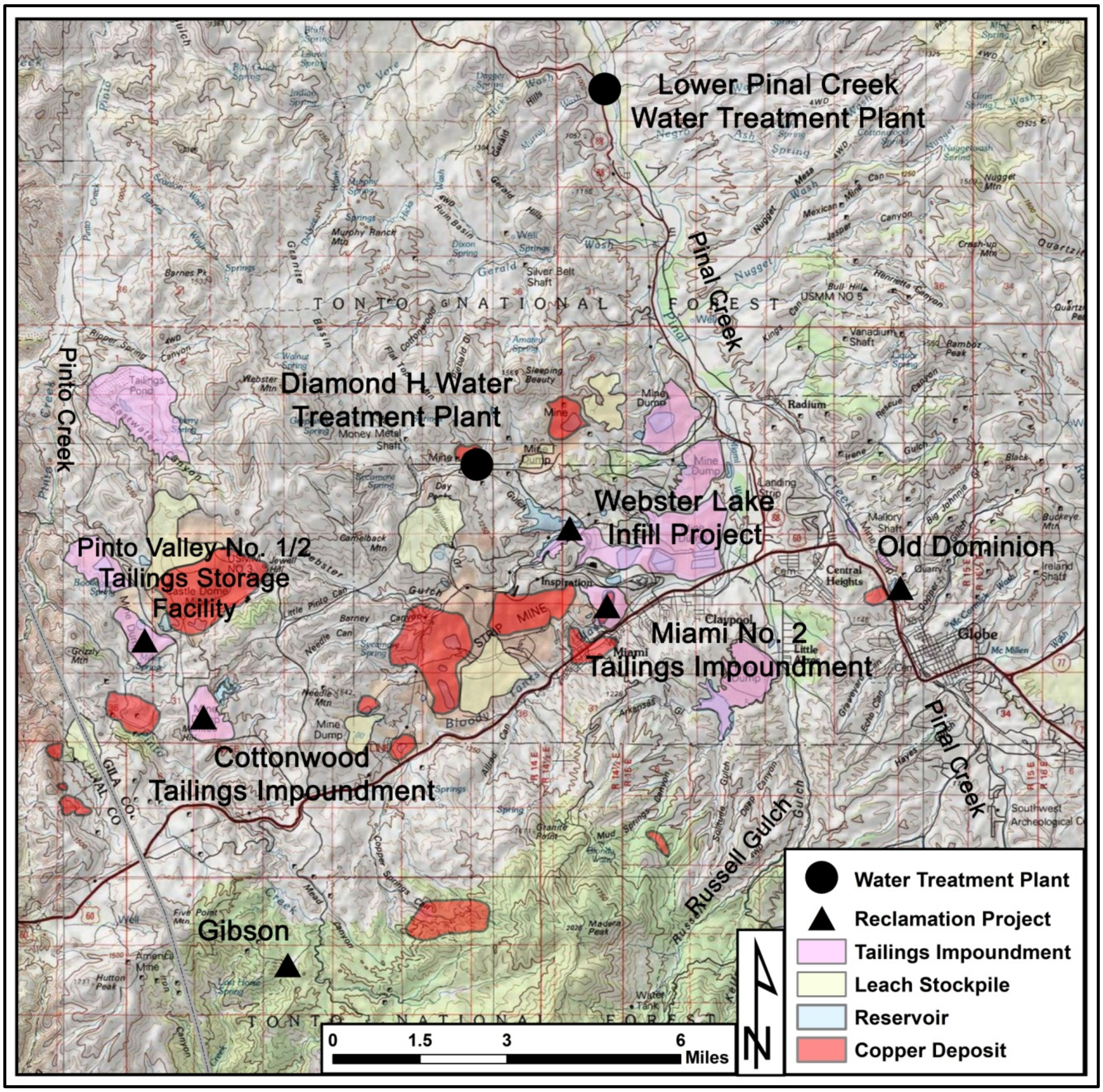


Figure 100. Map showing location of water treatment plants and major reclamation projects in the Globe-Miami area.

Several of the more significant reclamation projects in the Globe-Miami area include the Webster Lake infill project, Gibson mine, Cottonwood tailings impoundment and reservoir, Miami No. 2 tailings impoundment, Pinto Valley No. 1/2 tailings storage facility, and the Old Dominion mine/smelter site (Figure 100).

5.3 Webster Lake Infill Project

The Webster Lake infill project was located at the confluence of Upper Webster Gulch and Lost Gulch, approximately 2 miles west-northwest of where Webster Gulch empties into the Miami Wash (Figure 101). Designed to provide passive and stable routing of uncontaminated stormwater flows from Lost Gulch and Myberg Basin around disturbed areas, this project included the remediation and reclamation of the Webster Lake process solution pond along Lost Gulch, vat leach plant tails along upper Webster Gulch, and reclamation of the adjacent 31 and 94/95 overburden stockpiles (Freeport-McMoRan Copper and Gold, Inc., 2008b).

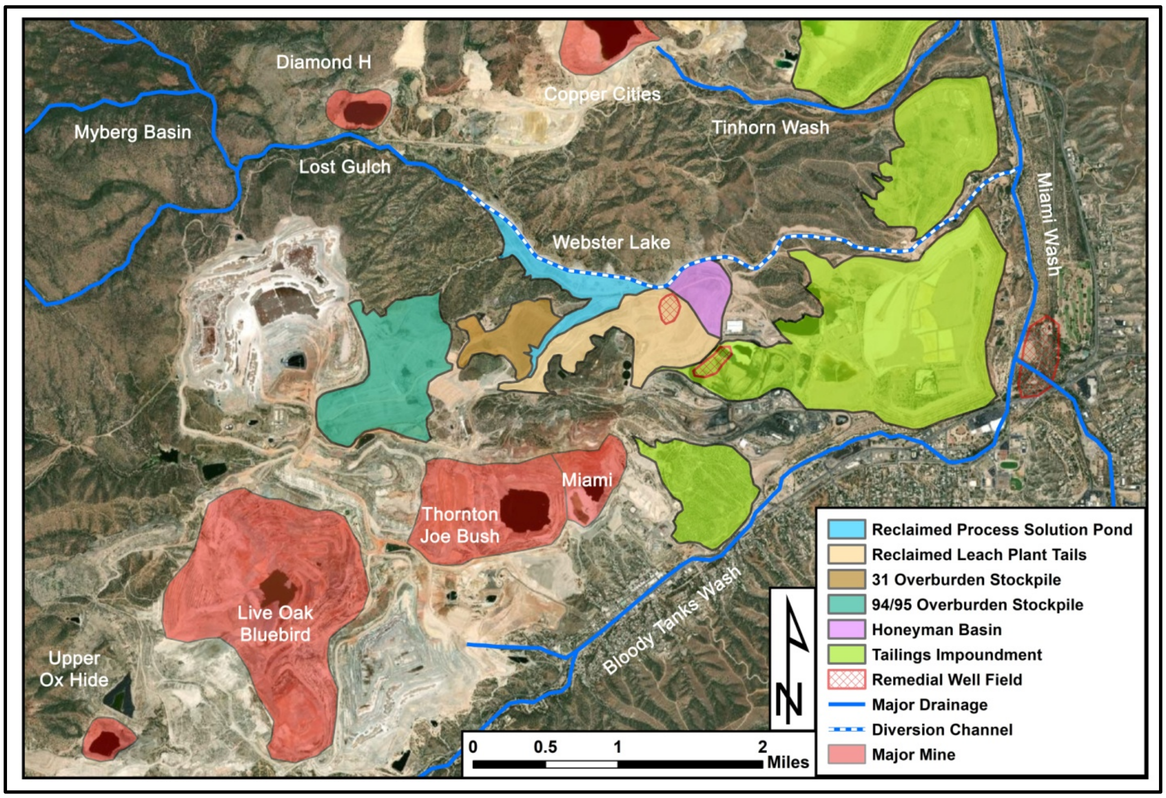


Figure 101. Satellite photo showing major components of Webster Lake in-fill project (modified from Freeport-McMoRan Copper and Gold, Inc., 2008b)

Tailings from the leach plant/tankhouse complex located in Upper Webster Gulch included approximately 79 million tons of tailings from the acid-ferric-sulfate leaching process employed from 1926 until 1956 and about ten million tons of tailings from a vat-leach process from 1966 until 1976. These tailings were composed of approximately 28% gravel, 66% sand and 4% fines. The pH of the water contained within the tails ranged from 3 to 4. Tailings from the acid ferric sulfate leach process contained approximately 10% acidic water by weight with about 10,000 milligram/liter iron (Freeport-McMoRan Copper and Gold, Inc., 2008b).

By the early 1940s, a process solution pond known as Webster Lake was formed at the confluence of Webster Gulch and Lost Gulch, when tailings from the vat leaching operation blocked the channel of Webster Gulch at Webster Narrows. Upper Webster Gulch formed the southern arm of the pond, while the northern arm of the pond occupied Lost Gulch (Freeport-McMoRan Copper and Gold, Inc., 2008b).

In addition to stormwater collection, Webster Lake was also used for process water storage and mine wastewater disposal. At its maximum height, the lake covered an area of about 130 acres and contained approximately 1.7 billion gallons of low pH metal-laden water. Discharges from the lake occurred as seepage into the underlying alluvium and shallow bedrock along Webster Gulch as well as occasional overflow events that followed large storms. Overflow from the spillway was directed to a storage site in Honeyman Basin (Figure 101) or was conveyed via a system of unlined channels to Miami Wash (Freeport-McMoRan Copper and Gold, Inc., 2008b).

Covering an area of 111 acres along the northwest side of Upper Webster Gulch, the 31 overburden stockpile contains 28 million tons of unreclaimed Pinal Schist and Schultze Granite, which had been mined between 1984 and 2001. The 94/95 stockpile was located in the upper reaches of Upper Webster Gulch and Lost Gulch. Covering an area of 341 acres, it contains approximately 68 million tons of mostly Pinal Schist and Gila Conglomerate mined during the same time period. Testing of overburden contained in both stockpiles determined it to be chemically inert (Freeport-McMoRan Copper and Gold, Inc., 2008b).

Inspiration Consolidated Copper Company began dewatering Webster Lake during the summer of 1986, which was largely completed by June 1988. The first study on the remediation and reclamation of the Webster Lake area was completed by Inspiration Consolidated Copper in 1987 (Sergeant, Hawkins & Beckwith, 1987). Over the next two decades, a number of alternatives designed to resolve various issues on remediation and reclamation of Webster Lake were evaluated, culminating in Freeport McMoRan's plan submitted to the Arizona Department of Environmental Quality in February 2008 (Freeport-McMoRan Copper and Gold, Inc., 2008b).

During the interim, remedial measures designed to minimize further contamination included the installation of seven groundwater extraction wells near the mouth of Webster Gulch. The first of these wells was commissioned in December 1987, with the additional wells added in 1991 and 2006. These wells were augmented by the 48 shaft and drift, which were driven beneath the alluvium near the mouth of Webster Gulch in October 1992. During 1998, the WX Remedial Wellfield (three wells) and LPX Remedial Wellfield (three wells) were installed along Webster Narrows immediately below the former Webster Lake footprint and down-gradient from the Vat Leach Plant Tails footprint, respectively. As of December 31, 2004, these well facilities collectively removed about 2.7 billion gallons of contaminated water (Freeport-McMoRan Copper and Gold, Inc., 2008b).

Figure 102. Webster Lake prior to reclamation (2008 left) and during reclamation (2013 right) (photos from Freeport-McMoRan, Inc., 2014)

Construction of the Webster Lake infill reclamation project began in 2009 and was completed in late 2015 (Figure 102) (Arizona Department of Environmental Quality, 2021). In restoring the stream channel that had not been "free flowing" since the 1930s, this project backfilled the Webster Lake bed and Honeyman Basin with Gila Conglomerate and established surface channels designed to safely convey a 100-year, 24-hour storm event in the Myberg watershed around the contaminated site. The vat leach plant tailings and overburden stockpiles were covered with Gila Conglomerate to provide erosion control, protect surface water quality and provide a growth medium for revegetation at the site. Stormwater draining from reclaimed sites is collected in downstream catchment basins, where it is either evaporated or pumped to the Thornton-Joe Bush pit (Figure 101) (Freeport-McMoRan Copper and Gold, Inc., 2008b).

5.4 Gibson Mine Reclamation Project

Following a number of large storms the presence of turquoise-colored water in drainages downstream from the Gibson copper mine (Figure 100) was reported to the Arizona Department of Environmental Quality in November 1990. An investigation swiftly confirmed the source of this pollution was the Gibson mine, where the leach solution ponds had been overwhelmed by heavy precipitation and overflowed into Pinto

Creek. Abandoned in-place solution mining operations were freely discharging acidic copper-bearing solutions from several adits. Acid rock drainage, formed from the oxidization of sulfides in more than 100,000 tons of waste rock and tailings that were not properly contained was also being released into the environment (Eshraghi and Ford, 2015). A subsequent water quality survey confirmed the Gibson mine contributed more than 90% of the dissolved copper in the upper portion of the Pinto Creek watershed (Anonymous, 2016).

Having not obtained any of the required environmental permits to conduct such a project, the operators of this small scale and poorly funded operation could not be found. In searching for the responsible party, Arizona Department of Environmental Quality turned its attention to the property owners, but could only find one partial owner, the Franciscan Friars of Saint Barbara, who were gifted a 50% interest in Gibson mine by Albert Stevens after his death in 1969 (Eshraghi and Ford, 2015).

With the assistance from the Arizona Department of Environmental Quality, The University of Arizona, BHP Copper, and Quadra Mining, the first phase of reclamation began during 2006 with the excavation and transport of more than 100,000 short tons of contaminated waste rock and vat leach tails for proper disposal on the low-grade leach stockpile at Pinto Valley. Impacted soils underlying the process solution ponds were excavated down to bedrock and disturbed areas re-contoured. This initial phase reduced Gibson's contribution of dissolved copper in Pinto Creek by approximately 50% (Eshraghi and Ford, 2015).

The second phase of reclamation consisted of contouring and stormwater management. It began during 2011. Clean stormwater from undisturbed lands was diverted around disturbed areas and discharged downstream. Stormwater generated from previously disturbed sites, including all previous mining operations, was channeled to newly constructed impoundments that were designed to retain impacted water on the site. More than 30,000-cubic yards of clean soil were distributed over previously disturbed areas and vegetative cover was established. This reduced Gibson's contribution of dissolved copper in Pinto Creek by more than 75% (Eshraghi and Ford, 2015). Since 2017 Arizona Department of Environmental Quality has conducted additional on-site water quality and soil sampling studies to help determine which remedial option is best for this site.

5.5 Cottonwood Reservoir and Tailings Impoundment

Located along Cottonwood Gulch, the unlined Cottonwood tailings impoundment (Figure 100) received tailings from the Castle Dome concentrator from June 1943 until December 1953 and was reactivated in July 1974 to store tailings from the Pinto Valley project. Deactivated during 1984, the surface of the tailings impoundment was graded and covered with a minimum of 6 inches of Gila Conglomerate during 1988 (WestLand Resources, Inc., 2016a). Revegetation with a seed mix of native grasses and live planting of prickly pear and cholla cacti was completed during the spring 1989 (Kelley et al., 2016).

Originally a supernatant pond that was used reclaim water from the Cottonwood tailings impoundment for the milling process, the Cottonwood reservoir is currently utilized as the primary water storage facility for the Pinto Valley operation. However, water continues to infiltrate into the adjacent Cottonwood tailings impoundment. This water is recovered by a seepage collection or reclamation system and used by the milling operations. Evaporation and settling ponds are currently employed to manage stormwater that falls on the impoundment surface (U.S. Forest Service, 2019).

Figure 103. Cottonwood reservoir (foreground) with Cottonwood tailings impoundment (middle left), looking southwest (photo from U. S. Forest Service, 2019)

Final reclamation of the Cottonwood tailings impoundment and reservoir (Figure 103) will be made at the end of active mining operations at Pinto Valley. This will involve draining the reservoir and the disposal of sediments that have accumulated over the years. The bottom of the reservoir will be graded and covered by a 2-foot layer of schist from an adjacent dump. A spillway and culvert will be installed to promote the gradual release of stormwater as the reservoir is allowed to fill naturally from local runoff. Diversion channels around the tailings impoundment may be required to manage stormwater discharging from the reservoir (WestLand Resources, Inc., 2016b).

Final reclamation of the Cottonwood tailings impoundment will include recontouring and covering the embankment face with soil cover, revegetation with a final seed mix and the placement of rock armor at sites susceptible to erosion. Depending on the quantity and quality of the water seepage from the impoundment, it will be discharged directly into Cottonwood Canyon or collected and treated by a passive or active water treatment system. Passive water treatment may include aerobic or anaerobic wetlands or anoxic limestone. Active water treatment may involve chemical treatment or if necessary its disposal in the open pit (WestLand Resources, Inc. 2016b).

5.6 Pinto Valley No. 1/2 Tailing Storage Facility

The Pinto Valley No. 1 and 2 tailings storage facilities were unlined tailings impoundments that were merged over time to form a single tailings storage site (Figure 100). Constructed concurrently and operated from July 1974 until late 1987, this facility contains an estimated 70 million tons of mill tailings, which is covered by approximately 50 to 70 feet of waste rock (U.S. Forest Service, 2019).

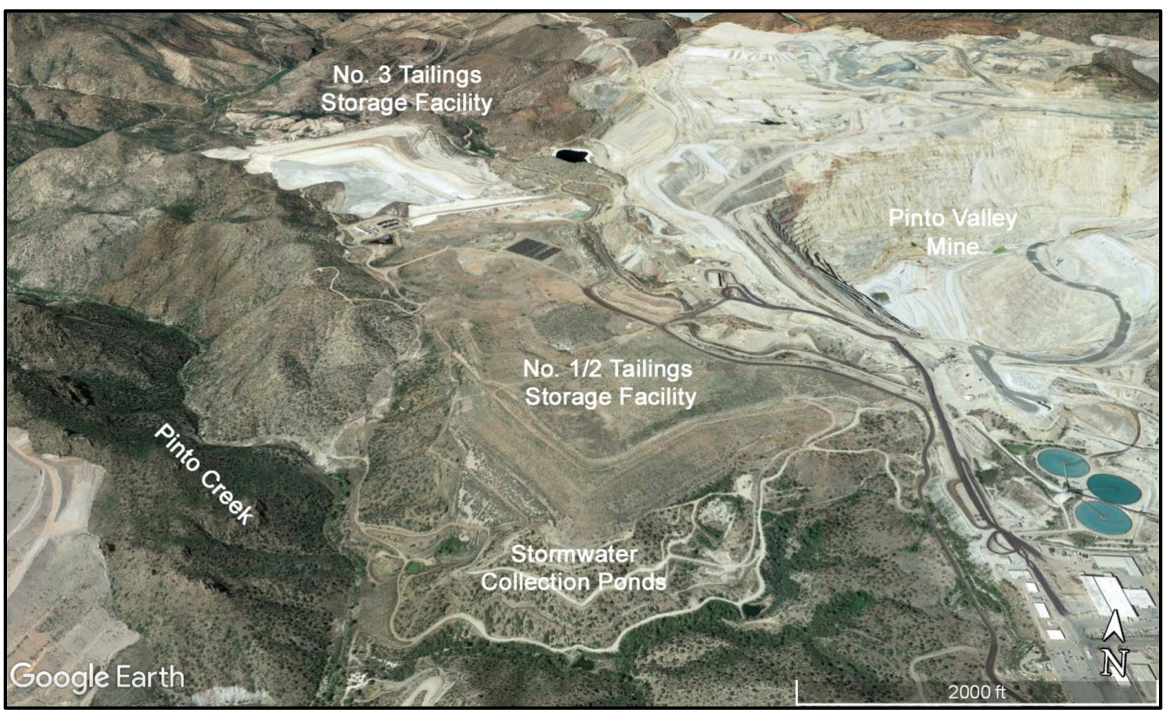


Figure 104. Oblique aerial view of the reclaimed Pinto Valley No. 1/2 tailings storage facility, looking north, circa May 2019 (photo modified from Google Earth)

The No. 1/2 tailings storage facility was covered with 2-feet of Gila Conglomerate and revegetated with a local seed mix during 2011-2013 (Figure 104). The side slopes of the tailings impoundment were also rock armored to protect them from erosion. A system of diversion channels and collection ponds was installed to move stormwater from the reclaimed surface of the tailings impoundment. This water is allowed to evaporate or is pumped to the process solution pond for reuse by the mining operation (U.S. Forest Service, 2019).

5.7 Miami No. 2 Tailings Impoundment

Located northeast of the town of Miami, the Miami No. 2 tailings storage facility (Figure 100) contained tails from ores treated by Miami Copper's concentrator from 1911 until 1932. Between April 1989 and July 2001, Magma Copper Company and its successor BHP Copper reclaimed approximately 38 million tons of this material by hydraulic mining techniques and reprocessed it at their tailings leach plant, recovering copper using SX-EW technology. Waste from the tailings retreatment operation was pumped via a 4.5-mile slurry pipeline to the abandoned Copper Cities pit (McWaters, 1990).

Figure 105. Oblique aerial view of the reclaimed Miami No. 2 tailings impoundment, looking northwest, circa May 2019 (photo modified from Google Earth)

Final reclamation of tailings that remained in the Miami No. 2 tailings impoundment at the completion of the tailings retreatment operation began during the spring of 2005. At that time, BHP Copper widened Bloody Tanks Wash adjacent to their Miami No. 2 tailings impoundment and removed the retaining wall that separated the wash from the tailings impoundment. Tailings that remained behind the retaining wall were relocated outside of the 100-year flood plain. Old processing and support facilities were removed from the site (Arizona Department of Environmental Quality, 2021).

During the summer of 2005, the remaining tails were consolidated, re-contoured, and capped with clean fill (i.e., Gila Conglomerate). Drainage channels, evaporation ponds and sediment ponds were established to contain stormwater runoff on the site (Figure 105). Excess water collected by this system is pumped to the top of a caved zone above the former Miami underground operation. Capping and revegetation of the No. 2 tailings impoundment was completed in early 2006 (Arizona Department of Environmental Quality, 2021).

5.8 Old Dominion Mine, Mill and Smelter Sites

Since its last recorded production during late 1950s, the Old Dominion mine and smelter site remained idle, except for serving as the source of water used by mining operations at Miami, Copper Cities and Pinto Valley (Figure 100).

In response to a consent decree with the U. S. Environmental Protection Agency and Arizona Department Environmental Quality, Magma Copper Company commenced environmental studies at Old Dominion in 1994, which were designed to develop measures to avoid potential water quality impacts along Pinal Creek. Magma Copper and its successor BHP Copper sampled the groundwater, surface water and soils from around waste dumps, slag pile and mill tailings at the Old Dominion site to evaluate impacts along Pinal Creek. Results from this study demonstrated stormwater runoff from the site was compromised by the tailings and waste rock, but constituent concentrations in groundwater did not exceed Arizona Aquifer Water Quality Standards (BHP Copper, Inc., 2010).

BHP Copper began remediation efforts at the site in September 2002, employing Neilsons Skansk, Inc. a specialty mine remediation contractor from Cortez, Colorado and E & N Mining and Construction, Inc., an Arizona-based civil earthworks contractor (BHP Copper, Inc., 2010). In addition to removing outdated and unused structures from the property, this work included re-contouring the mill tailings impoundments and waste rock dumps and the placement of an impermeable barrier over these areas to minimize further contamination. A stormwater diversion system was installed to prevent acid-metal runoff from reaching Pinal Creek. Revegetation of the Old Dominion waste rock and tailings impoundments was substantially completed in the January 2004 (Arizona Department of Environmental Quality, 2021).

BHP Copper completed the capping and/or removal of other numerous waste rock dumps along Copper Gulch during 2008. Material from several of these waste piles was dumped in the caved zone located above the former Miami Copper underground operation, where its copper content was gradually recovered by the in-place solution mining operation until August 2013 (Arizona Department of Environmental Quality, 2021).

During the course of planning the reclamation of the Old Dominion property in 2000, a number of Globe-Miami residents expressed a desire to preserve as much of the remaining historic infrastructure as possible and use the site to promote the region's mining heritage. BHP Copper in partnership with the City of Globe, Gila County Historical Society and other local groups decided to establish the Old Dominion Historic Mine Park (Wilshire, 2017).

Much work had to be done before the proposed public park became a reality. In addition to remediation and reclamation of the site, BHP Copper had to deal with many safety issues before public access was permitted. Legal easements and site insurance were obtained. Unsafe areas such as mine shafts, tunnels, old buildings, and other structures had to be made inaccessible to the public (Wilshire, 2017).

Figure 106. Old Dominion Historic Mine Park (photo from City of Globe)

Historical research was performed to prepare educational descriptions with old photographs of the various mining facilities and other artifacts displayed at the site. Large picnic pavilions, smaller ramadas with picnic tables, a public restroom, and a water fountain were constructed to accommodate visitors as they explore the 13 hiking trails that wind their way through the Old Dominion Historic Mine Park (Figure 106), which was officially dedicated in February 2011 (Wilshire, 2017).

6 EXPLORATION AND FUTURE POTENTIAL

Since the discovery of copper in the Globe-Miami Mining Region during the late 1800s, exploration has evolved from the solitary prospector and mule to sophisticated, multi-million dollar programs designed to search for concealed targets that are covered by several thousand feet of barren post-mineral cover.

6.1 Advances in Exploration

Prior to the turn of the 20th century, early exploration activities in the Globe-Miami mining region as well as other areas throughout the West involved excavating prospect pits, shallow shafts or adits to access potential mineralization at favorable sites. More often than not, economic mineralization was not encountered and the site was abandoned as prospectors redirected their efforts elsewhere.

In the event of a discovery, the vein or lodes were then followed and exposed by a system of horizontal and vertical underground workings (i.e., drifts, cross-cuts, raises and winzes). Although bulk samples were occasionally taken at this stage, the walls of the underground workings were systematically sampled in a process known as "blocking out the ore", to obtain a rough approximation of the size and grade of the ore body (Parsons, 1933).

These early methods of evaluating an ore body's potential worked well with smaller vein deposits such as the Old Dominion mine, where it served a dual purpose of also providing access to excavate any ore that might be discovered. However, early evaluation of larger, lower grade porphyry copper targets at Bingham Canyon and Miami by similar methods showed this process to be very risky due to its costly, labor intensive and time-consuming nature (Parsons, 1933). A cheaper method was needed to test these targets.

Initially adapted to examine porphyry copper deposits near Ely, Nevada around 1906 and at Ray, Arizona in 1908, churn drilling was found to be more economical than diamond drilling, which was initially used to explore the Mesabi Iron Range of Minnesota in 1890. During the early 20th century, more than 90% of porphyry copper ores were delineated by churn drilling (Parsons, 1933).

A churn drill is a type of percussion drill, which was employed to bore a vertical hole in relatively soft rock (Figure 107). Powered by steam or gasoline, it was composed of a string of tools, consisting of a tempered steel bit attached to a heavy stem, which was attached to a rope or wire cable that was repeatedly raised and allowed to drop, pulverizing the rock in the bottom of the hole with successive blows. Capable of drilling to depths of up to 1,500 feet, samples in the form of sludge were bailed or pumped out at 5-foot intervals to determine rock type, its mineralogical composition and grade of the ore (Parsons, 1933). The Inspiration and Miami deposits were initially examined by churn drilling programs in January 1909 and early 1910, respectively.

Figure 107. Churn drill along Pinal Creek near the Old Dominion mine, circa 1916 (photo from Gila County Historical Museum)

Initially employed at Miami in 1912 (Burgin, 1976), diamond drilling employs a string of drill pipe with a hollow bit attached to its working end. Industrial diamonds are embedded in the outside rim and annular face of a soft steel drill bit. Powered by steam or gasoline, the rotating drill bit (300 to 800-rpm) cuts through rock, collecting a cylindrical-shaped core sample in the hollow pipe. With each 2 to 8 feet of advance in the drill hole, it was necessary to pull the entire string of drill pipe from the hole to recover the sample behind the bit (Parsons, 1933). Development of the wire-line core retrieval system by Boart Longyear in 1958 eliminated this expensive and time-consuming process, and allowed the core to be retrieved without removing the drill pipe from the hole.

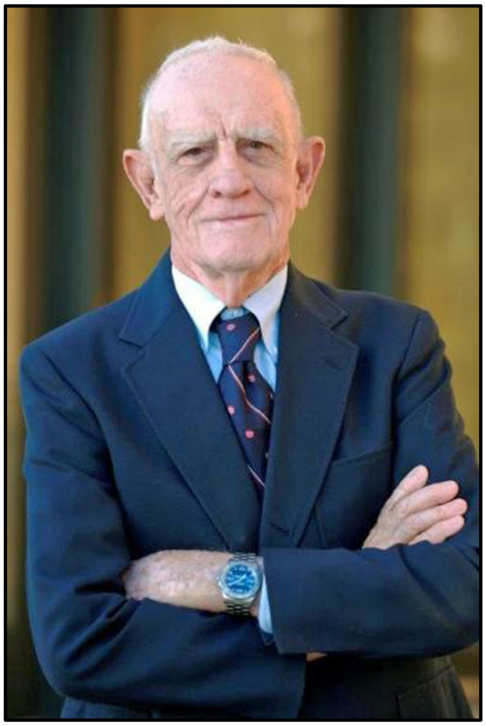
While a number of recent porphyry copper discoveries have been credited to geochemical and geophysical surveys, the ultimate determination of their economic value is currently based on data mainly gathered by diamond drilling programs. Capable of boring a hole at any angle, diamond drilling provides information about the nature and spatial distribution of lithologies, alteration and mineralization. It also supplies good quality samples for assaying and study by geologists. Geotechnical data collected from oriented core samples is used to plan open pit and underground mines, while metallurgical data from large diameter core samples are used to design ore treatment facilities.

6.2 Evolution of our understanding of Porphyry Copper Systems

Early geologists and prospectors understood the significance of leached capping and focused their efforts on areas where it outcropped at the surface, which were known to commonly overlie enriched copper mineralization at depth. By the early 1920s, many of the obvious exploration targets in the Globe-Miami Mining Region had been examined to some extent, successfully identifying the large zones of secondary chalcocite enrichment that were the source of much of the area's early copper production. This was followed by the development of the district's large mixed oxide-sulfide resource. Examination of areas covered by post-mineral sediments was limited to searching for extensions of the enrichment blanket (i.e., Miami East) and exotic copper mineralization (i.e., Van Dyke) in the downthrown hanging wall of the Miami normal fault.

Due to the low-grade nature of the primary sulfide mineralization underlying the enrichment blanket, there was little incentive to study its nature, distribution and associated alteration assemblages until the early 1950s, when mining operations at Inspiration began encountering increasing amounts of chalcopyrite in the ores (Hardwick, 1963). This incentive was further enhanced during the 1960s with Cities Service's evaluation of the primary sulfide resource at Porphyry Mountain (Burgin, 1976).

The first accepted conceptual model for porphyry copper systems was proposed by J. David Lowell (Figure 108, left) and John M. Guilbert (Figure 108, right). Contributing to the understanding of alteration and mineral zoning in this deposit type, their model was based on research of the relatively intact porphyry copper system at San Manuel in Arizona (Lowell and Guilbert, 1970). However, its application to deposits in the Globe-Miami Mining Region was complicated by post-mineral tilting and structural dismemberment of these porphyry copper systems (Maher, 2008).



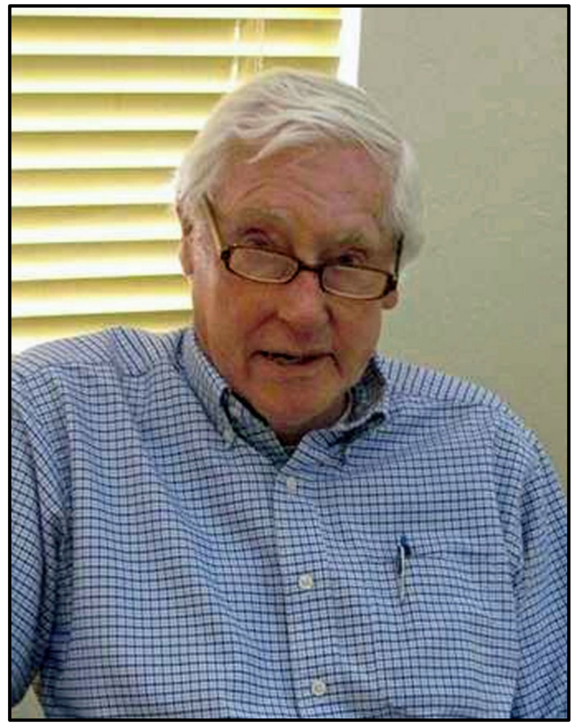


Figure 108. J. David Lowell (1928-2020) (left) and John M. Guilbert (1931-2017) (right), authors of the first conceptual model of porphyry copper systems (photos from University of Arizona and Arizona Daily Star)

Over the next several decades, geological studies have enhanced our knowledge of Middle Tertiary extension and its impact on the Laramide porphyry copper occurrences of Arizona's Copper Triangle (Keith, 1986; Dickinson, 1991; Corn and Ahern, 1994; Wilkins and Heidrick, 1995; Richard and Spencer, 1998; Seedorff et al., 2008; Maher, 2008).

In an effort to better understand a dozen or more Laramide (i.e., Late Cretaceous to Paleocene – 74 to 61 Ma) porphyry copper systems located in a complexly faulted region of east-central Arizona, Maher (2008) restored the post-mineral extensional deformation, which occurred from 25 to 15 million years ago. Including the porphyry copper systems in the Globe-Miami Mining Region, this research had important implications on the appraisal of the area's mineral potential and identification of concealed exploration targets shown in Figure 109.

Upon completing his Ph.D. degree at the University of Arizona in late 2007, Dave Maher joined Bronco Creek Exploration, who subsequently acquired property positions on a number of porphyry exploration targets based on his research, including several in the Globe-Miami Mining Region.

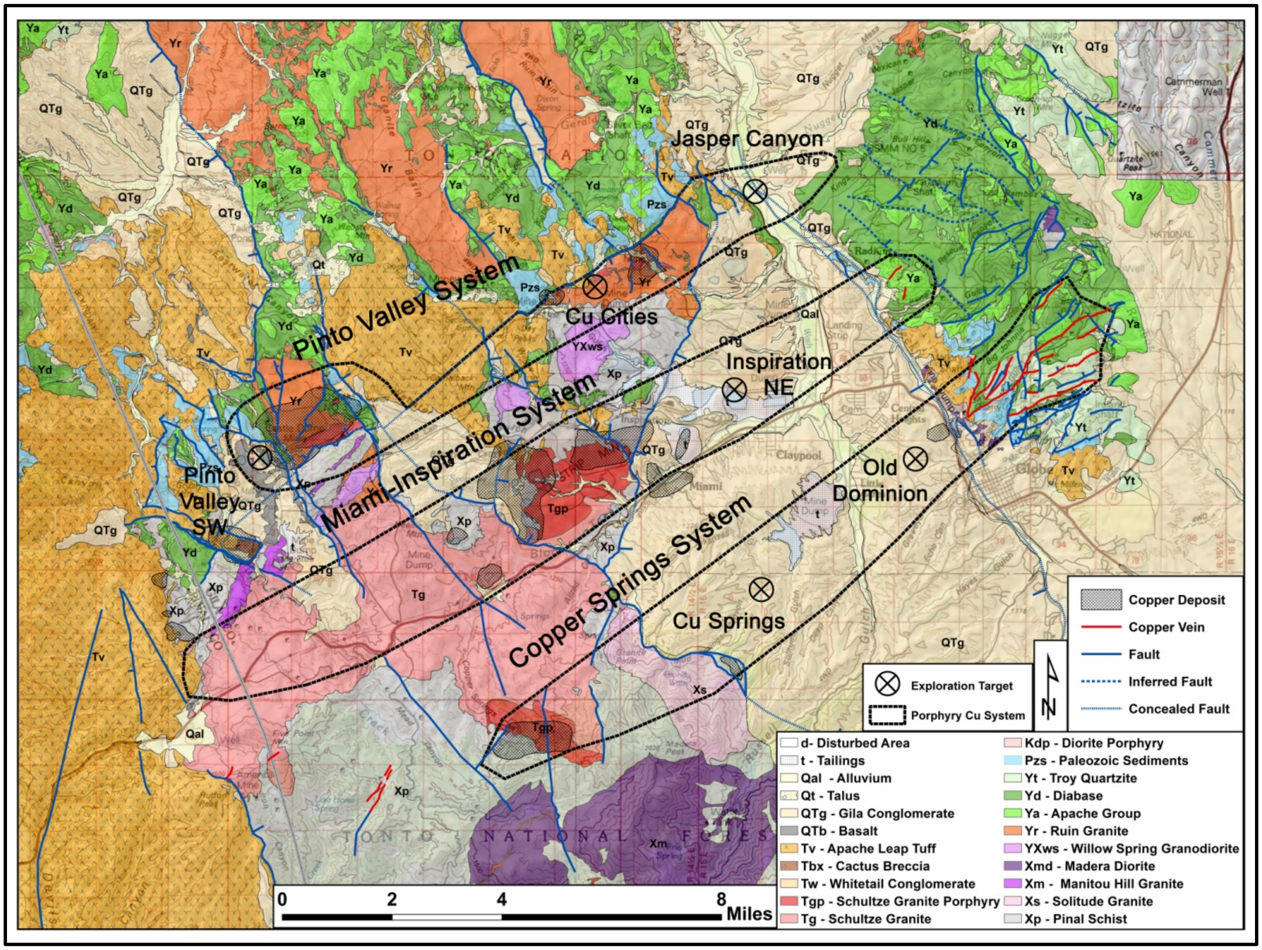


Figure 109. Geologic map showing structurally dismembered porphyry copper systems and potential exploration targets in the Globe-Miami Mining Region (modified from Maher, 2008)

Anglo American Exploration (U.S.A.), Inc. acquired an option on the Cu Springs target in February 2017 and proceeded with geophysical surveys of the area to constrain depths to bedrock and identify drill exploration targets (Figure 109). Over the next two exploration seasons, they completed seven deep diamond drill holes, totaling approximately 27,800 feet (Figure 110). Although this effort encountered favorable alteration assemblages and anomalous concentrations of copper; Anglo American relinquished its option on Cu Springs in late 2019 (EMX Royalty Corporation, 2020a).

In December 2018, Bronco Creek Exploration, Inc. and South 32 USA Exploration, Inc. formed a regional strategic alliance, where South 32 agreed to provide annual funding for Bronco Creek personnel to identify properties suitable for further exploration. Jasper Canyon was one of these projects in the Globe-Miami Mining Region that was selected for this program (Figure 109) (EMX Royalty Corporation, 2020a).

Figure 110. Exploration drilling at Cu Springs, looking southwest (photo from EMX Royalty Corporation, 2020b)

6.3 Future Potential

During its first four decades of the Globe-Miami region's productive history, copper output rose slowly but steadily until the beginning of World War I, when it doubled due to the increased demand for the red metal (Figure 111). With the exception of a sharp, post-World War I decline during 1921, annual copper production remained at 150 to 200 million pounds until the height of the Great Depression during the early 1930s, when mining all but ceased. Copper production slowly resumed during the late 1930s and with increased demand during World War II returned to pre-Depression levels, where it remained until the mid-1970s.

At that time, commissioning of the Pinto Valley operation pushed annual production levels higher, reaching its peak of 350 million pounds in 1997. Copper production declined rapidly thereafter with the temporary suspension of mining operations at Pinto

Valley in February 1998 and Inspiration in January 2002. Leaching from existing dumps and in-place solution mining operations continued to produce copper cathode for several years until Inspiration and Pinto Valley resumed conventional mining operations in 2010 and 2012, respectively.

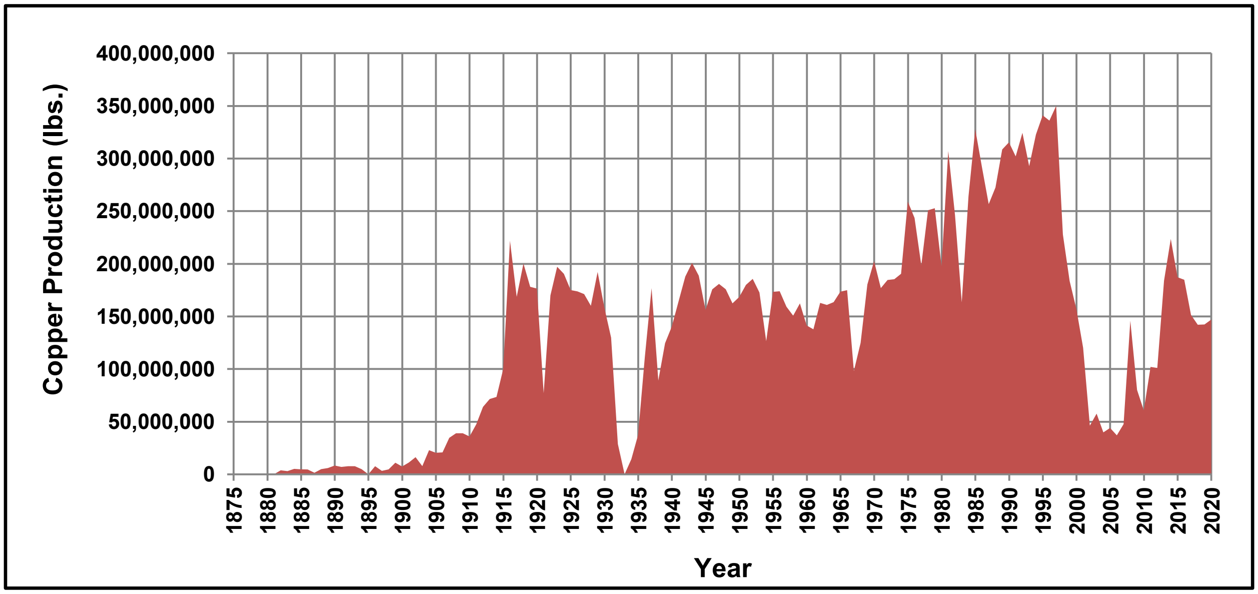


Figure 111. Annual copper production for the Globe-Miami Mining Region from 1875-2020 (modified from U. S. Bureau of Mines Data)

Table 23. Unmined measured, indicated, and inferred mineral resources (excludes proven and probable reserves) in the Globe-Miami Mining Region (data for Cactus-Carlota, Eder North, Eder Middle, and Eder South have been estimated from reported data; unmined hypogene resources that remain at Inspiration and Copper Cities are unavailable)

Project	Mineral Resources Short Tons	Cu %	Mo %	Contained Copper lbs.	Contained Molybdenum lbs.	References
Pinto Valley	1,202,000,000	0.29	0.005	7,030,000,000	121,200,000	Capstone Mining Corp., 2021
Miami East	100,000,000	1.44	-	2,880,000,000	-	Magma Copper Co. 1995
Van Dyke	292,845,000	0.29	-	1,724,000,000	-	Bird et al., 2020
Miami	236,000,000	0.31	-	1,448,000,000	-	BHP Billiton PLC, 2004
Old Dominion	40,000,000	1.20	-	960,000,000	-	Kinnison, 1977
Cactus-Carlota	55,218,000	0.42	-	464,000,000	-	Wellman et al., 2006
Copper Springs	20,000,000	0.40	-	160,000,000	-	Corn, 1990
Eder South	17,357,000	0.26	-	91,000,000	-	Wellman et al., 2006
Eder North	13,565,000	0.29	-	79,000,000	-	Wellman et al., 2006
Azurite	1,700,000	0.26	-	9,000,000	-	Gatchalian, 1975
Eder Middle	2,064,000	0.14	-	8,000,000	-	Wellman et al., 2006
Total	1,980,749,000	0.38	-	14,853,000,000	121,200,000	

After one and half centuries of mining activity, the Globe-Miami Mining Region is showing its age. Despite having passed its prime during the 1980s and 1990s, its future remains relatively bright as production continues at several sites, identified mineral resources (Table 23) are readied for production, exploration opportunities are evaluated and innovative metallurgical processes are developed to cope with future challenges.

Mining continues at Pinto Valley, where Capstone Mining produces approximately 130 million pounds of copper, annually. At its current level of production, Pinto Valley has sufficient ore reserves to sustain mining operations until 2039 (Capstone Mining Corporation. 2021a). Limited mining also continues at Eder South, a small satellite deposit at KGHM's Carlota project.

While Freeport-McMoRan ceased active mining operations at Inspiration in September 2015, copper recovery from residual leaching of material already placed on stockpiles is expected to remain economically viable through 2025. Freeport-McMoRan continues to treat copper concentrates from its domestic mining operations at its Miami smelter and high-quality copper rod is sold to wire and cable manufacturers. Sulfuric acid, a by-product of the smelting process, is used to recover copper at Freeport McMoRan's North American leaching operations (Freeport-McMoRan, Inc., 2021).

Copper Fox Metals is currently developing its Van Dyke property, where it plans to mine a large, low-grade oxide copper resource that lies beneath the town of Miami. Intermittently mined by conventional underground mining methods from 1929 until 1945, an in-situ leaching method has been chosen to recover copper from this resource, due to its depth, location, metallurgical character, and low copper content of the mineralization (Bird et al., 2021).

6.3.1 Future Challenges

Encouraged by BHP Copper's 1995 discovery of the large high-grade copper resource at Resolution (Briggs, 2015a), similar deep exploration drilling programs have been conducted in the Globe-Miami Mining Region. Much of this effort has been focused on examining concealed targets in the Upper Pinal Creek Basin (Figure 109). Should these efforts bear fruit; any future discovery will be presented with a number of challenges that must be met before production can begin. Like the Old Dominion mine more than a century ago, the drainage of groundwater from overlying basin aquifers will be major issue for any future conventional mining operation developed in this area.

Use of in-situ leaching methods has its own limitations, especially in deeply buried deposits, where low permeability of the host rock impedes recovery (i.e., Santa Cruz copper deposit near Casa Grande, Arizona). Both physical and chemical constraints restrict its application to a few sites (i.e., Florence), where conditions are favorable. Like conventional heap leach methods, solution mining operations only recover copper from ores containing soluble minerals, such as chrysocolla, brochantite, azurite, malachite, and chalcocite. Solution mining technology is presently incapable of leaching copper from insoluble primary sulfides, such as chalcopyrite and bornite (Briggs, 2015b).

The composition of gangue mineralogy of the ores is also important. The presence of significant amounts of calcite or other soluble minerals not only increases the amount of sulfuric acid required to treat the ores, escalating operating costs, but also results in the precipitation of gypsum within fractures and pore spaces. This results in two problems. Gypsum coats the copper minerals within the fractures, isolating them from the leach solutions, thereby reducing their capacity to dissolve the copper (i.e., reduces copper recovery). Gypsum also fills the fractures in the rock, reducing the rock's overall permeability, impeding the flow of the leach solutions between the injection and recovery wells (Briggs, 2015b).

6.3.2 Will there be a Silver Revival?

During the early days it was the high-grade silver veins that first attracted the prospectors to the Globe-Miami Mining Region. However by late 1880s, the exhaustion of the bonanza ore shoots and falling market price, production from the silver deposits ceased. By that time, copper had become district's primary product as it remains today.

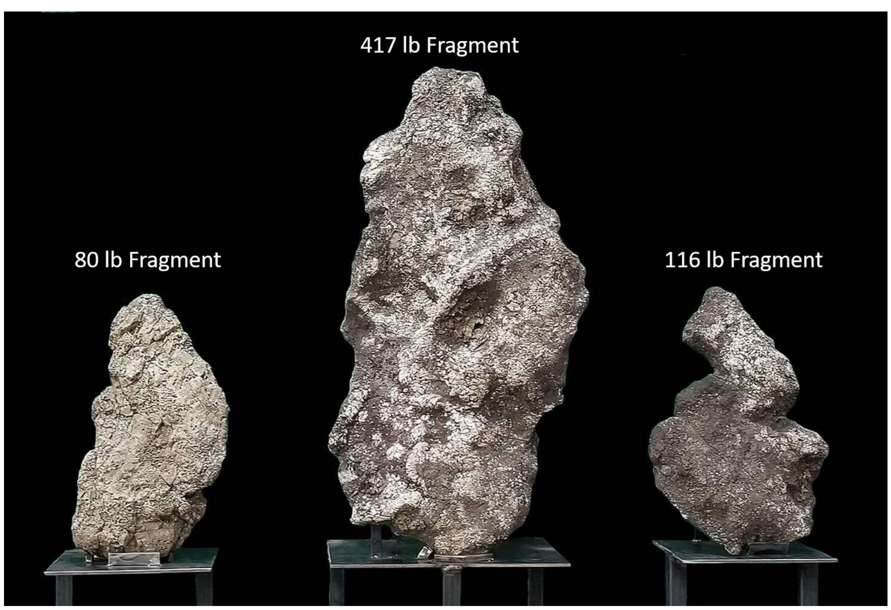


Figure 112. Large silver nuggets from the 417 Project, Gila County Arizona, which is on display at the University of Arizona Alfie Norville Gem & Mineral Museum in Tucson, Arizona (from Anonymous, 2020)

Recent exploration in the northern portion of the Globe Hills by a weekend prospector uncovered a 16 lb. silver nugget. This eventually stimulated interest in finding the source for these nuggets. Pacific Silver Corporation negotiated a lease and staked a large block of unpatented lode and placer claims along Mexican Mine Canyon and Jasper Canyon. Metal detectors were used during their initial evaluation of the claim block, resulting in the discovery of a number of additional silver nuggets. Tracing these nuggets upslope, their size increased with several large silver nuggets (Figure 112), including one weighing in at 417 lbs. found very close to their source, which outcrops as a quartz-siderite vein with anomalous silver. Although occasionally pure, these silver nuggets commonly contain native silver (Ag), acanthite (Ag_2S), chlorargyrite (AgCl), jalpaite ($3Ag_2S.Cu_2S$), and mckinstryite ($Ag_5Cu_3S_4$) with up to 40% quartz by volume (Osterman, 2021).

The geological setting is characterized by Mesoproterozoic diabase and clastic sediments at the base of the Apache Group, which is similar to the rich silver deposits of the Cobalt mining camp in Ontario, Canada (Joyce et al., 2012). Like Cobalt, the native silver at Globe contains anomalous amounts of arsenic and mercury (as amalgam), but lacks nickel and cobalt. At the present time much work remains to be done before the economic potential and nature of these occurrences are known, but if confirmed, silver mining may once again return to the Globe Hills (Osterman, 2021).

6.3.3 Modifying Mining Practices and New Technologies

Like many businesses, mining companies constantly search for ways to improve the profitability of their operations. As have been shown by historical mining operations in the Globe-Miami Mining Region, modification of mining practices and the introduction of new technologies continue with an ultimate goal of lowering operating costs while increasing the overall recovery of the metals mined.

At Pinto Valley recent efforts have been made during blasting to increase the amount of fine material in the run-of-mine ore, which allows for greater mill throughput. This practice lowers the amount of power required by the secondary and tertiary crushing circuits and reduces the circulating load around the tertiary screens (Craig et al., 2021).

Metallurgical studies at Pinto Valley are currently examining coarse particle flotation technology from Eriez Flotation (Figure 113). Under this scenario, tailings from the copper rougher flotation circuit, which currently report to the tailings impoundment, will be redirected to Eriez HydroFloat circuit, which recovers the coarse fraction of copper particles that are reground and recycled to rougher flotation circuit. Other benefits from this technology include lower grinding costs by increasing the grind size as well as reductions in water and energy use (Capstone Mining Corporation, 2021b).

Studies are also being conducted to recover copper from copper cleaner circuit tails, which are currently lost in the tailings impoundment. A pyrite agglomeration circuit produces a product that reports to dump leach pads (Figure 113). Benefits are threefold. It benefits the environment by diverting acid generating minerals (i.e., pyrite and chalcopyrite) from the tailings impoundment to the dump leach pad, where additional copper can be recovered. Furthermore, the oxidation of the pyrite generates sulfuric acid, which will lower overall operating costs by reducing the amount of acid purchased from outside sources (Capstone Mining Corporation, 2021b).

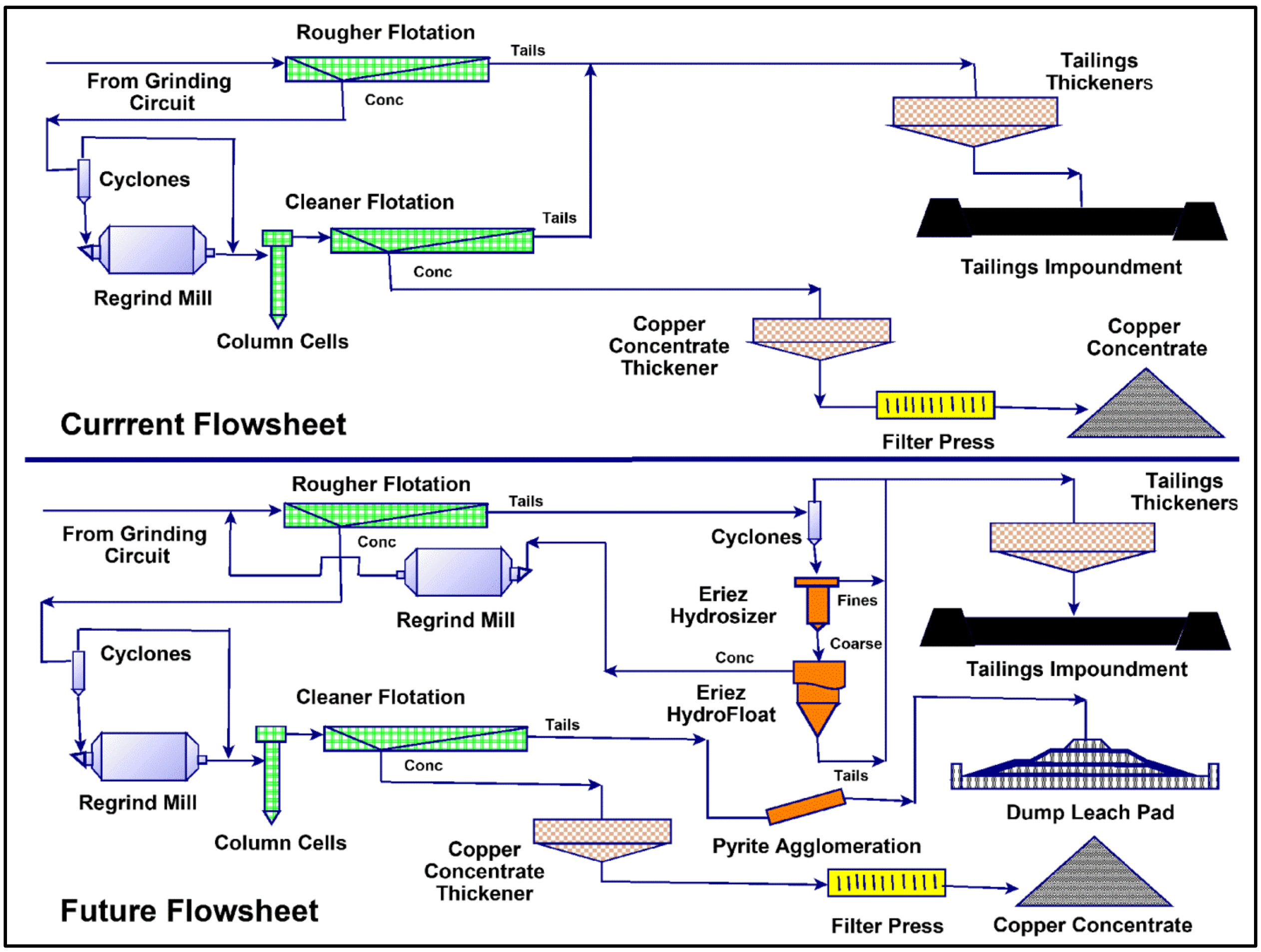


Figure 113. Current and future flowsheets of the Pinto Valley concentrator copper recovery circuits (modified from Capstone Mining Corp., 2021b)

Successful application of Eriez Hydrofloat technology and pyrite agglomeration at Pinto Valley will increase current copper recovery (85%) by 6 to 8% (Craig et al., 2021).

Recent advances in metallurgy have the potential of creating ore from low-grade waste. Developed by Jetti Resources, this proprietary technology employs a catalyst during the leaching process that is capable of recovering copper from primary sulfide ores (i.e., chalcopyrite) (Capstone Mining Corporation, 2020). Future success of the on-going, first commercial application of this catalytic technology at Pinto Valley will have important and far-reaching implications, both in the Globe-Miami Mining Region and for the copper mining industry worldwide.

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Production from the district's mining operations was derived from unpublished U. S. Bureau of Mines data provided by Stan Keith and from other sources. Discussions with Eric Seedorff, Stan Keith and Jan Rasmussen have been very helpful in understanding the geology and mineral deposits of the Globe-Miami Mining Region. Early drafts of this paper have been reviewed and edited by Cori Hoag, Colleen Kelley, Jan Rasmussen, Ken Krahulec, Dan Aiken, Avi Buckles, and Mike Conway, greatly improving its content and presentation.

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9 APPENDICES

9.1 Globe-Miami Mining Region Historical Time Line

Year	Month	Event
1225	-	Besh-Ba-Gowah pueblo established by the Salado culture about 1 mile southeast of Globe, Arizona. This site was abandoned around A.D. 1400.
1400	-	Western Apache initially settled the Globe-Miami area between A.D. 1400 and A.D. 1600.
1848	February	Under the terms of the Treaty of Guadalupe Hidalgo at the end of Mexican American War, the Globe-Miami Mining Region became a part of the United States.
1864	January	An expedition to the Globe-Miami region led by King Woolsey resulted in the deaths of approximately 19 to 24 Apaches, including Paramuca, chief of the Pinal Apaches at the Bloody Tanks Massacre.
1869	October	Silver was discovered in Big Johnnie Gulch.
1870	November	First mining claims in the Globe-Miami Mining Region were located in Big Johnnie Gulch.
		Camp Picket Post was established by General Stoneman at a site located approximately 3 miles west of Superior, Arizona.
1871	April	Camp Pinal was established near the present day community of Top of the World.
		A group of Tucsonans and Tohono O'odham attacked a Western Apache camp killing 85 to 144, mostly women and children in the Camp Grant Massacre.
	July	Camp Pinal was abandoned.
	November	White Mountain Indian Reservation was established.
1872	December	San Carlos Indian Reservation was established.
1873	September	David Anderson, Robert Anderson, Benjamin Reagan, Charles Mason, William Long, and Isaac Copeland staked the Globe and Globe Ledge claims at the future site of the Old Dominion mine.
1874	-	Silver was discovered at Richmond Basin.
1875	March	Benjamin Reagan, Charles Mason, William Long, and Isaac Copeland discovered the Silver King mine.
	August	Rich lead-silver ores were discovered at Ramboz Camp.
	November	Globe Hills Mining District was organized by Bill Hope, Doc Hammond, Jim Winters, Dr. Brown, Robert Metcalfe, Al Wheelock, George Scott, and Black Jack Harvey.
1876	March	Rich silver ores were discovered at the Stonewall Jackson mine near McMillenville.
	April	President Grant issued an executive order returning the portion of the San Carlos Indian Reservation located in the Globe Hills to the public domain.

Year	Month	Event
1876	July	Globe City was established (renamed Globe in 1878).
1878	May	Judge Aaron H. Hackney published the first edition of the Arizona Silver Belt, Globe's first newspaper.
	-	First reported copper production in the Globe-Miami Mining Region occurred at the Hoosier mine.
	-	Regular stagecoach service was established between Silver City, New Mexico and Globe.
1880	April	Reverend J. J. Wingar established the St. Paul's Methodist Church in Globe.
	December	Old Dominion Copper Mining Company was incorporated by Mitchell H. Simpson.
1881	February	Gila County was established with Globe as the county seat.
	March	Southern Pacific Railroad linked with the Atchison, Topeka & Santa Fe Railroad at Deming, New Mexico, completing America's second transcontinental railroad.
	April	Old Dominion Copper Mining Company erected two 30-ton blast furnaces near the confluence of Bloody Tanks Wash and Smelter Canyon, southwest of the present-day town of Miami.
	September	The first water-jacketed blast furnace in the Globe Hills Mineral District was erected at the Carrie smelter.
	December	Buffalo Mining and Smelting Company began smelting operations, treating copper ores from the Buffalo and Hoosier mines.
	-	The first recorded mining claim (i.e., Continental claim) was located near the future site of the Castle Dome mine.
1882	-	Old Globe Copper Company began production during the spring of 1882.
	September	The Old Dominion Copper Company purchased the assets of the Old Globe Copper Company. This operation became known as the Old Dominion mine.
	October	Long Island Copper Company began operations.
1883	February	Takoma Copper Company began operations.
	-	Falling copper prices halted copper production at the Buffalo, Long Island and Takoma operations during the summer of 1883.
1885	April	A fire destroyed much of the Globe business district.
	May	The Old Dominion Copper Mining Company suspended mining operations at the Old Dominion mine and declared bankruptcy.
1886	February	Assets of the Old Dominion Copper Mining Company were purchased by William Keyser of Baltimore. Production resumed in the spring of 1886.
1887	-	Alex Trippet leased the Buffalo mine and smelter and resumed operations.
1888	January	The Old Dominion Copper Mining Company was reorganized as the Old Dominion Copper Company of Baltimore City.

Year	Month	Event
1890	-	J. J. Marshall staked the initial four mining claims at the Live Oak property.
1891	February	A flash flood along Pinal Creek destroyed portions of Globe and disrupted mining operations at the Old Dominion mine.
	November	Phelps Dodge and Company formed the United Globe Mines Company, which consolidated several properties including the Buffalo, Hoosier, Grey, Cuprite, and other mining claims that adjoined Old Dominion's property to the north and east.
1892	January	The Old Dominion Copper Company of Baltimore City commissioned a new smelter at the Old Dominion mine. A double rope-type tram system was installed to transport the ore from the mine to the smelter.
1894	January	Gila Valley, Globe and Northern Railroad was incorporated to build a standard gauge rail line from the Southern Pacific railhead at Teviston (renamed Bowie in 1908) to Globe.
	February	Construction of the Gila Valley, Globe and Northern Railroad began at Teviston.
	June	A fire destroyed 40 buildings in Globe.
	-	Schulze copper property (i.e., Lower Oxide and Upper Ox Hide) was initially staked.
1895	May	Lewisohn-Bigelow interests purchased the assets of the Old Dominion Copper Company of Baltimore City.
	July	The Old Dominion Copper Company of Baltimore City was reorganized as the Old Dominion Copper Mining and Smelting Company.
1896	January	Gila Valley, Globe and Northern Railroad reached Geronimo, where construction was halted for two years while an agreement to cross the San Carlos Indian Reservation was negotiated with the Apache Tribe and Federal Government.
		United Globe Mines Company resumed mining and smelting operations.
	-	Girard Mining Company was organized to develop small gold and silver lode occurrences along Lost Gulch.
	-	First serious water problem was encountered on the eighth level of the Old Dominion mine.
	June	First labor strike at the Old Dominion mine. Miners succeeded in getting daily wages restored to $3.00.
	October	James A. Fleming and J. M. Ford organized the Black Warrior Copper Company.
	December	Pinto Creek Mining and Smelting Company was organized to explore and develop 36 mining claims along Pinto Creek.
1897	February	United Globe Mines Company commissioned a double rope-type tram system connecting its mines with the Buffalo smelter.
1898	-	Con Crowley staked the first mining claims at the Cactus mine along Pinto Creek.

Year	Month	Event
1898	June	Forest Kaldenberg acquired the Live Oak property and organized the Live Oak Copper Mining and Smelting Company.
	December	Gila Valley, Globe and Northern Railroad was completed to Globe, Arizona.
1899	January	The Old Dominion mine made the largest single shipment of copper in Arizona (1,120,000 lbs.) to date.
	-	Old Dominion Copper Mining and Smelting Company purchased the Continental mine.
	September	Black Warrior Copper Company commissioned a 100-ton day leach plant. Operating for only one month, it was a commercial failure.
1900	-	Buffalo smelter was closed around 1900 (?).
	-	The Black Warrior Copper Company merged with the Donellan Company to form the Black Warrior Company Amalgamated.
	-	The first mining claims were staked at the future site of the Bluebird mine.
1902	-	Black Warrior Company Amalgamated resumed production in early 1902
1903	-	Sam L. Gibson and William M. Henderson located the Gibson claim group.
	August	Black Warrior Company Amalgamated suspended operations.
	December	The Old Dominion Company, a holding company controlled by Phelps Dodge and Company, acquired 95% of the outstanding stock of the Old Dominion Copper Mining and Smelting Company and 100% of the stock of the United Globe Mines Company.
1904	-	The Inspiration Mining Company was incorporated.
	August	A flash flood swept through Globe, resulting in six deaths, destroying 20 businesses and washing away railroad bridges.
	September	Old Dominion smelter was modernized with the addition of a converter, allowing it to produce a blister copper product.
1905	January	Arizona Commercial Copper Company was incorporated to develop and mine the northeast extension of the Old Dominion vein system.
	July	Arizona Commercial Copper Company achieved production, mining ore from the Great Eastern vein.
	-	Keystone Copper Company was organized.
	August	A 300-ton per day concentrator was commissioned at the Old Dominion mine.
	November	National Mining Exploration Company was organized to develop seven mining claims held by the Iron Cap Mining Company.
1906	January	Adolph Lewishon organized the General Development Company.
	February	Interloper shaft fire claimed the lives of three miners at the Old Dominion mine.
	March	Black Warrior Company Amalgamated was reorganized as the Warrior Copper Company and resumed shipments of direct smelting ore to the Old Dominion smelter.

Year	Month	Event
1906	-	Gibson Copper Company was organized.
	November	Superior and Boston Copper Company was organized.
		J. Parke Channing negotiated an option to purchase the Oaks-Newman claim group.
1907	March	Arizona Commercial Railroad began operations, connecting its mines at Copper Hill with the Gila Valley, Globe and Northern Railroad.
		Aerial tramway at the Old Dominion mine was abandoned.
	April	Miami copper deposit was discovered.
	November	General Development Company organized the Miami Copper Company to develop its new discovery at Miami, Arizona.
1908	February	Superior and Boston Copper Company achieved production from the Great Eastern vein.
	April	Castle Dome Copper Company was organized.
	November	Cleve Van Dyke purchased a large tract of land (now known as Upper Miami) along Bloody Tanks Wash from the Miami Land and Improvement Company for $25,000.
	December	Inspiration Copper Company was incorporated to acquire the assets of the Inspiration Mining Company.
	-	Lost Gulch United Mines Company was organized to develop small precious metals occurrences along Lost Gulch.
1909	January	Miami Copper Company decided to proceed with the development of Miami copper project.
		Hoval A. Smith and Henry B. Hovland acquired a lease and an option to purchase the assets of the Live Oak Copper Mining and Smelting Company.
	March	Live Oak Copper Mining and Smelting Company was reorganized to form the Live Oak Development Company.
	April	Miami Copper Company began construction on its concentrator.
	May	Hoval A. Smith and Henry B. Hovland organized the Cordova Copper Company.
		Inspiration Copper Company began a churn drill exploration program.
	June	Castle Dome Copper Company reorganized as the Castle Dome Mining Company.
	July	General Development Company acquired the Keystone property and organized the New Keystone Copper Company.
	August	The Arizona National Copper Company, Pinto Creek Copper Mining Company and the Cactus Development Company merged to form the Cactus Copper Company.
	October	Arizona Commercial Copper Company commissioned a 500-ton per day water-jacketed blast furnace at its Eureka mine.
		Gila Valley, Globe and Northern Railroad's branch line was completed to Miami, Arizona.
		Miami, Arizona was established.

Year	Month	Event
1909	October	Warrior Development Company acquired a three-year lease on the Black Warrior property from the Black Warrior Copper Company.
	-	Miami's first school was held in a one-room school house located near the Miami mine.
1910	February	Arizona Eastern Railroad succeeded the Gila Valley, Globe and Northern Railroad.
	April	Arizona Commercial Copper's blast furnace ceased operations after the failure of the water jacket.
	June	Summit Copper Company acquired a lease/purchase option on the Gibson property.
	August	John D. Coplen incorporated the Barney Copper Company.
		Superior and Boston Copper Company temporarily suspended mining operations.
	September	The National Mining Exploration Company declared bankruptcy.
	October	The Cactus Copper Company abandoned its property along Pinto Creek.
1911	February	The National Mining Exploration Company was reorganized as the Iron Cap Copper Company.
	March	The Miami Copper Company commissioned a 3,000-ton per day concentrator.
	May	Iron Cap Copper Company reacquired its property at a foreclosure sale.
	June	Southwest Miami Development Company was incorporated to explore and develop a claim group located southwest of the Live Oak property.
	September	Arizona Commercial Copper Company temporarily suspended operations.
	October	Arizona Commercial Copper Company was reorganized as the Arizona Commercial Mining Company.
		Warrior Development Company surrendered its option to purchase the Black Warrior property.
	-	Inspiration Copper Company acquired the assets of the Cordova Copper Company during the fall of 1911.
	December	The Live Oak Development Company and Inspiration Copper Company merged to form the Inspiration Consolidated Copper Company.
1912	January	Summit Copper Company abandoned its option to purchase the Gibson mine and returned it to the Gibson Copper Company.
		Southwestern Leasing and Development Company acquired a lease on the Black Warrior mine.
	February	Arizona Commercial Mining Company resumed mining operations at the Copper Hill shaft.
	May	Inspiration Consolidated Copper Company purchased the Black Warrior town site.
	June	Inspiration Consolidated Copper Company collared twin main hoisting shafts along northern bank of Webster Gulch.

Year	Month	Event
1912	July	Lost Gulch United Mines Company was succeeded by Louis d'Or Gold Mining Company.
	September	Initial shipments of direct smelting ore from the Iron Cap mine were made to the Old Dominion smelter.
1913	-	Miami-Inspiration hospital was opened in early 1913.
	March	Superior and Boston Copper Company resumed production.
	April	Gibson Copper Company suspended operations at the Gibson mine.
		A 250-300-foot section overlying the Northwest ore body at Miami collapsed, killing five miners and injuring others.
	October	International Smelting and Refining Company purchased 32 acres of land from the Miami Copper Company for its new smelter at Miami.
	December	International Smelting and Refining Company began construction on its new Miami smelter.
1914	June	The town of Miami, Arizona was incorporated.
	October	The capacity of the Old Dominion concentrator was expanded from 300 to 800-tons per day.
1915	January	Assets of the New Keystone Copper Company were purchased by the Inspiration Consolidated Copper Company.
	June	Inspiration Consolidated Copper Company commissioned a 14,400-ton per day concentrator. It was the first large-scale concentrator in the United States to employ flotation as the primary method to process copper ores.
	July	International Smelting and Refining commissioned the Miami smelter.
		Callow pneumatic flotation cells were installed at the Miami concentrator to treat the slimes (i.e., fines) fraction of the ore.
	December	Castle Dome Development Company was incorporated.
1916	-	Porphyry Copper Company was organized to acquire the eastern 114 acres of the Barney Copper property.
	August	Cleve Van Dyke organized the Van Dyke Copper Company.
	-	Van Dyke deposit was discovered during the fall of 1916.
	-	Miami's first high school opened
	November	Louis d'Or Gold Mining Company was reorganized as the Louis d'Or Mining and Milling Company.
	December	Capacity of Miami Copper's concentrator was increased from 3,000 to 6,000- tons per day.
1917	-	Old Dominion Company acquired remaining assets of the Old Dominion Copper Mining and Smelting Company that it did not own.
	May	Gibson Consolidated Copper Company was incorporated to acquire the assets of the Gibson Copper Company and resumed shipments of direct smelting ores.
	July	Major labor strike occurred at the mining operations in the Globe-Miami Mining Region.

Year	Month	Event
1918	December	Gibson Consolidated Copper Company temporarily suspended production at Gibson mine.
1919	January	Gravity recovery methods were abandoned at Miami concentrator, when flotation cells were installed to treat the sands (i.e., coarse) fraction of the ore.
	May	Van Dyke shaft was collared.
1919	June	The Barney Copper Company and Porphyry Copper Company were reconsolidated to form the Porphyry Consolidated Copper Company.
	August	Gibson Consolidated Copper Company commissioned a 150-ton per day flotation concentrator at the Gibson mine.
1920	January	Inspiration Consolidated Copper Company acquired the Black Warrior mine property.
	-	Carlota Copper Company acquired the Carlota property.
	June	Iron Cap Copper Company commissioned a 350-ton per day concentrator at the Iron Cap mine.
	September	Gibson Consolidated Copper Company ceased all operations at the Gibson mine.
1921	January	Mining operations were temporarily suspended at the Arizona Commercial mine.
	February	All operations were temporarily suspended at the Iron Cap mine
	March	All operations were suspended at Inspiration Consolidated Copper's project.
	April	All operations were temporarily suspended at the Old Dominion mine.
		Mining operations were temporarily suspended at the Superior and Boston's mine.
	-	Inspiration Consolidated Copper Company acquired the assets of the Porphyry Consolidated Copper Company.
	December	Superior and Boston Copper Company resumed mining operations.
1922	February	Mining operations resumed at the Old Dominion mine.
		All operations resumed at the Iron Cap mine.
		The Inspiration Consolidated Copper Company resumed operations.
	March	Mining operations resumed at the Arizona Commercial mine.
	April	Old Dominion smelter resumed operations.
		Superior-Miami highway completed at a cost of $1 million.
1923	-	Gravity circuits at the Old Dominion concentrator were replaced by flotation.
1924	February	Assets of the Castle Dome Development Company were acquired by the Pinto Valley Company through a merger.
	September	Inspiration Consolidated Copper Company commenced construction of a 9,000-ton per day vat leach plant.
	November	Old Dominion smelter was permanently closed.
1925	October	Capacity of Miami Copper's concentrator was increased from 6,000 to 10,000-tons per day.

Year	Month	Event
1926	-	Capacity of the Old Dominion concentrator was increased from 800 to 1,400-tons per day.
	July	Assets of the Gibson Consolidated Copper Company were sold at a sheriff's auction.
	November	Milling operations ceased at the Iron Cap mine.
		Inspiration Consolidated Copper Company commissioned a 9,000-ton per day vat leach plant to recover copper from mixed oxide-sulfide ore.
1927	-	Superior and Boston Copper Company permanently suspended mining operations in early 1927.
	November	Iron Cap mine ceased all operations.
1928	July	Miami Copper Company commissioned a new tailings impoundment in Solitude Gulch.
		Assets of the Louis d'Or Mining and Milling Company were sold at a bankruptcy sale.
1929	-	Porphyry Reserve Copper Company was organized in early 1929 to develop the Copper Cities property.
	May	Assets of the Southwestern Miami Development Company were purchased by the Inspiration Consolidated Copper Company.
	-	Production was achieved at the Van Dyke property.
	September	Capacity of Miami Copper's concentrator was increased from 10,000 to 17,000-tons per day.
1930	June	Inspiration Consolidated Copper Company suspended operations at its sulfide concentrator, after which all of the ore was processed at its vat leach facility, using ferric sulfate leaching.
	December	Arizona Commercial Mining Company ceased operations.
		Assets of the Arizona Commercial Mining Company were purchased by the Old Dominion Company.
1931	October	Old Dominion mine was permanently closed.
1932	-	Van Dyke mine suspended production in early 1932.
	May	Miami Copper Company temporarily suspended operations due to low copper prices during the Great Depression.
		Inspiration Consolidated Copper Company suspended all mining and leaching operations.
	August	Miami Copper Company completed construction of a 3,000-ton per day "leach-precipitation-flotation" (L-P-F) plant to treat mixed oxide-sulfide ores.
1934	July	Miami Copper Company resumed limited production.
	-	International Smelting Company changed its name to International Smelting and Refining Company.
1935	September	Inspiration Consolidated Copper Company resumed limited production.
1936	-	Miami Copper Company expanded the capacity of its L-P-F plant from 3,000 to 6,000-tons per day.

Year	Month	Event
1937	February	The “Dual Process” was introduced at Inspiration Consolidated Copper’s ore treatment plant.
	December	Inspiration Consolidated Copper discontinued use of the “Dual Process”, reverting to the ferric-sulfate leaching.
1938	August	Miami Copper Company added a molybdenum recovery circuit to its concentrator.
1940	May	Miami Copper Company purchased the assets of the Old Dominion Company.
	August	Miami Copper Company began supplying water to its facilities from the Old Dominion mine.
1941	November	Miami Copper Company exercised its option to purchase the assets of the Pinto Valley Company and formed the Castle Dome Copper Company to develop and operate its Castle Dome project.
	December	In-place, solution mining operations began at the Miami mine.
1942	January	W. A. Bechtel Company commenced construction of the concentrator and removal of 14 million tons of waste rock at Miami Copper’s Castle Dome project.
		U. S. government instituted a premium price program for copper and other metals.
	July	Inspiration Consolidated Copper resumed operations at the old concentrator to meet wartime demand. The “leach-float” process was employed to recover copper from mixed oxide-sulfide ores.
	-	Miami Copper Company acquired claims held by the Porphyry Reserve Copper Company at a sheriff’s sale and formed the Copper Cities Mining Company to explore and develop the Copper Cities project.
1943	April	Van Dyke mine resumed production.
		Miami Copper took over mine excavation from the contractor at the Castle Dome project.
	May	Production of mixed oxide-sulfide ore at Miami Copper’s L-P-F plant was suspended.
	June	Miami Copper commissioned a 10,000-ton per day concentrator at the Castle Dome project.
	August	Miami Copper began a churn drilling program at its Copper Cities project.
	December	Miami Copper temporarily suspended its churn drilling program at its Copper Cities project due to manpower shortages during World War II.
1944	August	Inspiration Consolidated Copper discontinued using the leach-float process to recovery copper from mixed oxide-sulfide ores.
	October	Inspiration Consolidated Copper’s electrolytic tank house was destroyed by fire. The old concentrator was pressed into service employing the “Dual Process”.
	-	Miami Copper increased the capacity of the Castle Dome concentrator from 10,000 to 12,000-tons per day during the fall of 1944.

Year	Month	Event
1945	May	Inspiration Consolidated Copper commissioned a new electrolytic tank house.
	June	Mining operations were suspended at the Van Dyke mine.
1946	October	Miami Copper Company resumed exploration activities at the Copper Cities project.
1948	January	Inspiration Consolidated Copper Company commenced open pit mining operations at Live Oak.
1950	-	Inspiration Consolidated Copper Company began commercial in-place solution mining and dump leaching operations, recovering copper by precipitation methods.
1953	December	All mining and milling operations ceased at Castle Dome. Residual leaching of waste dumps continued to recover copper by precipitation methods.
1954	August	Miami Copper commissioned its Copper Cities project.
		Inspiration Consolidated Copper halted all underground block caving operations.
1957	January	Inspiration Consolidated Copper resumed production at its sulfide concentrator, using the “Dual Process”.
	April	Miami Copper resumed production of mixed oxide-sulfide ores, using the L-P-F circuit.
1958	March	Miami Copper suspended production of mixed oxide-sulfide ores.
	-	Inspiration Consolidated Copper Company added a molybdenum recovery circuit to its concentrator.
1959	July	Miami Copper ceased conventional block caving underground mining operations, after which all copper production was obtained by in-place solution mining methods.
1960	April	Inspiration Consolidated Copper Company purchased the Miami smelter from the Anaconda Copper Company.
	June	Tennessee Corporation purchased the assets of the Miami Copper Company.
1961	-	Tennessee Corporation began an exploration program at Porphyry Mountain to test the underlying primary sulfide resource at the former Castle Dome mine site.
	-	Inspiration Consolidated Copper Company abandoned all underground haulage of ore.
	-	Stovall Company was formed to explore and develop the Bluebird property.
1962	December	Dump leaching operations began at the Copper Cities mine.
1963	June	Cities Service Company acquired the Arizona holdings of the Tennessee Corporation through a merger.
1964	January	Ranchers Exploration and Development Corporation acquired an option to purchase the Bluebird property.
	March	Ranchers Exploration and Development Corporation exercised its option to purchase the Bluebird property.

Year	Month	Event
1964	October	Ranchers Exploration and Development Corporation achieved production at the Bluebird property.
	-	Inspiration Consolidated Copper Company acquired an option to purchase the Schulze copper property.
1965	-	Cities Service discovered the Diamond H ore body.
	-	A molybdenum flotation circuit was added to the Copper Cities concentrator.
1966	-	Inspiration Consolidated Copper Company commissioned a rod plant at Miami, Arizona.
	-	Arizona Mining Properties, Inc. acquired the Gibson property.
1967	July	Operations at Inspiration and Copper Cities halted by an industry-wide strike led by the United Steelworkers of America.
1968	March	The Bluebird mine became the first copper producer to commercially employ SX-EW technology to treat copper-bearing solutions from a heap leach operation.
		Industry-wide strike led by the United Steelworkers of America was settled allowing operations to resume at Inspiration and Copper Cities.
	April	Occidental Minerals Corporation acquired a lease with an option to purchase properties held by the Van Dyke Copper Company and Sho-Me Copper Company.
	July	Homestake Production Company acquired a lease on the Carlota property.
		Inspiration Consolidated Copper Company began mining operations at the Upper Ox Hide deposit.
1969	April	A diamond drilling program discovered a high-grade copper zone at Miami East.
	-	Arizona Mining Properties, Inc. commissioned a pilot heap leach and in-place solution mining project at Gibson during the fall of 1969.
	December	Parsons-Jurden Corporation was awarded a contract to perform a detailed feasibility study on the proposed Pinto Valley project.
1970	July	Cities Service Company began mining operations at Diamond H.
	-	Residue leaching of waste dumps ceased at Castle Dome.
1971	-	Positive feasibility study on the Pinto Valley project was completed in late 1971.
1972	May	Cities Service Board of Directors approved the Pinto Valley project.
	August	Cities Service personnel took over pre-production stripping at the Pinto Valley project.
1973	January	Inspiration Consolidated Copper Company began mining operations at the Lower Ox Hide deposit.
	-	The original reverberatory furnaces at the Miami smelter were replaced by an electric furnace.
1974	-	Inspiration Consolidated Copper ceased commercial in-place solution mining operations.

Year	Month	Event
1974	July	Cities Service Company commissioned a 40,000-ton per day concentrator at the Pinto Valley project.
1975	May	Cities Service suspended mining operations at Copper Cities.
	September	Milling of stockpiled ores at Copper Cities was completed.
		Cities Service postponed scheduled start-up of the Miami East project.
1976	January	Occidental Minerals began a two-phase test to evaluate the feasibility of recovering copper by in-situ leaching methods at Van Dyke.
	May	Precipitation recovery circuit at Miami in-place leaching project was replaced by a SX-EW facility.
1977	October	Ranchers Exploration and Development temporarily suspended mining operations at Bluebird.
	-	Inspiration Consolidated Copper Company ceased mining operations at Lower Ox Hide.
1979	February	Ranchers Exploration and Development resumed mining operations at Bluebird.
	September	Cities Service resumed development at Miami East.
	October	Inspiration Consolidated Copper commissioned at SX-EW facility at a cost of $14 million.
	-	First study of groundwater contamination was completed in the Globe-Miami Mining Region.
1980	June	Inspiration Consolidated Copper introduced the “Ferric Cure” leaching process.
	October	Occidental Minerals abandoned its efforts to develop Van Dyke project.
1981	July	Ranchers Exploration and Development suspended mining operations at Bluebird.
		Cities Service commissioned a SX-EW facility to treat leach solutions from sulfide waste dumps at Pinto Valley.
1982	June	Cities Service suspended all mining and milling operations at Pinto Valley and halted underground development at Miami East.
		Residual leaching of existing leach dumps at Copper Cities was suspended.
	-	Residual copper recovery from existing dumps at Upper and Lower Ox Hide ceased.
	October	Ranchers Exploration and Development halted all copper recovery operations at Bluebird.
	December	Cities Service Company became a wholly-owned subsidiary of Occidental Petroleum Corporation.
1983	March	Cities Service Company sold its Arizona assets (Miami, Copper Cities, Pinto Valley, and Old Dominion) to the Newmont Mining Corporation.
	July	Inspiration Consolidated Copper Company became a unit of its parent holding company, Inspiration Resources Corporation.
1984	March	Hecla Mining Company acquired the Bluebird project through a merger with the Ranchers Exploration and Development Corporation.

Year	Month	Event
	May	Newmont Mining Corporation resumed mining and milling operations at Pinto Valley, shipping its concentrates to the San Manuel smelter.
	July	Inspiration Consolidated Copper Company purchased the Bluebird property from the Hecla Mining Company.
1986	January	Inspiration Consolidated Copper permanently suspended milling operations.
	June	Inspiration Consolidated Copper cited for violating the Clean Water Act of 1972.
1987	March	Newmont Mining Corporation reorganized its domestic copper assets (i.e., San Manuel, Superior, Pinto Valley, and Miami) to form the Magma Copper Company.
	April	Magma Copper Company approved the development of the Miami tailings recovery project.
1988	January	Magma Copper commenced construction of Miami tailings recovery project.
	July	Cyprus Minerals Company acquired the Arizona assets of the Inspiration Consolidated Copper Company.
	December	Kocide Mining Corporation began in-situ leaching operations at Van Dyke.
1989	January	Westmont Mining, Inc. acquired a six-month option to lease the Carlota property from Sherwood Owens.
	April	Magma Copper Company commissioned the Miami tailings retreatment plant at a total cost of $22.4 million.
	May	Former and existing mining operations bordering Pinal Creek were placed on Arizona's WQARF Priority List by the Arizona Department of Environmental Quality.
	August	Westmont Mining, Inc. acquired a 20-year lease on the Carlota property from Sherwood Owens.
	October	Kocide Mining Corporation suspended in-situ leaching operations at Van Dyke.
1990	May	A consortium known as the Pinal Creek Group, composed of the Cyprus Minerals Company and Magma Copper Company, was formed to voluntarily conduct remedial investigations on how to proceed with the clean-up of the area and implement these reclamation efforts.
	June	Arimetco International, Inc. acquired Kocide's leasehold interest in the Van Dyke property.
	October	Westmont Mining, Inc. purchased the Eder/Ghost claim group from the Cyprus Minerals Company for $500,000.
	November	Presence of turquoise-colored water in drainages downstream from the Gibson copper mine was reported to the Arizona Department of Environmental Quality.
1991	August	Cambior, Inc. acquired the Carlota project through its purchase of Westmont Mining, Inc. from Costain Minerals, Inc.
1992	June	The Miami smelter was converted to ISASMELT technology.

Year	Month	Event
1993	March	Cambior, Inc. acquired portions of the Cactus and Carlota deposits from the Magma Copper Company.
	November	The Cyprus Minerals Company and AMAX, Inc. merged to form the Cyprus Amax Minerals Company.
1994	October	Cyprus Amax Minerals Company replaced the original tank house refinery with a new refinery at a cost of $80 million.
1996	January	Broken Hill Proprietary Company Ltd. acquired Pinto Valley, Copper Cities and Miami projects through its merger with the Magma Copper Company and formed BHP Copper, Inc. to manage these assets.
1997	January	Arimetco International, Inc. declared bankruptcy and subsequently disposed of its assets including its leasehold interest in Van Dyke.
	October	A tailings dam for the No. 1/2 tailings storage facility at Pinto Valley failed, releasing 370,000 cubic yards of tails and waste rock into Pinto Creek.
1998	February	BHP Copper suspended all mining and milling operations at Pinto Valley.
	September	Tonto National Forest approved Carlota Mine Plan of Operation.
1999	October	Phelps Dodge Corporation acquired the Inspiration property through its merger with the Cyprus Amax Minerals Company.
	November	Lower Pinal Creek Water Treatment Plant was commissioned.
2001	May	Diamond H Water Treatment Plant was commissioned to treat contaminated water from Miami Wash.
	June	Broken Hill Proprietary Company Ltd. and Billiton Ltd. merged to form BHP Billiton Ltd.
	July	BHP Copper closed the Miami tailings retreatment plant.
2002	January	Phelps Dodge temporarily suspended all mining and refining operations at Inspiration.
	-	BHP Copper began reclamation at the Old Dominion mine and smelter site.
2004	-	Reclamation of the Old Dominion mine and smelter site was completed during the spring of 2004.
2005	June	Phelps Dodge permanently closed its Miami refinery.
	December	Quadra Mining Ltd. purchased the Carlota project from Cambior, Inc. for approximately $39.7 million
2006	-	Reclamation of the Miami No. 2 tailings impoundment was completed in early 2006.
	-	Reclamation began at the Gibson mine.
2007	March	Freeport-McMoRan Copper and Gold, Inc. acquired the Inspiration property through its merger with the Phelps Dodge Corporation.
	June	BHP Copper resumed mining operations at Pinto Valley.
2007	October	BHP Copper resumed milling operations at Pinto Valley.
2008	December	Quadra Mining Ltd. produced the first copper cathode from its Carlota project.

Year	Month	Event
2009	January	BHP Copper halted all mining and milling operations at Pinto Valley.
	-	Freeport McMoRan Copper and Gold, Inc. began the Webster Lake Infill reclamation project.
2010	May	Quadra Mining Ltd. merged with FNX Mining Company, Inc. to form Quadra FNX Mining Ltd.
2010	-	Freeport-McMoRan Copper and Gold, Inc. resumed mining operations at Inspiration in late 2010.
2011	February	Old Dominion Historic Park was officially dedicated.
2012	March	KGHM acquired the Carlota project through its merger with Quadra FNX Mining Ltd.
	April	Bell Copper Corporation purchased the Van Dyke property.
	December	BHP Copper re-commissioned mining and milling operations at Pinto Valley.
2013	April	Copper Fox Metals, Inc. purchased the Van Dyke property from the Bell Copper Corporation.
	August	BHP Copper ceased in-place solution mining operations at Miami.
	-	BHP Copper completed the reclamation of the Pinto Valley No. 1/2 tailings storage facility.
	October	Capstone Mining Corporation acquired the Pinto Valley mine and associated railroad operations from BHP Copper.
2014	-	Freeport-McMoRan Copper and Gold, Inc. was renamed Freeport-McMoRan, Inc.
	-	KGHM suspended mining operations in the Cactus-Carlota pit.
2015	September	Freeport-McMoRan ceased mining operations at Inspiration after depleting its remaining reserves. Leaching of existing ore stockpiles continues.
	-	Freeport-McMoRan completed the Webster Lake Infill reclamation project in late 2015.
2018	-	KGHM began mining the Eder South deposit.
2019	-	During the spring of 2019, the Capstone Mining Corporation partnered with Jetti Resources to test a novel patented catalytic technology, designed to recover copper from primary sulfide ores that are too low grade to treat by conventional methods.
2020	July	Capstone Mining Corporation announced that it will incorporate Jetti Resources' new catalytic technology into its existing operation at Pinto Valley, significantly expanding its dump leaching activities to fully utilize its SX-EW plant's capacity.

9.2 Glossary of Terms (American Geological Institute, 1976; U. S. Securities and Exchange Commission, 2021)

Adit – a horizontal passage driven into the side of a mountain or hill to provide access to a mineral deposit.

Amalgamation – a concentrating process in which gold and/or silver is mixed with mercury to form a metal-laden amalgam that is treated in a retort to separate the precious metals from the mercury.

Arrastra – a primitive mill used to crush and pulverize gold or silver ore. In its simplest form, arrastras consisted of two or more flat-bottom drag stones placed in a circular pit paved with flat stones and connected to a center post by a long arm. With a horse, mule or human providing power at the other end of the arm, the stones were dragged slowly around in a circle, crushing the ore.

Assessment Work – amount of work, specified by mining law that must be performed each year in order to retain legal control of unpatented mining claims.

Ball Mill – a steel cylinder filled with steel balls that are used to grinding the ore.

Batholith – large body of igneous rock that forms when magma rises into the earth’s crust, but does not erupt onto the surface. It covers an area of at least 40 square miles and extends to an unknown depth.

Black Copper – an unrefined copper product (also known as copper bullion) containing approximately 94 to 96% copper produced in a blast furnace by smelting oxidized copper ores.

Blast Furnace – a type of smelting furnace where a mixture of fuel (coke), ore and flux (limestone) is continuously supplied through the top of the furnace, while a hot blast of air is blown into the lower portion of the furnace through a series of pipes. This results in chemical reactions as the material falls downward, producing molten metal and slag that are recovered at the base of the furnace and waste gases that are vented from the top of the furnace.

Blister Copper – an unrefined copper product (98 to 99% copper) from smelting that has a blistered surface resulting from gases generated during solidification.

Block-caving – a bulk tonnage mining method, in which large blocks of ore are undercut, causing the ore to break or cave under its own weight.

By-product – a secondary metal or product recovered in the milling or smelting process.

Cathode Copper – a refined copper product containing more than 99.99% copper.

Cement Copper – a form of copper (aka - copper precipitate) containing 60 to 90% copper, which is created by the precipitation of copper ions in solution onto scrap iron.

Classifier – a device employed to separate ground rock into coarse (i.e., sands) and fines (i.e., slimes) fractions.

Converter – a type of smelting equipment where oxygen and silica are added to a mixture of copper and iron sulfides known as copper matte (50 to 70% copper), to produce an unrefined product known as blister copper (98-99% copper), slag and sulfur dioxide.

Crusher – a machine that is designed to reduce large rocks into smaller rocks, gravel, sand or rock dust.

Coke – a gray, hard and porous fuel with high carbon content and few impurities, which is produced by heating bituminous coal in the absence of air to drive off volatile constituents.

Collar – term applied to the timbering or concrete around the top of a shaft.

Copper Matte – an intermediate copper product containing 50 to 70% copper, iron, sulfur, and other impurities that is treated in a converter to form a blister copper product.

Cross-cut – a horizontal mine passage that cuts across a vein or ore body.

Custom Basis – ores are treated on a custom basis, when an operator of a mill or smelter purchases and/or treats the ore for customers.

Cut-and-Fill Mining Method – a method underground mining in which the ore is removed in slices or lifts and then the excavation is filled with rock or other waste material (backfill) before the next slice is extracted.

Dedicated Leach Pads - involves the preparation and placement of ore on a continually expanding leach pad (either vertically and/or horizontally). Following leaching, the ore is left in place.

Dilution – rock that is, by necessity, removed along with the ore during the mining process that lowers the overall metal content of the ore.

Direct-Smelting Ores (DSO) – high-grade ores that are treated in a smelter without benefit of prior beneficiation.

Drift – a horizontal mine passage that follows along the length of the vein or ore body.

Electrowinning (EW) – a process where an electric current is passed through a solution containing dissolved metals, causing the metals to be deposited onto a cathode.

Flotation – a milling process in which the valuable mineral particles are induced to become attached to bubbles and float as the others sink.

Flux – a chemical substance (i.e., silica) that reacts with gangue minerals to form slag, which is liquid at furnace temperature and low enough density to float on a molten metal or matte.

Footwall – the mass of rock beneath a fault plane, vein, lode or bed of ore.

Gangue – worthless minerals in an ore deposit.

Graben - a block generally long compared to its width that has been downthrown along faults relative to the rocks on either side.

Gravity separation – a milling process that is designed to recover valuable minerals based on the difference in specific gravity, shape and particle size as compared with the gangue or host rock and the carrying medium.

Greenschist Facies – a major division of the mineral facies classification of metamorphic rocks, which refers to low to medium-grade metamorphic facies corresponding to temperatures of 300 to 500^{o}C and pressures of 3 to 20 kilobars (crustal depths of 8 to 50 km). It is commonly characterized by mineral assemblages containing chlorite, actinolite, albite, epidote, serpentine, and muscovite.

Grizzly – a grating placed over an opening to an ore pass or chute usually made of steel rails that prevent large rocks or ore from falling below.

Hanging Wall - the mass of rock above a fault plane, vein, lode or bed of ore.

Holding Company – a corporation engaged principally in holding a controlling interest in one or more other companies.

Horst – a block generally long compared to its width that has been uplifted along faults relative to the rocks on either side.

Hypogene – mineralization within and below the Earth's crust that results from ascending thermal fluids, derived from a magmatic source. Also refers to primary unaltered ore formed directly from thermal aqueous solutions that are derived from great depths.

Inducted Potential (IP) Survey – a geophysical imaging technique that measures electrical chargeability of sub-surface materials such as ore.

In-place Leaching – a type of solution mining that employs permeability enhancement techniques such as blasting or previous mining activities (i.e., block-caving) to fragment or increase the permeability of the rock prior to applying a leach solution (i.e., water or dilute acid) to liberate a desired commodity from the ore without also extracting the rock.

In-situ Leaching – a type of solution mining that relies solely on the natural occurring permeability of the ore to convey a leach solution (i.e., water or dilute acid) used to recover a desired commodity from the ore without also extracting the rock.

Jig – a type of milling equipment used to concentrate ores on a screen submerged in water, either by a reciprocating motion of the screen or by the pulsation of water through it.

Laramide – the period of time corresponding with a series of mountain-building events that occurred in much of western North America from Late Cretaceous until Eocene time (i.e., 80 to 35 million years ago).

Mineral Reserve – an economically mineable portion of a mineral resource as demonstrated by a feasibility study.

Mineral Resource - a concentration or occurrence of minerals in such form and quantity and of such grade or quality that it has reasonable prospects for economic extraction.

Net Smelter Returns Royalty – a royalty that is based on the net revenue received from the sale of a mine's metal/nonmetal products less transportation and refining costs.

Normal Fault – a fault along which the hanging wall has been depressed, relative to the footwall.

Option – an agreement to purchase a property reached between the property owner and some other party, who wishes to further explore the property.

Orogeny – a period of uplift or mountain building.

Paleo-channel – old or ancient stream channel.

Par Value – the stated face value of a stock. Par value shares have no specified face value, but the total amount of authorized capital is set down in the company's charter.

Patented Mining Claim – a mining claim, which the Federal Government has conveyed its title to the claimant, making it private land.

Post-tectonic – refers to events occurring after a period of deformation within the Earth's crust.

Pregnant Solution – a leach solution containing dissolved metals (i.e., copper).

Pyrometasomatic – replacement of one mineral by another, mainly within limestone at or near intrusive contacts under influence of magmatic emanations at high temperature and pressure.

Raise – a vertical or inclined underground working that has been excavated from the bottom upward.

Rake – the inclination from the horizontal of ore shoots measured on the plane of the associated vein.

Refractory Ores – ores that are difficult to treat under normal processes.

Reverberatory Furnace – a type of a smelting furnace that isolates the material being processed from direct contact with the fuel, but not from contact with the combustion gases.

Reverse Fault - a fault along which the hanging wall has been raised, relative to the footwall.

Run-of-Mine Ore – ore derived directly from a mine in its natural, unprocessed state.

Shaft – a vertical or inclined excavation in rock for the purpose of providing access to an ore body.

Shrinkage Mining Method – an underground mining method that uses part of the broken ore as a working platform and as support for the walls of the stope.

Skarn – a metamorphic rock composed of lime-bearing silicates (i.e., garnet, diopside, tremolite, actinolite, wollastonite) that are derived from limestone or dolomite, which is commonly found adjacent to an intrusive body.

Slag – the vitreous waste material separated from recovered metals during the smelting process.

Solvent Extraction (SX) – a two-stage process employed to upgrade the copper content of pregnant solutions from dump leaching operations. It involves the use of an organic solvent to recover copper ions contained in the pregnant leach solution, exchanging them with hydrogen ions in the acid. A strong acid is then employed to strip the copper from the organic solution, to produce a blue, enriched copper-bearing solution that can be treated in an electrowinning plant.

Square Set Mining Method – an underground method of mining where the walls of a stope are supported by a system of interlocking framed timbers (i.e., square set) and filled with broken waste rock or sand fill.

Stamp Mill – a mechanical mill that employs heavy steel stamps to pound and break apart the rock, releasing the valuable metals from the worthless gangue, allowing for the recovery of gold and silver for further refining.

Stope – an excavation in an underground mine from which ore is or has been extracted.

Supergene – mineralization caused by descending fluids close the Earth's surface and is usually associated with weathering and alteration of the primary mineral assemblage.

Supernatant – clear liquid that lies above a solid tailings residue after settling.

Supernatant Pond – a pond that forms in a tailings storage facility due to supernatant runoff and precipitation.

Syntectonic - refers to events occurring during or coinciding with a period of deformation within the Earth's crust.

Table – a type of milling equipment used to separate heavy mineral particles from lighter gangue by means of longitudinal riffles that impede the downward flow and a horizontal reciprocating motion that carries the heavy particles off the end of the table.

Tailings – material rejected from a mill after most of the recoverable valuable minerals have been extracted.

Tailings Impoundment (also known as a tailings storage facility) – a site were tailings are disposed of. By convention, the term tailings impoundment is currently used for legacy tailings facilities, while active tailings sites are known as tailings storage facilities.

Top Slicing Mining Method – an underground mining method where the ore is extracted in a series of slices taken in descending order beginning at the top. Each floor is mined in small sections with the roof of each section being allowed or forced to cave before an adjacent section is extracted.

Turbidite – a type of sedimentary deposit that consists of material that has moved down a steep slope (i.e., submarine avalanche) at the edge of a continental shelf.

Vanner – a type of milling equipment used to concentrate ore consisting of a continuous rubber belt (4 feet wide by 27.5 feet long) that is passed over rollers to form the surface on a gently inclined plane. The belt travels up hill at a rate of 3 to 12 feet per minute while being laterally shaken 180 to 200 times per minute. Crushed ore is added about 4 feet from the upper end of the belt and is washed by small jets of water, which gradually wash the gangue off the bottom end of the belt, while the heavier ore minerals are collected from the upper end of the belt.

Unpatented Mining Claim – a mining claim that the Federal Government has not conveyed its title to the claimant. The claimant's rights are restricted to the extraction and development of a mineral deposit.

Up-stream Construction of Tailings Dam – a type of tailings dam consisting of trapezoidal embankments being constructed on top but toe to crest of another, moving the crest further upstream. It forms a relatively flat downstream side and a jagged upstream side, which is supported by the fine tailings slurry in the impoundment.

Winze – an internal mine shaft.

Working Capital – liquid resources a company has to meet day-to-day expenses of operation; defined as the excess of current assets over current liabilities.

9.3 Geologic Time Scale (simplified from Walker et al., 2018)

Eon/Era/Period/Epoch				Age (million years)
Cenozoic	Quaternary		Holocene	0 to 0.012
			Pleistocene	0.012 to 2.6
	Tertiary	Neogene	Pliocene	2.6 to 5.3
			Miocene	5.3 to 23.0
		Paleogene	Oligocene	23.0 to 33.9
			Eocene	33.9 to 56.0
			Paleocene	56.0 to 66.0
Mesozoic	Cretaceous			66.0 to 145.0
	Jurassic			145.0 to 201.3
	Triassic			201.3 to 251.9
Paleozoic	Permian			251.9 to 298.9
	Carboniferous	Pennsylvanian		298.9 to 323.2
		Mississippian		323.2 to 358.9
	Devonian			358.9 to 419.2
	Silurian			419.2 to 443.8
	Ordovician			443.8 to 485.4
	Cambrian			485.4 to 541.0
Precambrian	Proterozoic		Neoproterozoic	541 to 1,000
			Mesoproterozoic	1,000 to 1,600
			Paleoproterozoic	1,600 to 2,500
	Archean		Neoarchean	2,500 to 2,800
			Mesoarchean	2,800 to 3,200
			Paleoarchean	3,200 to 3,600
			Eoarchean	3,600 to 4,000

Back Cover. Upper Photo – Group photo of miners at United Globe Mines' Buffalo mine, circa 1900 (photo from Arizona Memory Project – Arizona State Library)

Lower Photo – Miami No. 5 shaft at BHP Copper's Miami unit, circa 2009 (photo from David Briggs)