History of the Copper Mountain (Morenci) Mining District, Greenlee County, Arizona

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Panorama of the Morenci operation, looking northeast toward the Metcalf pit with Copper King Mountain in the distance. Photo: David Briggs, July 2007

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Introduction

The Copper Mountain (Morenci) mining district is located approximately 115 miles northeast of Tucson, Arizona (Figure 1). It lies along the southern boundary of the Transitional physiographic province, a rugged mountainous region that separates the Colorado Plateau from the Basin and Range province.

Figure 1. Topographic relief map of Arizona and surrounding region, showing the location of the Copper Mountain mining district, Tucson, and present day boundaries of Arizona's counties.

The discovery of copper at Morenci during the turbulent years of the American Civil War brought new opportunities for many, but foreshadowed the end of a way of life for Native Americans, who had lived in the region for millennia. A diverse cast of characters has played a role in Morenci's history, including veterans who ventured west after the war, as well as immigrants eager to make a new life in America.
The first prospectors came to the area were searching for gold and silver, which could be easily extracted at little effort or expense. Although little gold or silver was found, this activity discovered of widespread copper mineralization. However, most prospectors lacked the knowledge, skills and resources required to develop this resource. Despite these handicaps, early efforts to extract the copper from these high grade lodes were successful, but only after much trial and error.

Mining activities at Morenci evolved from small pick and shovel operations that relied on burros to transport the ore to primitive adobe furnaces to a world class mining project that employs the latest mining practices and technology to produce copper, which makes our modern lifestyle possible. This transformation didn't just happen. It was the product of wise investments made by visionaries like Henry Leszinsky, William Dodge and Edinburgh capitalists, who provided the financial backing that made the early mining ventures at Morenci a reality.

This financial backing was funneled through a number of mining companies that were incorporated to produce copper from the various property holdings in the Morenci mining district (Figure 2). These business ventures not only developed the mines, concentrators, smelters and other infrastructure that were essential for copper production, but also provided amenities to company towns such as Morenci, Clifton and Metcalf, where the miners and their families lived.

Figure 2. Ownership history of the Copper Mountain (Morenci) mining district.

The most important infrastructure essential to the prosperity of these
business ventures and the remote communities where they were located was reliable rail service that connected these localities with the outside world. This substantially lowered the cost of shipping timber, coke, machinery and all sorts of dry goods required to support the district's mines and communities. It also provided the means for outbound shipments of copper to eastern markets.

The Longfellow Mining Company, Detroit Copper Mining Company, Arizona Copper Company and the Shannon Copper Company as well as a number of other smaller producers all made important contributions to the district's early history. The evolution of the district's ownership history is illustrated in Figure 2. By 1921, the district's producers had been consolidated under the management of a single company, the Phelps Dodge Corporation. Historical copper production is shown in Table 1.

<table>
<thead>
<tr>
<th>Operator Name</th>
<th>Years</th>
<th>Cu Production (lbs)</th>
<th>Source</th>
</tr>
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<tr>
<td>Longfellow Mining Company</td>
<td>1873-1882</td>
<td>24,914,005</td>
<td>Colquhoun, 1924</td>
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<td>Colquhoun, 1924</td>
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<td>1902-1918</td>
<td>192,391,787</td>
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<td>1902-1910</td>
<td>4,672,200</td>
<td>Modified from Tenney, 1927-1929</td>
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<td>New England &amp; Clifton Copper Co.</td>
<td>1906-1910</td>
<td>7,213,889</td>
<td>Tenney, 1927-1929</td>
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<td>Phelps Dodge Corporation</td>
<td>1917-1932</td>
<td>519,111,551</td>
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<td>Sub-Total (Underground Production)</td>
<td>1872-1932</td>
<td>2,031,547,482</td>
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<td>Phelps Dodge/Freeport-McMoRan (OP)</td>
<td>1937-2015</td>
<td>34,726,260,000</td>
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<td>District Total</td>
<td>1873-2015</td>
<td>36,757,807,482</td>
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Table 1. Summary of copper production for the Copper Mountain (Morenci) mining district (1873-2015). Open Pit (OP).

The Copper Mountain (Morenci) mining district has a long and complex history. A chronological sequence of events is shown in Appendix 1.

Phelps, Dodge and Company's wise investments in the Morenci and Bisbee mining districts during 1881 initiated the company's transformation from a prosperous eastern mercantile firm engaged in international commerce into America's largest domestic copper producer by 1985 (Anonymous, 1981a and Briggs, 2016). Its merger with Freeport-McMoRan Copper and Gold, Inc. in March 2007 created the world's largest publicly-owned copper company with annual copper production of nearly 3.9 billion pounds (Freeport-McMoRan Copper and Gold, Inc., 2009).

Morenci is also a story of notable mining professionals, like James Douglas, James Colquhoun, Louis Cates and countless others, whose management and technical expertise made mining ventures at Morenci a financial success.
Their contributions resulted in the successful development of the innovative mining practices and advancements in technology that gradually transformed a collection of primitive underground mining operations at this remote site into one of the world's largest copper mines.

**Five Phases of Production**

Development of Morenci's mining operations progressed through a series of five phases as new mining practices and technology were developed to cope with the changing character of the ores. A list of ore processing facilities that have operated at this site is provided in Appendix 2.

The initial phase of the production began in 1873 and lasted until approximately 1886. During this period, one to ten million pounds of copper were recovered annually from rich oxidized ores hosted by altered carbonate (skarn) lithologies that were mined from shallow cuts and underground workings (Figure 3). Averaging around 12% copper, but ranging as high as 35%, these early ores required no beneficiation prior to being smelted in primitive adobe furnaces or small water-jacketed blast furnaces to produce an impure copper product (60-85% copper), known as black copper, which contained residual ferrous and non-ferrous metals as well as other impurities.

By 1886, the average tenor of the oxide ores mined at Morenci had declined to 6.5% copper. Although the average ore grades were high compared to today's standards, it was too low to be successfully treated by blast furnaces of the mid-1880s without the benefit of pre-smelting beneficiation (Cogut and Conger, 1999a). The low grade oxide ores were upgraded by primitive gravity concentrators that employed jigs to produce a concentrate that was suitable for smelting. Although these early facilities were very inefficient, losing nearly one-half of the copper in the tails, district production during the second phase of production rose to 8 to 15 million pounds, annually. The change in the smelter feed also required modifications to the blast furnaces.
to prevent the loss of copper during the smelting process. Further efforts to reduce losses during the beneficiation process resulted in the development of a hydrometallurgical process during the early 1890s, which was designed to recover copper contained within the oxidized tails.

By the early 1890s, oxidized carbonate ores that had been the district's primary source of copper production were nearly exhausted. Efforts were made to find ways to process the sulfide ores, which were largely hosted by structural zones cutting porphyry. The third phase of copper production began during mid-1890s with the development of a gravity concentrators that were modified to treat the sulfide ores. Bessemer converters were added to the existing smelters in late 1896, allowing the copper content of their smelted products to rise to 98%.

Over the next thirteen years, annual copper production from the underground mining operations at Morenci steadily increased from 15 million pounds to a high of 77 million pounds in 1908. With the exception of a significant decline of copper production during the years following the end of World War I and the collapse of the international metals markets during the fall of 1920, district production remained relatively high until financial hardships of the Great Depression forced the closure of the district's underground mining operations in June 1932.

During the third phase (1896-1932) the concentrating capacity steadily increased to maintain production as the average copper content of the ores declined from approximately 4% to slightly less than 2% (Parsons 1933). The introduction of technological advances such as froth flotation improved efficiencies in the recovery process. The consolidation of mining properties under a single management allowed bulk mining techniques such as block caving to be introduced during the early 1920s.

The introduction of open pit operations at Morenci in 1942 marked the beginning of the fourth phase of production. Neither designed nor strategically located to cope with the large tonnages ore derived from a large open pit, were the existing facilities replaced by a modern crushing plant, 25,000 ton/day concentrator, reverberatory smelter, power plant and other ancillary facilities situated at the mouth of Morenci Gulch. Employing large electric shovels and in-pit rail haulage supplemented by off-road haul trucks, annual copper production rose from 100 million to 430 million pounds between 1942 and 1984. Economies of scale enabled Phelps Dodge to successfully mine ores ranging from 1.2% to 0.7% copper during the fourth phase of production (Parsons, 1957 and Briggs, 2016).

The Morenci project reached major crossroad in its long history during the early 1980s. A precipitous decline in the price of copper, combined with the impacts from the 1983 labor strike and failed efforts to bring its smelter into compliance with the Clean Air Act made the district's future uncertain despite the presence of the large copper resource that remained at the site. The transition from the fourth to final phase of production at Morenci began with the closure of its smelter in December 1984. The introduction of solvent extraction-electrowinning technology in September 1987 allowed Morenci to produce a marketable cathode product that did not require expensive smelting and refining. Transition from in-pit rail haulage to haul trucks with in-pit crushers and conveyors was completed in February 1989. These technological advances and innovative mining practices enabled Morenci
to expand its annual copper production to nearly 1.1 billion pounds over the last several decades (Figure 3). They also reduced the costs of production, making it possible to profitably treat ores, containing as little as 0.03% copper (Freeport-McMoRan, Inc., 2015-2016).

Discovery (1863–1872)

During the early 1870s, prospectors who first ventured into the area that would become the Morenci mining district found evidence of primitive excavations at the site. Although Native Americans did not attempt to smelt the colorful copper-bearing oxides extracted from these ancient mine workings, it appears they used these minerals as pigments in their pottery and for other decorative purposes (Colquhoun, 1924).

The first record of copper mineralization near Morenci appears in a report prepared by soldiers of General Carleton's Regiment of California Volunteers, who camped near the junction of Chase Creek and San Francisco River for a few days in January 1863 (Watt, 1956). While there, they noted the presence of strong copper oxide staining on numerous outcrops that lined the slopes along Chase Creek and named the area Copper Mountain. Scouting parties also discovered placer gold along tributaries of the Rio Prieta, now known as Eagle Creek, in concentrations that ran as high as "forty cents (i.e. 0.02 troy ounces) to the pan" (Cogut and Conger, 1999a).

After learning of this discovery, Henry Clifton, the recorder of the Hassayampa mining district near Prescott, Arizona led a prospecting party to search for gold along the Gila and San Francisco rivers during 1864. Although the party also noted the presence of copper along Chase Creek, the remote location and hostilities with Apaches made further development imprudent at that time.

On a moonlit night during the summer of 1870, an Apache raiding party stole a number of horses from several ranches near Silver City in the New Mexico Territory. On learning of their losses, a group of ranchers led by Captain Chase pursued the Indians over rugged mountainous terrain for more than one hundred miles. This pursuit took them to the valley of the San Francisco River, where they made camp at the mouth of Chase Creek.

Concerned about a possible ambush if they continued up Chase Creek, Captain Chase dispatched several small scouting parties to search for the Indians. One of the scouting parties included brothers, Robert and James Metcalf, former Confederate veterans from Texas, who discovered greenish stained copper showings at the future sites of the Longfellow and Metcalf mines. Joe Yankie, a member of another scouting party followed the trail of the Apaches down Gold Gulch, where he discovered fine particles of gold in the sand along the stream bed (Colquhoun, 1924). Realizing their precarious position, Captain Chase recalled his scouts and returned to Silver City.

Two years later peace was made with the Apache tribes that inhabited the area and conditions for prospecting improved. The General Mining Act of 1872 was passed in May of 1872, significantly reducing the risks of developing mineral discoveries on federal lands. In June 1872, Robert and James Metcalf and Joe Yankie returned with a much larger group to prospect along Gold Gulch. Finding it dry, they decided to follow the drainage down to Eagle Creek, where they camped until the rainy season. While waiting, some of the more
enterprising members of the group prospected the surrounding mountains, where they found numerous copper-stained outcrops above Chase Creek. When the rains finally arrived, they were able to wash the sands along Gold Gulch. The results of these efforts were disappointing and the search for gold was soon abandoned. However before returning home, they staked the Longfellow, Arizona Central, Copper Mountain, Montezuma and Yankie claims in the most favorable areas located around the future town site of Morenci (Colquhoun, 1924).

Early Challenges (1865-1886)

During the years following the Civil War, prospectors in the Arizona Territory focused their efforts on the search for gold and silver. Even if they recognized the presence of copper at these remote localities, there was little incentive for a prospector because development of such discoveries required considerable amounts of infrastructure, manpower, time and expertise that could only be provided by a well-financed business venture. On the other hand, gold and silver could be recovered by hand, transported out on a burro and sold for dollars per ounce instead of a few cents per pound (Anonymous, 1981b).

Business ventures that provided the capital to develop early mining operations throughout the West took huge risks. Although the surface dimensions and metallurgical character of these early high-grade, mineral deposits could be evaluated, little was known about what was present at depth, making it impossible to determine if there was enough recoverable metal present at a site to make a business venture profitable. Efforts to evaluate the size, tenor and metallurgical character of these ore bodies were labor intensive and very expensive.

During the early years, neither Clifton nor Morenci had few stores, houses or utilities. For many years, much of the water used in Morenci was brought in on burros (Watt, 1956). These communities also lacked the law enforcement required to protect the miners from outlaws, who passed through the region. This made it difficult to procure and maintain a sufficient labor force to work at these remote sites. The dominant workforce was Mexican, as they were commonly available, had experience working at mines and a rudimentary knowledge of smelting. However, they would commonly work for only a short time before returning home to their families. These difficulties were gradually solved as improvements were made to the site's infrastructure, which encouraged married men to bring their families to the mining camp. Contract laborers from China were brought to Morenci in 1877. They were more desirable because they would work for less money than the Mexican workers, were less likely to leave, and were more willing to work underground, where conditions were hazardous (Patton, 1945).

During the 1870s, the Morenci mining district was connected to the outside world by only two roads (Figure 4). The road to Solomonville wound its way down the San Francisco River to its junction with the Gila River, which it followed to Solomonville, near present day Safford, Arizona. The other road took a circuitous route to Silver City, New Mexico, located approximately 100 miles to the southeast. Both of these roads were typical of western roads of that time. They were constructed by clearing the mesquites bushes and other desert plants. With no bridges or culverts to divert from water from severe
thunderstorms, these roads were commonly impassable (Patton, 1945).

Figure 4. Topographic relief map showing the location of major towns, historic roads and Apache Indian reservations in southeastern Arizona and southwestern New Mexico during the mid-1870s.

Prior to the introduction of rail transportation to the Morenci mining camp
in late 1879, the ore was initially packed down steep trails on burros to the Stone House smelter, which was established along Chase Creek during the spring of 1873. A wagon road was later constructed, connecting the Longfellow smelter at Clifton with the mines at Morenci and Metcalf (Figure 5).

Figure 5. Mule teams hauling ore from Garfield to Metcalf (circa 1900). (Photo provided by the Arizona Geological Survey).

Figure 6. Wagon route for the shipment of copper ingots from Morenci to railheads for shipment to eastern markets prior to 1880.
Copper ingots produced at Morenci's early smelters were transported approximately 100 miles by wagon to Silver City, New Mexico. From there it was transported to eastern markets via distant railheads that were initially located at Kansas City, Missouri (Figure 6). Much of this route traversed the historic Santa Fe Trail, which connected Kansas City with Santa Fe, New Mexico. As railroads moved west, Morenci's copper was delivered to railheads at La Junta, Colorado in late 1875 and Las Vegas, New Mexico in July 1879 (Patton 1945).

The trails from Morenci to these distant railheads traversed Apache and Comanche territory, where the wagon trains were often attacked, teamsters killed and livestock stole. However, the Indians had little use for the heavy copper ingots, which were retrieved by subsequent wagon trains and delivered to the market. Supplies for the mines and small communities that supported the early mining camp at Morenci were hauled by wagons on their return trip from Silver City (Patton, 1945).

The Southern Pacific Railroad was completed to Lordsburg, New Mexico from the west in October 1880, significantly reducing the distance to the railhead. In March 1881, the Southern Pacific Railroad linked up with the Atchison, Topeka and Santa Fe Railroad at Deming, New Mexico allowing Morenci operations to ship their product to eastern markets. Many of the early challenges with respect to transportation were finally resolved with the completion of the Arizona and New Mexico Railroad from Lordsburg, New Mexico to Clifton, Arizona in April 1884 (Figure 7).

Figure 7. Major rail infrastructure in the southwestern New Mexico, southeastern Arizona and northeastern Sonora (circa 1905).
During the early 1800s, the Apaches considered Americans as allies against their bitter enemies, the Mexicans (Machula, 1996). This attitude was reinforced by the Mexican American War of 1846-1848. However, over the years as more Americans settled in the region, tensions gradually rose until February 1861, when an inexperienced army officer falsely accused Cochise, Chief of the Chiricahua Apaches of kidnapping a rancher's 12-year old stepson and stealing cattle. This encounter led to the deaths of several of Cochise's relatives, igniting a 25-year war between the United States and the Apaches (Southern Arizona Guide, 2015). The vacuum created by the transfer of federal troops east after the beginning of the Civil War in April 1861 only made conditions worse for settlers living in the New Mexico and Arizona territories.

In May 1872, President Ulysses S. Grant decided to resolve differences between the United States and the Apaches. He dispatched General Oliver Howard to Arizona to negotiate a peace treaty with the various Apache tribes. During the summer and fall of 1872, Howard negotiated treaties with the Chiricahua, Aravaipa and White Mountain Apache tribes and established the Chiricahua and White Mountain/San Carlos reservations (Machula, 1996). This resulted in a temporary cessation of hostilities in the region. However, harsh conditions at San Carlos forced many Apaches to leave the reservation and intermittently raid neighboring settlements. The Chiricahua Reservation was located in present day southeastern Graham County and much of Cochise County east of the San Pedro River (Figure 4).

Although the Indians seldom harassed larger settlements or large columns of troops, they were experts in guerilla warfare, commonly ambushing unwary settlers who ventured out alone or in small groups. Anyone who journeyed outside of Morenci or Clifton did so at their own risk. Trails connecting the Morenci mining district with the outside world and isolated ranches were often targets of raids.

Following the death of Cochise in June 1874, the U.S. government broke the Cochise-Howard peace agreement. They closed the Chiricahua Reservation in October 1876 and opened the area to settlers and prospectors, who discovered copper at Bisbee in August 1877. Approximately one-half of the Chiricahua Apache tribe was forcibly relocated to the San Carlos Reservation. The remainder, led by Geronimo, escaped capture and subsequently carried out intermittent raids on both sides of U.S./Mexico frontier over the next decade, interrupted by brief respites as Geronimo's followers returned to the San Carlos Reservation (Southern Arizona Guide, 2015).

One of the worst Apache raids in the Morenci/Clifton area occurred in April 1882, when Geronimo and approximately 200 warriors left the San Carlos Reservation (Patton, 1945). Over a period of several days, twenty-five people were killed in attacks around the Morenci town site, the Detroit Copper smelter along the San Francisco River, and outlying ranches. Although Geronimo continued to threaten areas in southwestern New Mexico and southeastern Arizona, he never returned to the Clifton area. Geronimo's surrender at Skeleton Canyon in the Peloncillo Mountains along the New Mexico-Arizona border in September 1886 marked the end of hostilities with the Apaches (Patton 1945).

Despite all of these challenges, there was no shortage of business ventures
willing to invest capital in developing Morenci or other remote mining camps throughout the West. Although many of these ventures were short-lived and failed, others flourished, unlocking the mineral wealth that built enormous business empires. Early successes at Morenci along with those at Bisbee helped make the Phelps Dodge Corporation one of the world's largest copper producers.

**Longfellow Mining Company (1872-1882)**

Julius Freudenthal and his nephew Charles Leszinsky were Polish immigrants, who ran a wholesale provisions business in the New Mexico Territory. Based out of Las Cruces, this lucrative enterprise supplied grain and flour to Federal garrisons and ranching and mining communities throughout the region. Charles' brother, Henry Leszinsky, joined the family business around 1868. Henry was an experienced prospector, who had searched for gold and silver in Australia and Nevada before settling in New Mexico. Assured that additional mining opportunities were available in southwestern New Mexico, the Leszinsky family opened a store in Silver City.

Shortly after returning home from Chase Creek, Robert Metcalf took a number of samples he had collected from the Longfellow claim and showed them to Eugene Goulding, the manager of Leszinsky's store in Silver City. Goulding shipped the samples to Henry Leszinsky, who was not familiar with copper ores, but realized the property merited further investigation. Satisfied with results of discrete inquiries about Metcalf's reputation, Leszinsky, Metcalf, Goulding and four well-armed men visited the Longfellow claim, where numerous outcroppings of oxide copper mineralization convinced Leszinsky the prospect should be developed. However, they were soon reminded of the challenges this business venture presented. When they returned to the bottom of the slope along Chase Creek, they found their horses and provisions had been stolen by Apaches. After a long hike to a nearby ranch, they safely returned to Silver City.

Charles and Henry Leszinsky and their uncle Julius Freudenthal purchased a controlling interest in the Longfellow property from Robert and James Metcalf for $10,000. The Francisco Mining Company was formed on August 28, 1872. It was later renamed the Gila Mining Company, which ultimately became the Longfellow Mining Company in May 1874 (Rickard, 1987).

During the early years, the Longfellow mine encountered many challenges. Initially consisting of small surface cuts near the top of a ridge along the steep, southwest slope of Chase Creek, the Longfellow mine was located in very rugged, inaccessible terrain that was vulnerable to raids by hostile Apaches (Figure 8). Distant railheads to eastern markets were only accessible by wagons drawn by teams of horses, mules or oxen. Labor was scarce, as was water, mining equipment and fuel for smelting. They also had little knowledge of copper smelting.
The earliest attempts to treat high-grade copper ores from the Longfellow mine were less than satisfactory. A small Mexican-style adobe furnace was built along Chase Creek during the spring of 1873. Known as Stone House, it was constructed with local quartzite and used kaolin as fire clay (Figure 9). This early smelter was fueled by charcoal derived from mesquite and scrub oak trees that grew along the Chase Creek drainage. Using cowhides as bellows, it was capable of treating rich copper carbonate ores (averaging 20% copper) at a rate of one ton per day. These self-fluxing ores were melted in these early furnaces. Once melted, an iron bar would be used to ream out a tap hole at the base of the furnace and its molten contents emptied into a masonry basin. The lighter slag floated on the surface and was skimmed off for disposal, while the copper-rich product was poured into simple molds. These primitive furnaces had to be rebuilt after each charge due to the intense heat required to melt the ores. This tedious procedure was a very time consuming and expensive process due to the excessive labor costs required to rebuild the furnace (Rickard, 1987).

By the fall of 1873, improvements in construction of these furnaces had been made by replacing local quartzite with sandstone from the Mimbres area in New Mexico. This lengthened the life of the furnaces from 36 hours to 10 to 14 days. Even with these improvements, the process was still inefficient; producing an impure "black copper" product containing approximately 85% copper with nearly a third of the copper being temporarily lost in the slag. Slag from old dumps was ultimately resmelted, recovering the copper as smelting technology improved. Charcoal consumption was also high, requiring one pound of charcoal for every three pounds of ore smelted (Rickard, 1987).

The Leszinskys established the first general store at the future site of Clifton, Arizona in 1873 to provide necessities to workers at their mines and smelter. Early houses in this community were constructed from adobe and were very rudimentary in nature. Commonly faced with shortages in working and investment capital, workers were paid in scrip, known as "boletas" that could only be exchanged at their company stores. The use of scrip also reduced the incentive for theft by the many desperados that passed through the area. Departing workers could exchange the scrip for silver, but at a discount. More importantly, the company stores earned a profit even when the mining operation did not, allowing the Longfellow Mining Company to remain solvent (Hyde, 1998).

In early 1874, the Longfellow smelter was relocated two miles downstream to a site near the confluence of Chase Creek and the San Francisco River (Figure 9). This allowed the furnace's hand bellows to be replaced with mechanical blowers that were powered by a water wheel. By April 1874, this smelter was producing 2,000 pounds of copper per day. It had eight furnaces, which allowed four furnaces to be in operation while the other four were being repaired.

These early challenges proved to be too much for the Metcalf brothers, who believed the ores at the Longfellow mine would soon be exhausted. They sold their minority interest in the project in April 1874 for $20,000, leaving the Leszinsky family as the sole owners of the business venture (Anonymous, 1981b).
In an effort to reduce the cost of constantly repairing the furnaces, the Leszinskys hired an experienced metallurgist from Baltimore, who assured them he could solve their problem. Construction of a ten-ton reverberatory-type furnace began in June 1874. Over the next eight months, 10,000 fire clay bricks that were used to build the shell of the new furnace were baked within the existing Mexican-style furnaces. Completed in January 1875 at a cost of $20,000, the new furnace failed, when it was melted into a heap of burnt brick after only 24 hours of operation (Rickard, 1987).

After much research and experimentation, early problems encountered with the mesquite-fired, Mexican-style adobe furnaces were finally resolved with the introduction of water-jacketed furnaces in 1877 (Hyde, 1998). Other improvements to the smelting process included pouring the molten copper and slag into a clay-lined, pre-heated metal pot. This allowed the slag to float to the surface, where it could be easily skimmed off for disposal. The remaining copper was then poured into molds to produce the final copper bullion product, which contained 95% copper. These were the first copper bullion bars cast in Arizona. By the late 1870s, the Longfellow smelter was producing 8,000 pounds of copper per day and the mining operation was finally making a profit for the first time (Rickard, 1987).

The cost of hauling ore and supplies by wagon between the Longfellow mine and the Clifton smelter was approximately $10 per ton in 1878. Efforts to reduce these costs led to a decision to build the first mine railroad in Arizona. The 20-inch baby-gauge Coronado Railroad was constructed along the Chase Creek from Clifton to a point below the Longfellow mine, where it was connected to a 2,200-foot long gravity incline (Figure 9). Descending 800 feet along the steep southwest slope of Chase Creek, the Longfellow incline was the first of nine inclines that would be constructed in the Morenci mining district. This incline consisted of a steep set of mine-car rails dropping from the mine portal located near the top of ridge to the canyon floor. It employed a reel with heavy metal cable used to raise and lower ore cars up and down the incline. The Longfellow incline was also unique; it was the only incline at Morenci that ran through a tunnel bored through the hillside (Cogut and Conger, 1999a).

Commissioned at a cost of $75,000 in December 1879, the 4.5-mile Coronado Railroad initially used mules to haul empty ore cars up the creek from the smelter to the base of the Longfellow incline, where they would be hoisted up to the mine (Hyde, 1998). Loaded ore cars were lowered to the canyon floor, where the mules and mule-skinner would mount a platform at the rear of the train and return to the smelter by gravity. The mules were replaced by a small steam locomotive, known as "Little Emma" during the fall of 1880 (Carmichael and Kiddie, 1924). Indian raids and livestock theft declined after the commissioning of this rail line. A loading facility consisting of large ore bins located at the base of the incline was added during a later expansion, enabling the mine and rail line to operate independently of one another.

Fuel for the Longfellow smelter was initially charcoal derived from trees that were harvested along Chase Creek. Once the trees in the Chase Creek area had been consumed, the Longfellow smelter obtained charcoal from mesquite groves along the Gila River (40 miles) near present day Solomon, Arizona, and from the Burro Mountains (80 miles) near Tyrone, New Mexico (Colquhoun, 1935). However, charcoal was never the ideal fuel for these
primitive blast furnaces. It slowed the smelting process and reduced the iron-bearing minerals contained in these ores to metallic iron, which combined with the copper to produce an impure bullion product (Rickard, 1987).

The Southern Pacific Railroad was completed to Lordsburg, New Mexico on October 18, 1880, connecting it with ports on the west coast. In March 1881, the Southern Pacific Railroad linked up with the Atchison, Topeka and Santa Fe Railroad at Deming, New Mexico allowing Morenci operations to ship their product to eastern markets. This transportation infrastructure significantly reduced the cost of shipping goods to and from the Morenci area. It also resulted in the change in the source and type of fuel used by the Longfellow smelter. Charcoal was replaced by coke derived from imported sources that was shipped from the west coast by rail to Lordsburg and hauled by wagon to Clifton. One of the disadvantages of using coke was the higher values of copper reporting to the slag. The use of coke at the Longfellow smelter resulted in an increase of the facility's output to 15,000 pounds of copper per day (Rickard, 1987).

By 1882, underground workings at the Longfellow mine covered an area of approximately 500 by 600 feet. There was no timber for support, ore cars, hoists or power of any form. The mine was accessed by gently sloping inclined adits driven into the hillside at different levels. Wheelbarrows were initially used to extract the ore. Open stoping methods employed at the Longfellow mine involved removing the ores from the stopes (i.e. underground excavation from which ore was mined) that were left open once mining had been completed. Backs of these stopes (i.e. roof of underground mine workings) were supported by pillars (i.e. unmined rock column used to support roof) of high grade ore, centered at intervals of 80 to 100 feet. As these pillars were thinned during times of financial stress, large areas in the mine became unstable and increasingly susceptible to caving (Mosier and Sherman, 1929).

Lacking sufficient capital to properly develop their holdings, the Longfellow Mining Company was placed on the market in spring of 1882. To make it more attractive to prospective buyers, a May 1882 agreement was made with the Detroit Copper Mining Company to use vertical sidelines rather than "extra lateral rights" allowed under the General Mining Act of 1872. This action avoided potential costly future litigation that might result from ownership disputes (Hyde, 1998). Over its ten-year life (1872-1882) the Longfellow Mining Company produced an estimated 24.9 million pounds of copper (Colquhoun, 1924).

**Detroit Copper Mining Company (1872-1917)**

The other early mining venture established to develop the copper resources of the Morenci area was the Detroit Copper Mining Company, which was originally incorporated in July 1872. It was reincorporated in March 1873 by a group of Detroit capitalists headed by Eber B. Ward. Initially capitalized at $500,000, it was two-thirds owned by Detroit interests with the remaining third held by seven investors from Silver City, New Mexico (Hyde, 1998).

This company enlisted support of a small group of miners lead by Miles Joy to survey the Yankie, Montezuma, Arizona Central, and Copper Mountain claims. This early effort gave rise to a small settlement known as Joy Camp at the site that eventually became the town of Morenci, which was named after a
small community in Michigan (Figure 8). However, danger from raids by Apaches and logistical difficulties of its remote location resulted in the failure of this early effort after the death of Eber Ward in January 1875 (Watt, 1956). Very little production was achieved during this early period.

William Church, a mining engineer from Colorado, acquired a controlling interest in the Detroit Copper Mining Company from the estate of Eber B. Ward. Church arrived at Morenci in 1880 and renewed efforts to develop the property. Recognizing the value of the Detroit Copper Mining Company's holdings, Church made a trip to New York in late 1880 to find the financial assistance he required to develop the property (Watt, 1956).

In January 1881, William Church visited Phelps, Dodge & Company and met with William Dodge, its senior partner. Church asked William Dodge for a $30,000 loan, offering his holdings at Morenci as collateral. Although William Dodge initially declined Church's proposal, he commissioned James Douglas to visit the property. James Douglas examined the property and prepared lengthy reports on the Detroit Copper Mining Company. Based on James Douglas's recommendations, Phelps, Dodge and Company purchased a substantial portion of the Detroit Copper Mining Company's stock for $50,000 in May 1881 (Conger, 1987). Over the next 36 years, the Detroit Copper Mining Company benefitted from the wisdom of James Douglas.

With financial backing in place, the Detroit Copper Mining Company erected a small smelter along the east bank of the San Francisco River, located approximately three miles downstream from Clifton, Arizona in April 1882 (Figure 9). Situated approximately six miles southeast of the mines at Morenci, wagons were used to transport the ores to this facility, which employed two 36-inch diameter water-jacketed furnaces driven by water-powered blowers.

Metallurgical problems plagued the start-up of this facility. Small blast furnaces of that time produced an impure copper product (60-85% copper), known as black copper, which contained residual ferrous and non-ferrous metals as well as other impurities. They commonly malfunctioned for no apparent reason, resulting in much of the copper being lost in the slag. On advice from James Douglas, the mixture of the smelter charge was adjusted, significantly increasing the efficiency of Detroit Copper's smelting operations and the quality of its black copper product (Anonymous, 1981b).

Although Detroit Copper's first smelter produced $700,000 of copper through the end of 1883, high ore haulage costs and danger of Indian attacks resulted in a decision to relocate the reduction works to the town of Morenci, where it was close to their mines (Figure 9). Construction of the new smelter began in January 1884 and it was commissioned in September 1884 (Figure 10) (Richard, 1987). This new smelter employed the two 36-inch diameter water-jacketed furnaces from its decommissioned smelter and a more efficient rectangular water-jacketed furnace designed by Carl Henrich, measuring 32-inches by 72-inches that could process 60 tons of ore per day (Hyde, 1998). A 120-ton furnace was added to the Morenci smelter in March 1888.
Figure 10. The Detroit Copper Mining Company smelter at Morenci (circa 1896). (Photo from a Phelps Dodge Morenci, Inc. brochure provided by Freeport-McMoRan, Inc.).

Early financial backing received from Phelps, Dodge and Company also enabled the Detroit Copper Mining Company to provide infrastructure required to support its workforce. A 44-inch Leffel water turbine at Detroit Copper's dam on the San Francisco River drove a pump, which lifted water from the river 1,700 feet via a 7-mile wrought-iron pipeline to two 90,000 gallon tanks that supplied the community and smelter (Hyde, 1998). Single workers resided in boarding houses that were constructed at its mines and smelter. As more workers moved to the area with their families, homes were constructed from available materials, including adobe, tin cans, barrel staves, dry goods boxes and anything else that could be fashioned into a shelter. Mainly consisting of saloons, dance halls, brothels and gambling houses, Morenci's business district soon earned the community a reputation of being one of the toughest mining camps in Arizona. Most of Morenci's early housing and businesses were situated along the narrow confines of Morenci Gulch, where few provisions were made for sanitary conditions. Mortality rates resulting from typhoid and dysentery were quite high (Watt, 1956).

In May 1886 the Detroit Copper Mining Company established Arizona's first concentrating plant, which made it profitable to treat low grade stockpiles contained in the old mine dumps. This 50-ton/day facility employed a gravity circuit using jigs to treat low-grade (about 6.5% Cu) oxide ores, containing azurite, malachite, cuprite, chrysocolla, chalcocite, brochantite and tenorite (Figures 11 and 12). With average recoveries of 55%, it produced a concentrate that assayed 23.28% copper with tails averaging 3.92% copper (Colquhoun, 1924). In an effort to make efficient use of their scarce water supply, tailings from this facility were allowed to settle in a tailings pond, so the water could be decanted off and recycled by the concentrator (Watt, 1956).
A decline in the copper price to 10 cents per pound during 1892 resulted in a temporary suspension of operations at the Detroit Copper Mining Company's mines. Although operations resumed a short time later, the high-grade oxide copper ores that had been mined previously were nearly depleted. A concentrator designed to treat the lower grade sulfide (chalcopyrite - Cu$_2$S) ores was built in 1895, but was a commercial failure. Detroit Copper's second attempt to concentrate low-grade sulfide ores succeeded in 1900 with the commissioning of the 400-ton/day West Yankie concentrator, substantially increasing the company's output (Figure 9). The capacity of this gravity plant was expanded to 800 tons per day in 1905 and reached 1,300 tons per day in 1908. A flotation circuit was added to the West Yankee concentrator in September 1915.

Froth flotation is a process in which finely ground ore is added to a flotation cell where it is agitated and mixed with chemicals that cause the copper-bearing minerals to adhere to air bubbles and rise to the surface as a froth. The copper-rich froth is skimmed off as concentrate, while the remaining material sinks to the bottom of the cell and reports to a tailings impoundment.

Interested in learning more about a new method for desulphurizing copper matte during the smelting process, William Church and James Colquhoun visited the Copper Queen Smelter in Bisbee in July 1896 (Watt, 1956). Known as the Bessemer process, it had been originally developed in England in 1856 by Henry Bessemer to remove impurities from iron during the production of steel. Modified to upgrade copper matte, this process employs a Bessemer converter, where air was blown through molten copper matte. This process partially converts the copper sulfide (Cu$_2$S) into copper oxide (Cu$_2$O), which reacts with the remainder of the Cu$_2$S to produce molten copper. The product of this process is known as blister copper (approximately 98% copper) because as it solidifies sulfur dioxide (SO$_2$) gas contained within it escapes producing a blister on the surface. Impressed by the efficiency of this process, William Church installed a Bessemer converter at the Detroit Copper's smelter in late 1896 (Watt, 1956).

During the spring of 1897, Phelps, Dodge and Company acquired the remaining outstanding stock of the Detroit Copper Mining Company for $1.8 million (Cogut and Conger, 1999a). With this acquisition, Dr. James Douglas
succeeded William Church as president of the Detroit Copper Mining Company. Most of its underground operations were located around and beneath the town of Morenci. Its larger producers included the Yankie, West Yankie, Arizona Central, Montezuma, and Lone Star mines (Figure 13).


Shortly after Phelps, Dodge and Company completed its purchase of the remaining stock of the Detroit Copper Mining Company, a fire destroyed much of the older portion of the community, known as “Hell Town”, which was located along Morenci Gulch. The burned over area was condemned, preventing residents and businesses from rebuilding. At the same time, work began on clearing a new town site at the head of the canyon, where space was available to expand the community.

One of the earliest challenges at Morenci was providing a reliable source of water for the community and mines. Water was initially delivered to Morenci via a 7-mile pipeline from the San Francisco River. However, quality of water from this source was poor due to suspended fines and dissolved salts.
It commonly had to be set aside in barrels for several days to allow the suspended material to settle out before it could be used. The Morenci Water Company was organized in October 1898 to construct and manage the infrastructure required to provide water from a well located along Eagle Creek, five miles to the southwest. Water from this source was delivered to Morenci via a 4-inch pipeline to storage tanks located on a hill 300 feet above the town. This new water distribution system made it possible to build houses on higher ground and significantly improved the general health of the community (Watt, 1956).

During the late 1890s, Detroit Copper officials realized Morenci's future prosperity was tied with linking it to the outside world with a railroad. However, the only feasible route was through Slag Town, a small community of Mexican and Italian immigrants located along Morenci Gulch. Announcements were made regarding Detroit Copper's intention to proceed with the project without first consulting the property owners. Outraged at having their property rights ignored, citizens of Slag Town banded together and forced Detroit Copper to compensate those holding established mining claims. This was the first time Mexicans and Italians to joined forces to confront the mine owners. It would not be the last (Martinelli, 2009).

Figure 14. Morenci Southern Railroad loop in Morenci Gulch (circa 1900s). (Photo provided by the Arizona Geological Survey).

Having obtained the right-of-way for the proposed rail line, the Detroit Copper Mining Company formed the Morenci Southern Railroad in October 1899 (Figure 9). Construction on the 36-inch narrow gauge rail line began in February 1900 and was completed in December 1901 at a cost of approximately $504,000 (Carmichael and Kiddie, 1924). Connecting mines at the Morenci town site with the Arizona and New Mexico Railroad at Guthrie, this 18-mile rail line required a series of five loops (known as the Corkscrew Route of America) to negotiate the 1,400-foot change in elevation from the San Francisco River to Morenci (Figure 14). One of these loops included a tunnel located along the west bank of the San Francisco River, while the other loops used high wooden trestles in the narrow canyon below the town of Morenci. Three loops were replaced by a pair of switchbacks during 1914, adding about
0.4 miles, but reducing maintenance expenses and enhancing safety of the operation.

In June 1900, molten slag at the Detroit Copper Mining Company's Morenci smelter was poured into a pot containing shavings and cotton waste, causing an explosion and fire. This accident resulted in a suspension of smelting operations for more than a month (Rickard, 1987). The smelter was rebuilt and expanded during the summer of 1901.

Incorporated in 1900, the Morenci Improvement Company was the second company that was organized to improve living conditions at Morenci. By March 1901, this firm erected more than 50 three- to five-room residences that were rented for $12 to $20 per month. They also constructed a 42-room boarding house with a connecting barber shop and bath. There were also many privately owned residences in the town of Morenci that were located on company-owned lands that required the payment of a monthly ground rent to the land owners (Watt, 1956).

With all of the business activity generated by the Morenci's mines, the need for a local banking institution became imperative. The area's first bank was the Gila Valley Bank. Founded by Isidor Solomon at Solomonville, Arizona in January 1900, the Gila Valley Bank was subsequently reorganized under the name of Gila Valley Bank and Trust Company, which opened its first branch in Morenci in January 1902. This banking institution would later become the Valley National Bank of Arizona (Watt, 1956).

Although residents of Morenci benefited from company and citizen sponsored improvements to the community, many of the workers harbored grievances that eventually lead to series of labor disputes. The first dispute arose out of a bill passed by the Arizona Territorial Legislature in 1903 that made eight hours the standard work day for underground miners. In response to this legislation, the district's mining companies reduced the miners' wages proportionately. This led Morenci's miners to strike on June 3, 1903, demanding better working conditions and a 25 cent per day pay raise.

Mainly of Mexican and Italian extraction, Morenci's strikers were not represented by a union. At that time, established unions like the Western Federation of Miners were reluctant to support Morenci's workers because it threatened the economic advantages and better working conditions enjoyed by the white union membership (Martinelli, 2009).

Concerned about potential violence, the Territorial Militia and U. S. Cavalry from Fort Huachuca and Fort Grant were ordered to Morenci to keep the peace. As tensions rose, both sides braced for an inevitable showdown. However, at 4 pm on June 11, 1903, an intense thunderstorm resulted in a flash flood that sent a 12-foot high wall of water down Chase Creek that destroyed many of the miner's homes and caused 40 deaths. Although a few strikers attempted to reorganize after this catastrophe, federal troops quickly established martial law and arrested the strike leaders. On June 12, 1903, the workers accepted the original proposal from the mining companies, which offered 9 hours of pay for 8 hours of work (Sullivan, 2013).

In April 1906, one of the earliest attempts to recover copper by in-situ methods began at the Medler mine (Austin, 1911a). This in-situ leaching project involved flooding the drifts on the second level of the underground
Medler mine and allowing the solutions to percolate downward to the third level. The copper-bearing solutions were collected and transferred to a precipitation plant, where the copper was precipitated onto scrap iron (Ahlness and Pojar, 1983). The first carload of precipitate copper, averaging 52.04% copper, was shipped to the smelter in July 1908. This project was abandoned during 1909, when the Shannon-Arizona Railroad by right of "eminent domain" drove a tunnel through the mine, rendering conditions too hazardous to continue the in-situ leaching project. Although this project was pre-maturely terminated, it demonstrated groundwater could be used as a lixiviant to profitably recover copper from a large body of mineralized porphyry (Austin, 1911b).

Figure 15. Two men working a churn drill with dumps in the background (circa 1930s). Photo provided by the Arizona Geological Survey).

Between 1914 and 1916, a 50,000-foot churn drilling program on the Colorado Hill and Ryerson claims delineated a resource hosted by porphyry of approximately 12 million tons, averaging 1.34% copper (Figure 15). A westward extension of the Colorado tunnel during 1917 significantly increased this resource to 26 million tons. This work confirmed this resource was a part of the large Clay ore body that was being developed on the neighboring Arizona Copper property (Patton, 1945).

The Phelps, Dodge and Company partnership was incorporated as Phelps, Dodge and Company, Inc. in 1908. Dr. James Douglas was elected President and moved to its corporate offices in New York. His son, Walter Douglas was appointed general manger of its western operations, which included the Copper Queen Consolidated Mining Company in Bisbee, Detroit Copper Mining Company in Morenci, Moctezuma Mining Company in Nacozari, Sonora, and Stag Canon Fuel Company in Dawson, New Mexico (Anonymous, 1981a).

Phelps, Dodge and Company, Inc. reorganized its corporate structure in April 1917, transitioning from a holding corporation to an operating company. The name of its affiliated Copper Queen Consolidated Mining Company was changed to the Phelps Dodge Corporation. Properties held by the Detroit Copper Mining Company became the Morenci Branch of the Phelps Dodge Corporation (Rickard, 1987).
Over its 45-year life (1872-1917) the Detroit Copper Mining Company produced approximately 443.5 million pounds of copper (modified from Colquhoun, 1924).

**Arizona Copper Company (1882-1921)**

A Scottish syndicate purchased the Longfellow Mining Company in September 1882 for $1.2 million and formed the Arizona Copper Company to manage their assets. They also purchased Robert Metcalf's claims in the Metcalf area for $300,000. This business venture was initially capitalized at $5 million with the majority of the preferred shares held by Edinburgh capitalists.

Following its acquisition, the Arizona Copper Company allocated $3.0 million dollars for a major expansion program at Morenci. This project included: 1) construction of a narrow gauge (36-inch) rail line connecting Clifton, Arizona with the Southern Pacific Railroad in Lordsburg, New Mexico; 2) erecting a new smelter in Clifton; 3) extending the Coronado Railroad from the Longfellow Incline to Metcalf; 4) construction of inclines to connect all of its mines with the Coronado Railroad; 5) construction of the Longfellow Railroad from the top of the Longfellow Incline to its operations in Morenci; and 6) equipping all the mines and inclines with locomotives, railroad cars, buildings and machinery (Conger, 1987).

In an effort to reduce animosity of American and Mexican workers, the Arizona Copper Company discontinued the use of Chinese labor, which constituted approximately 25% of its workforce in 1883 (Sullivan, 2013). The practice of using cheap contract foreign labor was outlawed in February 1885 with the passage of the Foran Act. Anglos generally held the higher paying management positions, while the majority of the workforce was composed of Mexicans, Italians and immigrants from southern Europe.

![Figure 16. Baby gauge locomotive on the Coronado Railroad by an engine house in Metcalf during the 1890s. (Photo from a Phelps Dodge Morenci, Inc. brochure provided by Freeport-McMoRan, Inc.).](image-url)
By 1883, the Arizona Copper Company extended the Coronado Railroad to the Metcalf area and connected it to inclines that were used to haul ore from its Queen, Metcalf, and Coronado mines located on the steep slopes above Chase Creek (Figure 16). Inclines employed during the early years of the Morenci district were constructed on slopes of up to 36 degrees and ranged from 800 to 3,200 feet in length. Residents of Morenci commonly rode the ore cars on the Longfellow incline when traveling to Metcalf or Clifton. Although public access to this incline was prohibited in November 1885 after several serious accidents, miners continued to ride ore cars up and down the inclines (Watt, 1956). On August 15, 1913, nine miners were killed and six injured, when ore cars plunged down Arizona Copper's Coronado incline (Figure 17).

Figure 17. Located in rugged mountainous terrain above Coronado and Santa Rosa Canyons west of the town of Metcalf, the Coronado incline handled ore from the Coronado mine. Rising almost 1,200 feet in elevation, it was reported to be largest incline in the nation (circa 1890s). (Photo provided by the Arizona Geological Survey).

The Longfellow incline also served as an important conduit for goods shipped to and from Morenci area mines for both the Arizona Copper Company and Detroit Copper Mining Company (Figure 9). Coke and other supplies were transported to the foot of the incline by the Coronado Railroad and hauled up the incline. From there they were transported to Morenci via narrow gauge railroad. Ore and copper from the Morenci area mines were lowered to Chase Creek by the incline and transported via rail to Clifton.
The Arizona and New Mexico Railroad was incorporated by the Arizona Copper Company on January 8, 1883 to provide its operations access with the outside world via Southern Pacific's transcontinental rail line, which passed through Lordsburg, New Mexico (Figure 7). Construction of this 71-mile narrow gauge (36-inch) rail line from Lordsburg, New Mexico to Clifton, Arizona began in January 1883 and was completed April 1884. Rail service included two trains each day to and from Lordsburg. Each train consisted of a long string of freight cars with a single passenger car at the rear. With the completion of this rail line the cost of coke at Clifton declined from $50 to $37.42 per ton (Hyde 1998).

Substantially exceeding its budget, Arizona Copper's expansion program and a cave-in at the Longfellow mine in November 1882 almost bankrupted the company. By October 1883 the Arizona Copper Company was almost $1.0 million dollars in debt. The company was reorganized in August 1884 as the "new" Arizona Copper Company. The property mortgaged for $1.8 million allowing them to successfully complete the expansion program.

James Colquhoun, a Scottish mining engineer arrived in the Morenci district in August 1883. A site for Arizona Copper's new smelter was selected at the mouth of the Chase Creek in September 1883 (Figure 9). Instead of locating this facility close to the creek bottom like the older Longfellow smelter, the new smelter was situated on two benches excavated on the north bank of Chase Creek. The new smelter was commissioned on July 1, 1884. It employed three 48-inch, 60-ton Fraser and Chalmers furnaces and two 36-inch, 40-ton Pacific Iron Works furnaces. Three water-powered turbines powered five Baker blowers for the furnaces, the ore crushers and pumps (Rickard, 1987). Unlike other smelters of the time, the slag from this facility was not stored for later retreatment. Molten slag from this facility was granulated by dropping it in a running stream of water and dumped in the San Francisco River, where any copper remaining within the slag was lost forever (Colquhoun, 1924).

By the end of 1884, James Colquhoun was promoted to smelter superintendent (Conger, 1987). The Arizona Copper Company commissioned a 100-ton/day oxide concentrator adjacent to its Clifton smelter in January 1887. Similar to the one established by Detroit Copper Mining Company at Morenci the previous year, this facility also employed gravity methods (jigs) to produce an oxide concentrate. It was not very efficient with nearly half of the copper being lost in the tails (Colquhoun, 1924).

The introduction of oxide/sulfide concentrators in the Morenci mining district led to additional challenges at the early smelting operations. Smelters in use at the time employed blast furnaces that were ideally suited for the direct-smelting ores. However, smelting fine material, such as 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. Efforts to resolve this problem included the introduction of dust chambers, where the fine material was allowed to settle out, so it could be recovered and recycled to the smelter. Briquetting plants were commonly used to agglomerate the fines prior to the smelting (Levy, 1912). However, this issue was not completely resolved until the induction of reverberatory furnaces around the turn of the 20th century (Colquhoun, 1924).
James Colquhoun was promoted to the General Manager of Arizona Copper's Morenci operations in 1892 (Conger, 1987). He developed a process which used a dilute sulfuric acid solution made from inferior pyritic ores to leach copper from tailings derived from oxidized porphyry ores. Copper-bearing solutions reported to two revolving 40-gallon barrels, where the copper was plated onto scrap metal to produce a copper precipitate product that was suitable for smelting. Leach and sulfuric acid plants were commissioned adjacent to the Clifton smelter in October 1893 at a cost of $100,000. Reported to be the first facility of its type in Arizona, it enabled the Arizona Copper Company to increase its output by 40% and reduce production costs by 2 cents per pound (Colquhoun, 1924). This allowed Arizona Copper to remain in production at a time when low copper prices (10 cents per pound) forced the Detroit Copper Mining Company to temporarily suspend operations (Rickard, 1887).

Up until the early 1890s, mining operations at Morenci had been solely confined to mining oxidized copper ores hosted by altered limestone. Convinced the rich copper deposits hosted by limestone had been ultimately derived from the adjacent porphyry, John Colquhoun and Paul Nicholas, Arizona Copper's mine superintendent decided it was time to examine the mineral potential of Copper Mountain. Until that time, this area had never been considered to be an important exploration target (Colquhoun, 1924). Spurred by the discovery of a small vein of pay ore along the southeast flank of Copper Mountain by a Mexican leaser, they drove the Humboldt tunnel into the hill side (Figure 13). This tunnel encountered the vein at approximately 600 feet, but its tenor was so poor they almost abandoned their effort. At this point, their attention shifted to the oxide showings along the Fairplay lode, located approximately 1,400 feet to the west. The trajectory of the Humboldt tunnel was modified to test the Fairplay lode. After approximately 400 feet of additional drifting, the Humboldt tunnel intersected the Eagle lode, which had a width of 30 feet of low-grade sulfide ore, ranging from 1 to 4% copper with a streak of first class ore (>4%) on one wall. After evaluating this discovery, they returned to point where they had deviated Humboldt tunnel and continued driving it toward the Liverpool mine as was originally planned; intersecting the Humboldt and Wellington lodes (Colquhoun, 1933).

The lodes encountered by the Humboldt tunnel during 1893, are localized along a system of northeast trending, steeply dipping fissures that primarily occur within the porphyry stock along its contact with adjacent metasediments (Figure 18). Measuring less than 2 miles in length, the most important ore bodies of this system were the Wellington, Humboldt, Ryerson and West Yankie lodes, which were the principle source for sulfide ores mined by the Arizona Copper Company and the Detroit Copper Mining Company between 1895 and 1921 (Figure 13).

Best developed within porphyry hosts, these lodes narrow and are poorly mineralized or barren where the fissures cut the metasediments. Their mineral content varies with depth – surface zone, chalcocite zone and pyritic zone (Table 2). At the turn of the century, underground mining operations at Morenci focused their attention on the chalcocite zone, where high-grade seams (generally less than 4 feet in thickness) of massive chalcocite (assaying up to 70% copper) were enclosed within large masses of mineralized rock that constituted ore. Ore boundaries were determined by assay with the first class ores exceeding 4% copper, second class ores assaying between 2.75 and 4.00% copper and third class ores running 2 and 2.75% copper. Third
class ores were only removed during mine development or when they occurred with high-grade ores under conditions that required its removal (Lindgren, 1905).

Figure 18. Vertical cross-section of the Humboldt mine (looking NNE) showing high-grade fissure lodes (modified from Lindgren, 1905).

Between 1903 and 1921, porphyry-hosted sulfide ores treated by Arizona Copper's concentrators averaged 3 to 4% copper. Much of this material was derived from the Wellington, Humboldt, Fairplay, Eagle and West Yankie lodes, which were accessed by workings of the Yavapai, Humboldt and Liverpool mines (Figure 13). Stopes generally measured from a few feet to more than 50 feet in width, 200 feet in length and 200 feet vertically. One of the larger stopes measured 300 feet long by 200 feet wide and nearly 200 feet high (Lindgren, 1905).

<table>
<thead>
<tr>
<th>Zone Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Zone</td>
<td>Extends to depths of 50 to 200 feet. Rarely shows gossan or iron oxide cap. It is either barren or contains oxide copper minerals.</td>
</tr>
<tr>
<td>Chalcocite Zone</td>
<td>Thickness ranges from 100 to 400 feet or possibly more locally. Contains chalcocite and pyrite.</td>
</tr>
<tr>
<td>Pyritic Zone</td>
<td>Located at depths of 200 to 600 feet. Contains pyrite, chalcopyrite, sphalerite and molybdenite.</td>
</tr>
</tbody>
</table>

Table 2. Ore zones of Morenci-type fissure deposits (from Lindgren, 1905).
The ore bodies at the Humboldt mine were initially extracted by a square-set-and-fill mining method at a cost of $1.50/ton. Oregon fir was used for all square-set timbers. This system of mining achieved a mined product that was higher in grade than the average grade of the ore body by rejecting as waste everything carrying less than 1% of copper. This waste rock was used to fill the empty stopes. "Glory holes" were also employed to supply waste rock to fill mined out stopes. The square-set-and-fill mining methods were later replaced by a more cost efficient top slicing mining method, which was similar to the longwall retreat mining method used in many coal mines (Scotland, 1915).

The discovery of low-grade sulfide (chalocite - Cu,S) ores at the Humboldt mine hosted by the porphyry in 1893 led the Arizona Copper Company to develop the district's first successful sulfide concentrator (known as the No. 2 concentrator) at Clifton. It was commissioned in July 1896. Ores treated by this 300-ton/day facility were reduced by crushing and milling circuits before reporting to a series of gravity circuits composed of jigs and Frue vanners. Jigs were employed to recover the coarser material during the first stage of recovery. Tails from the jigs were reground in mills and treated by vanners to recover the finer material. Vanning was similar to gold panning, where the fines were agitated to get the material into suspension. The heavier copper-bearing minerals were allowed to settle out, while the lighter waste was decanted off and discarded. The final concentrate product of these facilities averaged 20% copper, while its tailings assayed 1.25% copper (Cogut and Conger, 1999a).

Following his tour of the Copper Queen smelter in Bisbee in July 1896, James Colquhoun added a small 5-ton Bessemer convertor to Arizona Copper's Clifton smelter in August 1897 at a cost of $85,000 (Colquhoun, 1933). With the success of its first sulfide concentrator, Arizona Copper erected the 700-ton/day No. 3 concentrator at Clifton in 1898 and the 500 ton/day No. 5 concentrator near its Longfellow mine at Morenci in 1901.

Arizona Copper's oxide concentrator at Clifton was destroyed by fire on Christmas night of 1897. It was rebuilt and restored to service in March 1898. The oxide concentrator and its adjacent tailings leach plant continued to produce copper until the fall of 1914 (Flynn, 1916).

The Arizona Copper Company commissioned the 400-ton/day No. 4 concentrator at Clifton in December 1900. This facility was designed to recover an additional 0.5% copper from the tails derived from the two older sulfide concentrators (Colquhoun, 1924). Dewatered tails from the older sulfide concentrators were reground by Huntington mills to liberate the fine sulfides that were recovered by a gravity circuit, consisting of various sizes of vanners (Colquhoun, 1933).

The first successful treatment of low-grade, sulfide porphyry ores on a large scale occurred at Arizona Copper's Morenci operation in 1901, four years prior to the commencement of similar operations at Utah Copper's Bingham Canyon mine (Colquhoun, 1933).

Arizona Copper's Coronado rail line was converted to narrow gauge (36-inch) from Clifton to the Longfellow incline in August 1901. Large ore bins at the foot of Longfellow incline were used for approximately one year to transfer ores from mines in the Metcalf area that were accessed by the baby gauge (20-
inch) rail line. Conversion of 20-inch line to 36-inches was completed during 1902.

In late 1901, Arizona Copper's Clifton Smelter was completely redesigned to cope with the changing nature of the ores (Figure 19). Modifications included five roasting furnaces that produced a matte copper product (50 to 55% copper), which was kept in a liquid state by reverberatory furnaces prior to its conversion into blister copper in one of nine 7.5-ton capacity Bessemer converters (Hyde, 1998). They also replaced timber with steel and concrete, significantly reducing the fire hazard (Colquhoun, 1924). In an effort to divert smelter smoke from the town of Clifton, modifications included the excavation of a tunnel into the ridge behind the smelter, which acted as dust chamber. A smelter stack on top of the ridge was connected to the tunnel by a 450-foot vertical shaft (Rickard, 1987).

Figure 19. The town of Clifton was the site for smelters operated by the Longfellow Mining Company (1874-1882) and Arizona Copper Company (1882-1913). Photo of Arizona Copper's Clifton Smelter, looking west up Chase Creek, circa early 1900s. (Photo obtained from Lindgren, 1905).

The Arizona and New Mexico rail line was converted to standard gauge in May 1901. Since the Arizona Copper Company had completed its rail line in April 1884, the Detroit Copper Mining Company was one of the Arizona and New Mexico railroad's best customers. James Douglas, president of the Detroit Copper Mining Company persuaded James Colquhoun to build a 38.5-mile standard gauge rail line from Lordsburg to Hachita, New Mexico. This rail line provided a connection with the El Paso and Southwestern Railroad, a major hauler of goods for the copper mines in Bisbee, Arizona. The Lordsburg and Hachita Railroad was incorporated in August 1901 and completed in September 1902 (Anonymous, 1981e). With the completion of the El Paso and Southwestern Railroad to El Paso in December 1902, the mining operations at Morenci...
significantly improved their bargaining position in negotiating haulage charges with several major transcontinental rail lines; the Southern Pacific at several localities, the Atchison, Topeka and Santa Fe Railroad at Deming and the Rock Island Railroad via the El Paso and Northeastern Railroad that connected El Paso and Tucumcari, New Mexico (Anonymous 1981e). The Lordsburg and Hachita Railroad was acquired by the Arizona and New Mexico Railroad through a merger in June 1911.

The Arizona Copper Company pioneered the use of electric haulage in 1905, replacing mules with electric locomotives on the surface and on important levels of its Humboldt mine (Figure 8). Ore car capacities ranged from one to ten tons and used 20-inch baby gauge track. A company electrician designed a system where three locomotives joined in tandem could be operated by a single operator. This enabled 300-ton ore trains to be used at Arizona Copper's underground operations (Cogut and Conger, 1999a). The installation of electric lines throughout the mines also provided power for lighting and mining equipment.

Another cost saving measure employed the use of electrolysis to produce copper by a forerunner of the process that is employed by modern-day copper refineries. Electrolysis was used to convert impure precipitate copper, which had been plated onto tin in long sluiceways through which copper-laden mine waters had passed, into a nearly pure copper product. This was the cheapest method of producing copper at the time (Patton, 1945).

The Arizona Copper Company commissioned the 900-ton/day No. 6 concentrator at Morenci in July 1906 (Figure 9). Designed to treat lower grade, chalcocite-rich, porphyry-hosted ores from the Humboldt mine, this facility employed two jaw crushers supplemented by two sets of Cornish rolls and three stages of grinding to reduce the ores. The copper minerals were concentrated in six stages by a gravity circuit employing jigs, Wilfley tables and vanners (Crowfoot, 1931). The No. 6 concentrator was expanded to 1,600 tons/day in October 1911 and 3,000 tons/day in December 1914. Its milling capacity was further increased to 4,000 tons/day in August 1916 with the installation of two secondary disk crushers and the replacement of fine tables and vanners with a Callow flotation circuit (Crowfoot, 1931).

Located in the valley along the San Francisco River, the town of Clifton has endured many floods (Figure 8). One of the most severe flood events at Clifton occurred on December 3, 1906, when it rained continuously for thirty hours. Peak flow along the San Francisco River was estimated to be 70,000-cubic feet/second. Although many sought refuge on higher ground, eighteen lost their lives that day. The greatest flood in Clifton's history (90,900-cubic feet/second) occurred on October 2, 1983, when moisture from tropical storm Octave surged through southeastern Arizona (Cogut and Conger, 1999b).

The first coordinated exploration of Arizona Copper's Clay ore body began in 1903. By 1908, it was realized the higher grade sulfide veins being mined from the Clay ore deposit were actually a part of much larger resource that was 1,000 feet thick and contained 1.5 to 2% copper. A systematic churn drilling program designed to delineate and evaluate this resource commenced in 1912 (Patton, 1945).
Arizona Copper's No. 2 concentrator was destroyed and its Clifton smelter badly damaged by a fire in 1909. The No. 5 concentrator was closed and dismantled in 1911 to accommodate the expansion of the No. 6 concentrator.

The shareholders of Arizona Copper approved the issuance of bonds to finance the construction of a modern reverberatory smelter during the fall of 1911. Construction began in February 1912. The new facility was located approximately three miles south of Clifton along the east bank of the San Francisco River at a site locally known as Smelter Hill (Figure 9). Slag disposal was easier and stack emissions were less of a nuisance at this locality. The facility included eight Herreshoff air-cooled roasting furnaces, three oil-fired reverberatory furnaces, three Bessemer converters and dust chambers (Hyde, 1998). Commissioned in October 1913 at a cost of $2.1 million, this facility was the first Arizona smelter constructed without any consideration for blast furnaces (Figure 20). Operations at the older Clifton smelter were discontinued in December 1913 (Rickard, 1987).

![Arizona Copper's smelter at Smelter Hill](Photo provided by Arizona Geological Survey),

A new electric haulage system connecting the underground operation at the Coronado mine with the main haulage system of the Humboldt mine was completed during 1915, allowing ore from the Coronado mine to be transported directly to their No. 6 concentrator at Morenci (Weed, 1916). Prior to its completion, ores from the Coronado mine were hoisted to the collar of the Matilda shaft in 1-ton ore cars. The ore was dumped in surface bins from which it was transferred by a 1-mile baby gauge rail line to the Coronado incline, where it was lowered 1,200 feet to the Coronado rail line and transported to one of Arizona Copper's concentrators at Clifton.
Following its completion, the ores from the Coronado mine were dropped down ore passes to ore pockets located on the 1,100-foot level. From there it was transported 4.2 miles via 20-inch gauge rail line by electric trains of 200-ton capacity (Figure 21). Seventy-five percent of this 4.2-mile ore haulage system was underground. Upon reaching the No. 6 shaft, the ore was hoisted to surface ore bins located adjacent to the No. 6 concentrator at Morenci (Carmichael and Kiddie, 1924).

In August 1915, Guy Miller one of the leaders of the Western Federation of Miners arrived in Morenci mining camp and pursued a vigorous campaign to organize the area's workers. As efforts to mobilize the workers gained momentum, threats of a strike soon were soon heard. In an effort to avoid a confrontation, the managers of the Arizona Copper Company, Detroit Copper Mining Company and the Shannon Copper Company requested a meeting with a workers' committee to discuss the situation on the condition the workers' committee was not connected with the Western Federation of Miners (Patton, 1945).

Unable to resolve this issue, a general strike began on September 11, 1915, bringing a halt to all mining activities. Efforts by the Arizona Governor George Hunt to mediate the dispute failed. By early October, the situation had deteriorated. The company managers, fearing for their safety fled to El Paso. Most of the company's supporters also left the district with many of them ending up at a tent city that had been established in Duncan, Arizona.
Over the next several months, the union found it increasingly difficult to provide the strikers the necessities of life. On January 11, 1916, the miners voted to withdraw from the Western Federation of Miners and requested another conference with the mine managers (Patton, 1945).

An agreement was reached at this conference and the workers voted to return to work for 15 days while a new wage scale and other agreements were negotiated. Five thousand miners returned to work on January 31, 1916. Over the next two weeks the miners and managers finalized the agreement. Its main points were: 1) the companies will not recognize any unions; 2) a sliding daily wage scale based on the price of copper with a minimum ranging from $2.50 for laborers to $5.31 for machinist and boilermakers; and 3) the establishment of a district grievance committee (Patton, 1945).

By 1917, the Arizona Copper Company had delineated a resource of more than 47 million tons at the large low-grade sulfide deposit, known as the Clay ore body. Metallurgical studies conducted at one of the older concentrators during 1918 demonstrated copper could be profitably extracted from low-grade sulfide ores using existing flotation technology (Watt, 1956).

The settlement of the 1915-16 labor dispute did not fully resolve labor troubles in the Morenci mining district. By June 16, 1917, the Miners Grievance Committee issued a threat of another strike unless the mining companies met their demands. At this point the mine managers didn't wait until real trouble developed. Like the previous strike, they left the state and remained in El Paso until the strike was over. Unable to find common ground, the strike began on July 1, 1917. After several months of unrest, President Woodrow Wilson appointed a commission to settle the strike in late October 1917. After two days of conferences, a settlement was reached, allowing the miners to return to work on November 1, 1917. The terms of the settlement included: 1) the district grievance committee was replaced by committees for each company; 2) unresolved complaints by the grievance committees will be resolved by an U. S. Administrator; 3) establishment of a right-to-work rule, 4) time and a half must be paid for all overtime, Sunday work and holidays and 5) an increase in wages by 50 cents per day (Patton, 1945).

The impacts of these strikes were catastrophic for both workers and the mining companies. Not only did the workers suffer from the loss of wages, but the defeat of Arizona's copper unions severely impacted their ability to organize workers of Arizona's mining camps, including Morenci, over the next two decades (Hyde, 1998). These strikes also shut down all of the mining operations at a time of high copper prices during World War I (Mellinger, 1995). The loss of income that would have been generated from the sales of copper during this turbulent period of Morenci's history had a profound impact on the future of the district's producers.

The collapse of the price of copper following the end of World War I forced the Shannon Copper Company to sell its assets to the Arizona Copper Company in October 1919. As copper prices continued to fall, the Arizona Copper Company closed its mining operations in the Metcalf area and suspended operations at its No. 4 concentrator in April 1919. Lacking sufficient capital to develop their reserves, all development was halted in November 1920. Declining copper prices resulting from the collapse of international metals markets during the fall of 1920, high taxation and the low tenor of
the remaining ores resulted in the closure of the Arizona Copper Company's operations at the end of May 1921. Its assets were sold to the Phelps Dodge Corporation in October 1921 for 50,000 shares of capital stock (Anonymous, 1981b).

Over its 39-year life (1882-1921), the Arizona Copper Company was the district's largest underground producer. Total copper production from its operations was approximately 839.7 million pounds (Colquhoun, 1924). Under the leadership of John Colquhoun, the Arizona Copper Company met many challenges through wise management and innovation, only to succumb to the economic downturn that followed the end of World War I (Cogut and Conger, 1999a).

**Shannon Copper Company (1899-1919)**

Charles and Baylor Shannon, nephews of Robert and James Metcalf, also prospected the region around the headwaters of Chase Creek during the early 1870s. Although Baylor Shannon was more interested in the cattle business and eventually established a successful ranch along Eagle Creek, his brother Charles located a number of claims in the Metcalf area. He sold some of these claims, including the Coronado to the Arizona Copper Company, but kept others, which he peddled to eastern capitalists (Patton, 1945). He eventually sold the Shannon property to William Boyce Thompson, who organized the Shannon Copper Company in November 1899. Initially capitalized at $3.3 million, this project was Thompson's first successful mining venture (Wikipedia, 2015). Shortly after the purchase of the property, the Shannon Copper Company acquired additional adjoining claims from the Arizona Copper Company, expanding its property holdings to 50 claims.

![Miners with a mule-drawn train at the entrance to the Shannon mine (circa early 1900s).](Photo from a Phelps Dodge Morenci, Inc. brochure provided by Freeport-McMoRan, Inc.)
The Shannon Copper Company operations were developed by small open cuts, shafts, tunnels and underground workings extending to depths of approximately 1,300 feet below the crest of Shannon Mountain (Figure 8). This underground operation used 12-foot by 12-foot square sets. The ores were extracted via rail through tunnels (Figure 22). One of these tunnels was connected to a 1,400-foot, double-track incline, which was completed during the spring of 1902 (Figure 23). The Shannon incline employed 10-ton ore cars operating in counter-balance to transfer the ore to the six ore bins located along Chase Creek, where it was transferred to the Coronado Railroad for haulage to Shannon Copper's processing facilities near Clifton (Genealogy Trails History Group, 2015).

Situated on the west bank of the San Francisco River, Shannon Copper's smelter was located on Shannon Hill, approximately one mile south of Clifton. It was commissioned in May 1902 (Figure 24). Initially employing two 350-ton water-jacketed furnaces, a subsequent expansion in 1908 combined the two furnaces with a new section, making a single blast furnace that had a daily capacity of 1,000 tons. It was reported to be the largest blast furnace in Arizona (Stevens, 1909). This facility initially produced a matte product, averaging 55 to 60% copper, which was shipped to Arizona Copper Company's Clifton smelter for conversion into a final blister copper product.

![Figure 23. The Shannon incline connected its mines on Shannon Mountain with the ore bins located along Chase Creek. At 36 degrees, it is reported to be the steepest incline in the Morenci mining district (circa early 1900s). (Photo obtained from Lindgren, 1905).](image-url)
Within a few months, high-grade, direct smelting ores had been exhausted, temporarily closing Shannon Copper's smelter in late September 1902. A 400-ton per day concentrator was commissioned in March 1903 allowing Shannon Copper's smelting operations to resume (Rickard, 1987).

The Shannon concentrator was a gravity plant, which employed Harz jigs, Wilfley/Standard tables and Frue vanners to produce a concentrate product that was suitable for smelting. Early operation of this facility encountered considerable problems related to acidic waters that dissolved the iron screens, while copper or brass screens in the jigs were rapidly worn out by the abrasive nature of the ores. Difficulties were resolved by applying a low-voltage electric current to the jigs, making the screens a cathode in the circuit. This attracted hydrogen ions in the water, which reacted with metallic salts, freeing copper, which was deposited on the screens (Stevens, 1907).

The installation of converters at the smelter in March 1906 allowed the Shannon Copper Company to produce its own blister copper product, saving the company approximately 0.5 cents per pound of copper smelted (Stevens, 1907). The Shannon Copper Company was producing 1 million pounds of copper monthly during 1906. It was the second largest producer in the Morenci mining district in 1909.

Figure 24. Shannon Copper's concentrator and smelter along the west bank of the San Francisco River, approximately one mile south of Clifton, Arizona (circa 1900s). (Photo provided by the Arizona Geological Survey).
Following a dispute with the Arizona Copper Company about haulage rates on the Coronado Railroad, the Shannon Copper Company formed the Shannon-Arizona Railroad in March 1909. It was completed in February 1910 at cost of $600,000 (Patton, 1945). This narrow gauge (36-inch) rail line transported the ore ten miles from the foot of the Shannon incline north of Metcalf to its smelter, south of Clifton (Figure 9). It traversed very rugged terrain along Chase Creek and included a 900-foot tunnel.

Approximately a third of Shannon Copper's mine output consisted of siliceous ore. It was too highly oxidized to concentrate well and of insufficient tenor to smelt (Stevens, 1908). However, metallurgical testing showed copper could be profitably recovered from these ores, when it was blended with other ore types. A 150-ton oxide leach plant, designed to treat mill tails and semi-oxidized siliceous ores, was erected in 1916 and achieved full production in May 1917 (Weed, 1918).

Low copper prices forced the Shannon Copper Company to suspend operations in September 1914. Although operations resumed in March 1915, striking miners halted production during district-wide strikes in 1915 and 1917, when copper prices were high due to increased demand resulting from World War I. This was unfortunate for the Shannon Copper Company, a high cost producer, whose operations were only profitable when the price of copper was high. With the decline in the price of copper at the end of World War I in November 1918, the Shannon Copper Company ceased operations and shut down its railroad on January 1, 1919 (Irvin, 1987). On May 14, 1919, the Arizona Copper Company took over the assets of the Shannon Copper Company, including its mine, concentrator, smelter, and railroad. The sale of these assets to the Arizona Copper Company for $600,000 was ratified by Shannon Copper's shareholders in October 1919. The Shannon Copper concentrator and smelter were dismantled a short time later. Over its 17-year life (1902-1918), the Shannon Copper operation produced approximately 192.4 million pounds of copper (modified from Tenney, 1927-1929).

**Other Small Producers (1901-1912)**

Two additional operations developed and mined copper ore in the Metcalf area during the decade that followed the turn of the 20th century (Tenney, 1927-1929). Organized by English investors in February 1901, the Standard Copper Company (reorganized as the Standard Consolidated Copper Company in December 1903) achieved limited production from surface workings at the Standard mine during 1902 (Figure 8). Their high-grade, direct smelting ores (28% copper) were initially transported by burro at a cost of $2 per ton to the Coronado rail line for shipment to Shannon Copper's smelter. The burros were soon replaced by a 3,200-foot aerial tram that connected the mine with ore bins located along the rail line, reducing the transfer costs to 5 cents per ton. Custom smelting of Standard's ores was moved to Detroit Copper's facility in January 1906 (Stevens, 1908). Production continued until late 1910 and the property was sold to the Detroit Copper Mining Company in 1912. Over its brief life (1902-1910), this operation produced approximately 4.7 million pounds of copper (modified from Tenney, 1927-1929).
English capitalists acquired a second group of claims in the Metcalf area during 1901 and organized Clifton Consolidated Copper Mines of Arizona. In 1903 it was merged with an adjoining group of claims held by the Boston-based New England Copper Company (organized in 1902) to form the New England and Clifton Copper Company. Their mines included the Antietam, Olivette, and Copper King (Figure 8). A 3-mile, 20-inch gauge ground tram was built, connecting the mines with the Coronado rail line along Chase Creek. Production commenced in early 1906 with the ores being shipped to Shannon Copper's reduction works. Ore shipments continued until April 1910, when the General Development Company acquired an 18-month purchase option. This option was not exercised and the property was sold to the Detroit Copper Mining Company in 1912 (Tenney, 1927-1929). Over its brief life (1906-1910), this operation produced about 7.2 million pounds of copper (Tenney, 1927-1929).

Phelps Dodge Corporation - Underground Operations (1917-1932)

Phelps, Dodge and Company, Inc. reorganized its corporate structure in April 1917. The name of its affiliated Copper Queen Consolidated Mining Company was changed to the Phelps Dodge Corporation. Properties held by the Detroit Copper Mining Company became a part of the Morenci Branch of the Phelps Dodge Corporation (Rickard, 1987). Dr. James Douglas retired later that year, with his son, Walter Douglas succeeding him as president.

Depressed copper prices following the end of World War I resulted in the suspension of Phelps Dodge's Morenci mining, milling and smelting operations in September 1919. Unlike Morenci's other producers, which did not have sufficient capital to survive this severe economic downturn, Phelps Dodge was able to draw on cash reserves derived from their mercantile business (Cogut and Conger, 1999a).

Phelps Dodge purchased the assets of the Arizona Copper Company in October 1921, becoming the sole copper producer in the Morenci area. With the ownership of the properties in the Morenci area now under one management, they were able to introduce cost efficient block caving methods at the Humboldt mine, when mining operations resumed in early 1922 (Parsons, 1933). Prior to that time, the Humboldt ore body had been principally mined by top-slicing and square set-and-fill methods (Mosier and Sherman, 1929).

Phelps Dodge resumed milling operations at newly acquired 4,000-ton/day Arizona Copper No. 6 concentrator in early 1922 initially shipping its copper concentrates to its Douglas smelter. Its older West Yankee concentrator was decommissioned, while the capacity of the No. 6 concentrator was expanded to 4,500-tons/day in May 1923 and 5,000-tons/day in 1929 (Crowfoot, 1931). Following its acquisition of Arizona Copper's assets, Phelps Dodge also decommissioned its older Morenci smelter and relocated its smelting operations to the modern Arizona Copper facility at Smelter Hill, which resumed operations in May 1923.
Initially established by Robert Metcalf at the junction of Chase Creek and Santa Rosa Canyon during 1875, the town of Metcalf became a company town following Arizona Copper's purchase of Metcalf's claims in September 1882. The community of Metcalf thrived until the economic recession that followed the end of World War I (Figure 25). It had a fine two story brick schoolhouse, theater, stores, a bank and hotel (Patton, 1945). The closure of Shannon Copper's and Arizona Copper's operations in the area during early 1919 marked the beginning of the end for the community, whose population had peaked at around 5,000 only a few years earlier. With the permanent closure of the Coronado mine in 1923 and dismantling of the Coronado incline, Metcalf's fate was sealed (Cogut and Conger, 1999a). Between 1920 and 1930 Metcalf's population declined from 1,740 to 529 as the town slowly decayed, residents abandoned their community, dismantled their homes and hauled them away. The last residents left during the late 1930s and its high school was demolished for scrap in 1940.

With its acquisition with the Arizona Copper Company in October 1921, Phelps Dodge also acquired the Arizona and New Mexico and the Shannon-Arizona railroads. In January 1922, the Arizona and New Mexico rail line became a part of the El Paso and Southwestern system, which was subsequently merged with the Southern Pacific Railroad in October 1924 (Anonymous, 1981e). The rail line connecting Lordsburg and Hachita, New Mexico was abandoned in 1933.

The Morenci Southern Railroad became unprofitable and was abandoned in May 1922. The southernmost 13 miles was dismantled, while the northernmost 5 miles was combined with four miles of the Shannon-Arizona Railroad and
reorganized as the Morenci Industrial Railroad, which served Phelps Dodge's Morenci operations until July 1932. The Shannon-Arizona rail line was rebuilt as a standard gauge line and resumed operation in July 1937, eventually becoming a part of the open pit mining operation (Hilton, 1990).

Experiments on leaching chalcocite ores were conducted by an electrolytic test facility that was erected adjacent to the No. 6 concentrator during the mid-1920s. Employing a primitive process, this plant was the fore-runner of solvent extraction-electrowinning (SX-EW) facilities used by many of today's copper operations (Cogut and Conger 1999b).

Copper prices gradually increased from a low of 11.6 cents per pound in August 1921 to nearly 13.9 cents pound in early 1928. This combined with declining underground reserves spurred management's decision to resume efforts to develop the Clay ore body. During 1928 and 1929 a systematic 88,000-foot drilling program from 150 stations was conducted on this large low grade resource. Underground diamond drilling was conducted at 400-foot intervals along tunnels and adits, while churn drills were employed on the surface. This exploration project delineated more than 200 million tons of low-grade copper ore, averaging slightly more than 1% copper (Anonymous, 1981b). Extensive metallurgical testing of the Clay ore body since 1917 demonstrated an acceptable concentrate product could be produced with existing flotation technology.

In October 1929, Phelps Dodge's management meet to decide on the mining method that would be used on the Clay ore body, which was overlain by 200 to 500 feet of barren leached cap. Both underground block caving and open pit mining methods were considered. It was decided to proceed with open pit methods because it would recover 10% more copper, reduce final average mining costs by more than 30% and yield 20 to 25% greater profits (Anonymous, 1981b). Other advantages favoring the open pit option included better segregation of ore and waste, larger labor pool, fewer health hazards, and greater operational flexibility (Patton, 1945).

Following the collapse of the financial markets in October 1929, efforts to develop the Clay ore body continued with a condemnation drilling program that was designed to find a suitable place for 110 million tons of waste rock, which would be generated by the proposed project. After considerable effort, it was decided Coronado and Fairbanks Canyons would be suitable places to dispose of this waste (Patton, 1945). A 150-ton/day milling-leaching pilot plant was erected during 1930 and continued metallurgical testing of the low grade ores through the end of 1931.

Louis Cates succeeded Walter Douglas as president of Phelps Dodge in May 1930. His previous 20-years experience as general manager at Utah Copper's Bingham Canyon open pit mine near Salt Lake, Utah provided him the expertise required to tackle the challenges faced in implementing Morenci's transition from underground to open pit mining methods.

As economic hardships of Great Depression grew, the price of copper declined from 21.3 cents per pound in March 1929 to 6.6 cents per pound in December 1931 (Julihn and Meyer, 1934). Phelps Dodge downsized its Morenci operations to cope with the falling prices. District copper production fell from 56.8 million pounds in 1929 to approximately 38.3 million pounds in 1931 (Gerry and Miller, 1934 and Julihn and Meyer, 1934). With the continued decline in
the copper price to 5.1 cents per pound in June 1932, all mining, milling and smelting operations were closed on June 23, 1932, marking an end of era at Morenci (Patton, 1945).

Copper production from Phelps Dodge's Morenci Branch underground operations (1917-1932) totaled 519.1 million pounds (modified from Tenney 1927-1929).

**Phelps Dodge Corporation - Open Pit Operations (1932-2007)**

Economic woes of the Great Depression were endured by citizens of the Morenci, Metcalf and Clifton following the suspension of Morenci's underground operations in June 1932. Many local businesses that served these communities closed as a large number of the area's residents, believing mining would never resume, sold their homes and moved to other localities in search for jobs to support their families. A few workers were retained by Phelps Dodge as watchmen, while others earned a meager living panning gold along the San Francisco River, Chase Creek and Gold Gulch (Wilson, 1961). Some of the long time residents, who remained, wisely invested in Clifton's real estate market and were rewarded when development of the open pit resumed during the late 1930s (Patton, 1945).

During the shutdown, management sought ways to resume production at Morenci. Realizing its future depended on the successful development of the Clay ore body, they conducted numerous studies on how this could be accomplished. An early study recommended a leaching operation, which produced copper-bearing solutions that could be treated by an electrolytic plant, similar to the one that had been used at Ajo. A later study completed by H. G. Moulton in March 1937 recommended conventional concentration followed by smelting (Cogut and Conger, 1999b). Neither the existing mill nor the smelting facilities were strategically located or designed to handle the large tonnages of ore from the proposed operation. This study recommended construction of a new crushing plant, concentrator, smelter, power plant and other ancillary facilities at a site located near the mouth of Morenci Gulch. Located approximately half way between the towns of Morenci and Clifton, this site was situated at a spot where much of the early ore production could be delivered by a down-grade haul from the mine (Anonymous, 1981b).

By 1937 the price of copper had risen to 13 cents per pound. Encouraged by this increase, a decision was made to reactivate the development of the Clay ore body (Morenci pit) based on Moulton's recommendations. The mineable reserve was reported to be 230 million tons, averaging 1.06% copper having a 1.04:1 waste-to-ore strip ratio (Lawson, 1938). The Morenci project was partially funded by a June 1937 public offering of $20.3 million of 15-year convertible 3.5% debentures. The remainder of the estimated cost of $35 million was funded from Phelps Dodge earnings (Anonymous, 1981b).

Pre-production stripping of approximately 50 million tons of waste commenced on the 5,350-foot level of the Morenci pit on August 24, 1937. Phelps Dodge's smelter at Smelter Hill along the San Francisco River resumed operation in September 1937. Initially treating copper precipitates derived from underground leaching of caved stopes, it later treated concentrates from the No. 6 concentrator, which was reactivated for metallurgical testing of ores extracted during the stripping operations. The older smelter was permanently closed in 1938 and was subsequently dismantled during the early
1940s, except for its 300-foot stack. Carefully placed explosives demolished the stack at Smelter Hill on February 12, 1997 (Schwantes, 2000).

Figure 26. A 22.5-cubic yd. haul truck (circa 1937) preparing to unload at a waste dump. (Photo provided by the Arizona Geological Survey).

Initial stripping of waste at Morenci was performed by 4.5-cubic yard electric shovels and 22.5-cubic yard (35-ton) chain-drive, haul trucks (Figure 26). Smaller 5-cubic yard end-dump haul trucks and 1.5-cubic yard diesel shovels were employed to build haul roads, establish new benches and construct the main rail line from the mine to the reduction works (Cogut and Conger, 1999b). As the Morenci pit was carved out of the steep, rugged terrain along the southwestern slope of Chase Creek, in-pit rail haulage was initially introduced during 1939 and fully augmented by July 1940 (Schwantes, 2000).

Excavation and grading at the concentrator and smelter site began in September 1939. The process flow sheet for the new concentrator was finalized in September 1940. The new 25,000-ton/day Morenci concentrator was commissioned on January 30, 1942, and the first copper anode was poured at the new reverberatory smelter on April 26, 1942. Its 600-foot stack was reported to be the world's tallest industrial stack at the time (Schwantes, 2000). A second 600-foot stack was added to the facility during 1967 to improve the draft on the converters.

In March 1942, Phelps Dodge reached agreement with the Defense Plant Corporation to expand the capacity of the concentrator to 45,000-tons per day. This expansion was completed in December 1943. By February 1944, capital expenditures at Morenci totaled about $68 million, which included a $26 million loan from the federal government's Defense Plant Corporation (Schwantes, 2000).

Arizona's copper industry had been largely free of unions since the end of World War I (Hyde, 1998). This changed with the Wagner Act in July 1935. This legislation established the National Labor Relations Board and guaranteed workers the right of collective bargaining. By 1937, the American Federation of Labor was the dominate labor union in Arizona (Kersten, 2006).
With Morenci's labor contract with the American Federation of Labor (AFL) set to expire in November 1942, negotiations between AFL's Morenci Metal Trades Council and Phelps Dodge became deadlocked. In November 1942, the International Union of Mine, Mill and Smelter Workers (IUMMSW) petitioned the National Labor Relations Board (NLRB) for elections to determine who would represent Morenci's workers. The IUMMSW was a member of the rival Congress of Industrial Organizations (CIO). This resulted in a dispute with the American Federation of Labor, who claimed the NLRB had already decided Arizona's mines would only be represented by craft unions. In January 1943, the NLRB found in favor of the IUMMSW and an election was held short time later. The AFL set up picket lines at the polling place and directed its members to boycott the election. AFL's Morenci Metal Trade Council ultimately lost and the National Labor Relation Board certified the International Union of Mine, Mill and Smelter Workers as the bargaining agent for Morenci's workers on May 1, 1943 (Kersten, 2006).

With the labor contracts about expire in November 1944, the AFL's Morenci Metal Trades Council petitioned the NLRB for certification as the bargaining agent at the Morenci mine. A new election was ordered. In May 1945, the AFL's Morenci Metal Trades Council defeated the IUMMSW and re-established itself as the bargaining agent for Morenci's workers. This rivalry would continue until December 1955, when the American Federation of Labor and Congress of Industrial Organizations merged to form the AFL-CIO (Kersten, 2006).

Figure 27. By the early 1960s remote control equipment had been installed, which enabled an engineer to remotely operate the locomotive, while the shovel loads the ore cars. (Photo from a Phelps Dodge Morenci, Inc. brochure provided by Freeport-McMoRan, Inc.).

The Morenci concentrator employed a three-stage crushing circuit to reduce the ore to 5/8-inch, followed by single grinding stage employing ball mills.
that further reduced it to the consistency of a fine sand. Grinding was followed by several stages of froth flotation, which recovered a copper concentrate product that was suitable for smelting. A molybdenum flotation circuit was added to the Morenci concentrator in November 1949.

Primary in-pit haulage at Morenci was accomplished by rail, using a combination of diesel-electric and trolley-diesel locomotives with 8- to 10-car trains composed of 40- to 43-cubic-yard side-dump ore cars, which were loaded by 6- to 8-cubic yard electric shovels (Figure 27). Ultimately, there would be approximately 90 miles of track used in the Morenci pit. Support was provided by 25- and 35-ton capacity haul trucks (1949-1968), which were used to prepare preliminary grades for the railroad tracks or used in areas where the amount of material did not justify the cost of establishing rail haulage. The ores at Morenci were mined on 50-foot benches, with the uppermost bench located at an elevation of 5,500 feet (Hardwick, 1959).

With the development of the open pit operation during the late 1930s, it was recognized that the historic sources for water (San Francisco River and Eagle Creek) were no longer sufficient to meet the Morenci project's needs. The most obvious sources for water were from the Salt and Verde River systems. Not owning any sizeable water rights along either of these watersheds, Phelps Dodge negotiated an innovative agreement with the Salt River Valley Water Users' Association that provided them access to additional supplies of water from the Black River in exchange for constructing the Horseshoe Dam, located along the Verde River approximately 40 miles northeast of Phoenix. The Horseshoe Dam project was completed in the 1946 at a cost of $2.5 million (Schwantes, 2000).

A second water project involved the construction of the Show Low Dam on a tributary of the Little Colorado River in 1953. This allowed surplus unappropriated water from the Little Colorado River system to be pumped from the reservoir overland to a tributary of the Salt River, enabling Phelps Dodge to pump additional water from the Black River.

Phelps Dodge began construction the Blue Ridge Dam project on East Clear Creek, a tributary of the Little Colorado River in central Arizona in May 1963. Located south of Winslow, Arizona, this project was completed in November 1965 at a cost of $6.9 million. Water from the reservoir is pumped up and over a 650-foot ridge, where it enters a pipeline and descends 1,500 feet, flowing through a hydro-electric plant before being discharged into the East Verde River. Electricity generated from this facility is used to power the pumps that lift the water over the ridge (Cogut and Conger, 1999b). This project allowed additional water to be diverted from the Black River for use at the Morenci operation. With the increased water supply, Phelps Dodge expanded waste dump leaching operations and commissioned a new precipitation plant in June 1966, expanding annual copper production at their oxide recovery facility by an additional 15,000 tons.

The 119-mile stretch of U. S. Highway 666 (named changed to U. S. Route 191 in 1993) between Clifton and Eager, Arizona was officially opened as the Coronado Trail in June, 1926. Located along the northeast bank of Chase Creek it began at Clifton, passed through the town of Metcalf and continued north along the drainage for several miles before leaving the Morenci mining district. With the commencement of open pit mining operations at Morenci in 1937, waste dumps along the west side of the canyon slowly encroached on the
highway right-of-way. Knowing the highway posed an impediment to future mining operations at Morenci, long range mine plans incorporated its relocation as early as 1950. Road construction began during the early 1960s, relocating the Coronado Trail from the town of Old Morenci around the western and northern sides of the Morenci pit to a point approximately two miles north of the former Metcalf town site, where it dropped back into Chase Creek (Cogut and Conger, 1999b). The new 10-mile section of Highway 666 was completed during 1973 (Skillings, 1975).

Located along the eastern slope of Chase Creek, the original 20 mining claims of the Western Copper property were staked in 1898 and patented in 1911. These claims were purchased by the United States Copper Mining Company, which staked an additional 56 mining claims in 1931. In 1933, the Western Copper property was sold to W. C. Scott at a sheriff's auction and immediately transferred to the Hanna Mining Company, which added five additional patented mining claims to the property in 1950, bringing the total number of claims to 81. Phelps Dodge Corporation entered a lease/option agreement with Hanna in August 1961 and commenced an exploration program at the site. In 1966, Phelps Dodge exercised its option to lease the Western Copper property for 75 years (Anonymous, 1981d). Phelps Dodge subsequently purchased the Western Copper property from the Hanna Mining Company in April 1981 for $10 million. This purchase allowed greater flexibility and efficiency in mining operations at Morenci and Metcalf. At the time of its purchase, estimated reserves in the 1,850 acre tract were 350 million tons, averaging 1.0% copper. Phelps Dodge began pre-production stripping at Western Copper in 2003 (Anonymous, 2015).

Figure 28. The company town of old Morenci during the late 1950s (looking north). Morenci high school located at former Detroit Copper smelter site (foreground right center), remnants of the Arizona Copper No. 6 concentrator at far right and Copper Mountain at the upper left. (Photo provided by the Arizona Geological Survey).

The town of Old Morenci had been established since the early 1870s, when the first underground mining operations commenced at the site. It had been a
company town for both the Detroit Copper Mining Company and Arizona Copper Company. Many of the residences were privately owned, but were built on ground now owned by Phelps Dodge. By the early 1960s, it became apparent the town would have to be relocated as open pit operations slowly consumed Copper Mountain immediately northwest of the community (Figure 28). Residents began dismantling their homes in 1965 as mining activities drew closer to town. Phelps Dodge paid the homeowners for their home. Each miner who had to demolish his home was offered a company-built home at the new town site situated on the flat-lying plateau southeast of the concentrator and smelter (Cogut and Conger, 1999b). Over the next seventeen years, the entire community (including a hospital, motel, shopping center, library, theater, park, bowling alley and 1,200 residences for Phelps Dodge's employees) was gradually relocated to the new Morenci town site (Figure 29). The old Morenci high school building was the last structure to survive at Old Morenci. It was replaced by the new Morenci high school in 1982.

![Figure 29. Town site of new Morenci during the early 1990s (looking southeast). Morenci Park in foreground with theater, library and shopping center at center left. Morenci hospital and motel in center of photo and resident housing in the background. (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).](image)

Labor union contracts with most U. S. copper producers expired on June 30, 1967. Allied with twelve smaller unions, the United Steelworkers of America and the International Union of Mine, Mill and Smelter Workers took the lead in negotiating new contracts. In addition to the usual issues such as wages, pensions and working conditions, the unions focused much of their attention on establishing bargaining procedures, demanding company-wide bargaining and company-wide contracts. Management of the major mining companies was uniformly opposed to this demand (Rowland and Greenspoon, 1968).
Despite a two week extension, efforts failed to resolve their differences. Workers at all plants without binding contracts, including Phelps Dodge's Morenci operation, went on strike on July 15, 1967 (Larson and Henkes, 1968). On February 28, 1968, the National Labor Relations Board ruled company-wide negotiations were illegal, since it amounted to an unlawful "refusal to bargain" (Stucki, 2009). Seeing the tide of government opinion was turning against them, as well as support from the local striking miners, the unions settled one of the longest copper strikes in history to that date. Workers at Morenci returned to work on March 19, 1968 (Larson and Henkes, 1970). Estimated loss in copper production from the Morenci operation amounted to approximately 91,000 tons, having a gross value of $69.4 million.

Figure 30. General overview of the Morenci mining operation, looking south. The Metcalf mine is in the foreground at the lower left and Northwest Extension is at the lower right. The Morenci pit is in the background at the center of the photo. The smelter stacks and tailings impoundments are visible at upper left (circa early 1990s). (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).

After exploring an area along the east slope of Chase Creek since 1953, the management of Phelps Dodge made a decision to proceed with the development of the Metcalf ore body in June 1969 (Figure 30). Estimated reserves at the time of this decision were 415 million tons, averaging 0.77% copper (Anonymous, 1981c). Located northeast of the Morenci pit, stripping of approximately 75.6 million tons of overburden from this site began in February 1970 (Figure 31). Other aspects of this expansion project involved the construction of primary and secondary crushing plants, a new 30,000-ton/day concentrator, power plant, ancillary facilities, housing for
employees and purchases of mining and other equipment. The first ore from Metcalf was delivered to the newly constructed Metcalf concentrator in January 1975 (Figure 32). Total cost of the project was approximately $194 million, including pre-operating mine development expenses of $28.5 million (Arundale, 1978). The addition of the Metcalf concentrator also provided additional flexibility for processing the ores at Morenci.

Figure 31. A 34-cubic yard P&H 2800XPA shovel loads a 190-ton Cat 789 haul truck at the Metcalf pit. Approximately four scoops from the dipper fills the truck in only two minutes (circa early 1990s). Today's open pit operations at Morenci employ 272-short ton haul trucks and electric shovels with 34- to 74-cubic yard dippers. (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).

In 1974, Phelps Dodge erected an acid plant at its Morenci smelter in an effort to bring it into compliance with standards set by Arizona's new air quality regulations. This resulted in additional challenges. Although sulfuric acid is used by numerous industries, local markets were limited. On-site storage was difficult and excessive transportation costs made it uncompetitive in distant markets (Schwantes, 2000).

The price of copper fell from a high of $1.27 per pound in February 1980 to $0.83 per pound in December 1980, when Phelps Dodge suspended mining operations at the Metcalf pit due to high operating costs. The Morenci and Metcalf concentrators continued treating ore derived from the Morenci pit until April 1982, when the price of copper had fallen to $0.69 per pound. At that time, Phelps Dodge suspended all mining, milling and smelting operations, laying off most of its workers. More than half of its workforce was recalled and limited production resumed at Morenci and Metcalf in October 1982. Mining operations were halted at Metcalf in December 1983 after accessible ore had been extracted without the need for additional stripping.
In February 1981, Phelps Dodge and the Environmental Protection Agency (EPA) agreed on a program to bring sulfur dioxide emissions at the Morenci smelter into compliance with the Clean Air Act by January 1, 1985. Under the terms of this agreement, Phelps Dodge was required to erect an oxygen plant, modify reverberatory furnaces and their associated feeding systems, install new gas collection systems, and upgrade the existing acid plant. Unable to meet air quality standards, the Morenci smelter was closed in December 1984. Economic conditions did not justify expenditures of $50 million that would have brought the smelter into compliance with existing environmental regulations. Following the closure of the Morenci smelter, concentrates were primarily shipped to Phelps Dodge’s Hidalgo smelter and later to the Hurley smelter (acquired by Phelps Dodge in December 1986). Dismantling of the Morenci smelter began during 1993 and was completed with the demolition of its two 600-foot smelter stacks, which were toppled by a controlled blast on November 16, 1996.

In April 1983, Phelps Dodge commenced negotiations with a coalition of 13 unions led by the United Steel Workers. Knowing their position was weak, the unions had agreed to freeze wages, but insisted on cost of living adjustments (COLA) based on the consumer price index. Having succeeded with these terms with other major copper producers, they felt Phelps Dodge would also agree to those terms. Unwilling to accept these terms, Phelps Dodge’s management made a counter proposal – not to cut wages but to discontinue COLA raises after July 1, 1983 (Cogut and Conger, 1999b). Unable to reach an agreement on a three-year contract, the strike began at midnight on July 1, 1983. Phelps Dodge increased security personnel at the site the following day. Unlike previous strikes, Phelps Dodge did not halt copper production. They
continued operations, using supervisors and office personnel as well as union workers who chose to cross the picket lines. This strike was particularly bad with numerous threats, acts of violence and sabotage of company property, all designed to bring a halt to operations by intimidating anyone who chose to cross the picket line.

On August 5th, Phelps Dodge announced they would begin hiring permanent replacement workers, offering the new workers the same deal the unions had turned down. This significantly increased tensions and threats of violence from the strikers, who now faced the loss of their jobs. In an attempt to calm things down, a 10-day halt of operations began on August 9th. Phelps Dodge mailed eviction notices to miners fired for misconduct on the picket lines on August 15th, compelling Governor Bruce Babbitt to send 350 National Guard soldiers and 425 state police officers to Morenci on August 17th. Under heavy military and police protection, Phelps Dodge resumed operations on August 20th without incident. About 35% of the original workforce returned to work with the remainder composed of newly hired workers. By October 1983, Phelps Dodge sent letters to all who had not returned to work notifying them they were no longer employed at Morenci. The unions challenged the company's actions by filing a legal action with the National Labor Relations Board, who dismissed their claims. Although picketing continued for a couple of years after this decision, the strike was effectively lost. The new workforce overwhelmingly voted to decertify the unions in October 1984 and the National Labor Relations Board formally rejected appeals from the unions to halt decertification on February 19, 1986, officially ending the strike (Cogut and Conger, 1999b).

Figure 33. In-pit crushing and conveying system. P-7 conveyor in foreground discharges coarsely crushed ore from the Metcalf pit onto a surge stockpile. No. 1 crusher (lower far right) delivers ore from Morenci pit via P-3 conveyor to the main conveyor, which transports ore from both pits to the Morenci and Metcalf concentrators (circa 1993). (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).
In an effort to replenish its operating capital, Phelps Dodge sold a 15% joint venture interest in the Morenci operation to Sumitomo Metal Mining Arizona, Inc., a jointly-owned subsidiary of Sumitomo Metal Mining Company (80%) and Sumitomo Corporation (20%), for $75 million in February 1986 (Cogut and Conger, 1999b).

Figure 34. Coarse ore stockpile located adjacent to the Morenci concentrator (Photo taken by David Briggs in August, 2007).

The conversion of in-pit haulage from rail to truck was completed during 1986, making Morenci the last open pit mine in Arizona to load mined ore and waste onto trains (Cogut and Conger, 1999b). After that time, haul trucks hauled the ore from the mining face to a truck-train transfer station on the 4,500-foot bench of the Morenci pit, where it is loaded onto rail cars for haulage to the concentrator. Construction of an in-pit crushing and conveying system began in September 1987 and was commissioned in February 1989 at a cost of $48 million, completely eliminating the need for rail haulage at Morenci (Figure 33). This system allowed the haul trucks to dump the ore into two semi-mobile primary crushers that were initially located on the 4,150-foot level of the Morenci pit. The crushed ore was conveyed from the mine through a 3,800-foot tunnel to a coarse ore stockpile located adjacent to the Morenci concentrator (Figure 34). Within a year of completing the overland conveyor system, detailed engineering planning commenced on its first expansion to resolve issues with adverse truck haulage and ore availability within the Morenci pit, as well as the resumption of mining operations at Metcalf that were scheduled for 1991. The first phase of this $43 million expansion program was completed December 1991, relocating
one of the semi-mobile in-pit crushers to the 3,800-foot level in the Morenci pit. Completed in April 1992, the second phase of this expansion relocated the other in-pit semi-mobile crusher to the Metcalf pit and connected it to a surge stockpile located along Chase Creek. This stockpile fed the main conveyor, which transferred ore from both primary crushers to the concentrators (Dowall and Linde, 1993).

Under an October 1986 consent decree with the State of Arizona and the Environmental Protection Agency, Phelps Dodge agreed to construct flood control and storm run-off facilities along Chase Creek and San Francisco River. Completed at a cost of $2 million in June 1987, the Lower Chase Creek Dam was a part of a $9 million project that included other flood control facilities, which prevent run-off from the mine area from leaving the mine property. It also included a 7-mile long fresh water pipeline that diverts pristine mountain water around the mineralized zone, significantly improving the quality of water downstream from the Morenci operation (Cogut and Conger, 1999b).

Since resuming mining operations in 1937, Phelps Dodge has recovered copper contained within solutions treated in precipitation plants, where it was precipitated onto scrap metal to produce cement copper. This precipitate product (70% copper) was smelted with copper concentrates to produce an anode product (99% copper) that required further refining to produce a marketable copper product.

From the late 1930s until the 1940s, solutions flowing from abandoned underground mine workings in the Coronado and Metcalf areas were treated to produce cement copper. In-place leaching operations also occurred at the Humboldt mine through the 1950s, where block-caving mining methods had been employed prior to its closure in 1932. The surface overlying the caved area was sprayed with water, which percolated down through the oxidizing column of broken rock to form a weak acidic solution that leached the copper. The copper-bearing solutions were channeled over scrap metal in lower levels of the Humboldt mine to produce precipitate copper, which was hoisted to the surface through the Joy shaft. Copper-bearing solutions that flowed out of the 18th level adit were also treated by a precipitate plant. Beginning in the 1960s, low-grade sulfide stockpiles were irrigated with water, resulting in the production of weak acidic solutions formed through the oxidation of sulfides. Copper leached by these solutions was also recovered by precipitation methods until 1989 (Cogut and Conger, 1999b).

Although solvent extraction/electrowinning (SX-EW) technology had been proven commercially viable at Ranchers Exploration and Development's Bluebird mine near Miami, Arizona in March 1968, Phelps Dodge continued to rely on the older technology at their operations until the early 1980s, when a severe downturn in the copper market demanded consideration of less expensive methods of production (Addison et al, 1999).

Following the successful transition of Phelps Dodge's Tyrone project to SX-EW technology in April 1984 and closure of the Morenci smelter in December 1984, Phelps Dodge decided to introduce low cost SX-EW technology at Morenci in December 1985. Phelps Dodge Morenci's first SX-EW facilities were commissioned in September 1987 at a cost of $92 million. Capable of producing 50,000 tons of cathode copper annually, these facilities employed three solvent extraction units (Metcalf, Southwest and Central) that supplied
a single electrowinning tank house (Central tank house) at a rate of 30,000 gallons per minute (Figure 35). The annual capacity of the SX-EW system was doubled from 50,000 to 100,000 tons in February 1989 (Addison et al, 1999).

![Central electrowinning tank house at Morenci (circa 1993). (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).](image)

Figure 35. Central electrowinning tank house at Morenci (circa 1993). (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).

The introduction of SX/EW technology in 1987 had a profound impact on long range mine planning at Morenci. Near-surface, low-grade oxide ore that had not been economic to mine only a few years earlier could be profitably mined. Furthermore, the mining of the low-grade, oxide ores would uncover higher grade supergene sulfide ores that could treated by the Morenci and Metcalf concentrators.

Unlike many of Arizona's copper deposits, most of the sulfide resource at Morenci occurs as chalcocite (Cu$_2$S) as opposed to chalcopyrite (CuFeS$_2$). This mineralogical composition permits recovery of copper by both conventional milling and hydrometallurgical methods. Furthermore, there is virtually no material that was considered waste at Morenci. It is either treated by conventional milling or placed on the low-grade stockpile for leaching (Addison et al, 1999).
Figure 36. Modoc SX plant at Morenci (circa 1993) (Photo from a 1993 Phelps Dodge Morenci, Inc. calendar provided by Freeport-McMoRan, Inc.).

The first such area to benefit from SX-EW technology was the low-grade oxide resource at the Northwest Extension deposit, which is located along the west slope of the Chase Creek north of the Morenci pit and south of the mouth of Santa Rosa Canyon (Figure 30). Phelps Dodge announced it would develop the Northwest Extension ore body in August 1989. This project included the expansion of the SX-EW capacity from 100,000 to 174,000 tons of cathode per year through the addition of 172 electrowinning cells at the Central tank house and construction of the Modoc SX plant (Figure 36) (Addison, et al, 1999). It also included the relocation of 2.2 miles of U. S. Highway 666 (completed in November 1990), additional grinding capacity at the Morenci concentrator and upgrading the flotation circuit at the Metcalf concentrator. This project was completed at a cost of $112 million in May 1992. After approximately ten years, mining operations at the Northwest Extension pit were completed in 2002.

In January 1991, Phelps Dodge announced the discovery of the Coronado deposit, located northwest of the Morenci pit near the site of the historic underground Coronado mine (Figure 37). Pre-production stripping of the Coronado deposit commenced in 1999. A large resource of leachable material was identified in the Garfield area north Metcalf during 1994. Pre-production stripping began at Garfield in May 2001 (Figure 37).
Figure 37. Recent satellite photo of Morenci operation. Key - 1) Morenci concentrator, 2) Metcalf concentrator, 3) Concentrate Leach plant, 4) Central SX, 5) Central EW, 6) Southside EW, 7) Stargo SX, 8) Stargo EW, 9) Modoc SX, 10) Metcalf SX, 11) Truck Maintenance shops (Photo from ESRI web site).
The Southside project came on line during the July 1995 (Figure 37). Involving the development of unmined ore located along the southern edge of the Morenci pit, this project also included an expansion of the annual cathode production capacity of the SX-EW facilities from 170,000 to 274,000 tons. Completed in 1996 at a cost of $197.7 million, this project included the Southside tank house and expansion of the Metcalf and Modoc solvent extraction plants.

Used to treat older dumps that had been previously produced copper by precipitation methods, the Southwest SX plant was closed around 1995, due to increased haulage costs resulting from the relocation of mining operations to more northern portions of the district. The Stargo SX plant was commissioned at this site in June 1998 in preparation for treating solutions derived from the new Stargo Canyon mine-for-leach stockpile, which came on-line in late 1998 (Addison et al, 1999).

![Figure 38. One of six low-grade leach dumps currently employed at Morenci fills the former Morenci open pit. (Photo taken by David Briggs in July 2007).](image)

In response to the steady decline of the price of copper during the late 1990s, Phelps Dodge announced plans to convert its Morenci project to a mine-for-leach operation during the fall of 1999. Milling operations at the Metcalf concentrator were temporarily suspended on June 30, 1999 and it was permanently closed at the end of December 1999. The Morenci concentrator was placed on care and maintenance status at the end of February 2001.
For the first time in nearly 60 years, there is no concentrator in operation at Morenci. With the completion of $220 million mine-for-leach project in March 2001, annual cathode copper production capacity at Morenci rose to 410,000 tons, making it one of the world's largest copper producers using SX–EW technology. This expansion included a new tank house, expansion of the Stargo SX plant and a 75,000-ton/day heap leach operation, where higher grade ores are crushed at the existing Metcalf crusher and conveyed to Stargo Canyon, where it is stacked on a dedicated leach pad (Figure 37). Low-grade, run-of-mine leach ores are currently stacked on eight dedicated leach dumps, including one located within the Morenci pit, where mining operations had been completed in 1994 after 57 years of operation (Figure 38). Approximately 30% of the copper produced at Morenci SX/EW facility is currently derived from the Stargo Canyon mine-for-leach facility, while the remainder comes from the run-of-mine dumps (Anonymous, 2015).

Weak sulfuric acid solutions are applied to the ores by a drip irrigation system, which is similar to those used by farmers to irrigate their fields. As the weak acidic solutions percolate down through the rock, the solutions dissolve the soluble copper contained within the ore. These copper-bearing solutions are collected from the bottom of the leach pads and upgraded in the solvent extraction plant. The upgraded solutions then report to the electrowinning tank house, where the copper is electroplated onto stainless steel starter sheets to produce a final, marketable, copper cathode product (99.999% copper).

In October 2001, Phelps Dodge entered a joint venture agreement with Placer Dome, Inc. to develop a copper concentrate leaching process. This project modified existing autoclave technology that had been developed to treat refractory gold ores during the 1980s to recover a marketable copper cathode product from copper concentrates without the need for conventional smelting and refining. Autoclaves operating at a temperature of 150- to 225-degrees Centigrade and a pressure of 305- to 475-psi oxidize the copper concentrates. This oxidation process produces a copper-bearing solution that is treated by another newly developed technological process, known as direct electrowinning, which produces a marketable copper cathode product (Cole and Wilmot, 2009).

A pilot plant was commissioned at the Bagdad copper mine in March 2003 at a cost of $40 million (Marsden and Brewer, 2003). Successful results from this test facility led to Phelps Dodge's decision in June 2005 to proceed with the development of a commercial-scale concentrate leach plant at Morenci. In preparation for the commissioning of this project, the Morenci concentrator resumed production during the spring of 2006.

**Freeport-McMoRan Copper and Gold, Inc. (2007 to present)**

Freeport-McMoRan Copper and Gold, Inc. (renamed Freeport-McMoRan, Inc. in July 2014) acquired an 85% interest in the Morenci project through its merger with the Phelps Dodge Corporation in March 2007.
Located at the site of the former Morenci smelter, the concentrate leach facility was commissioned in October 2007 at a cost of $250 million (Figure 39). With the precipitous collapse in the price of copper to $1.25 per pound during the fall of 2008, milling operations were suspended in February 2009 and the concentrate leach facility was placed on care-and-maintenance status. By early 2010, the demand for copper had strengthened, allowing the Morenci concentrator to resume production in March 2010. The concentrate leach facility was brought back on line during the spring of 2015.

Over the years, the successful development of new reserves, competent management and adoption of new technologies and mining practices have all played an important role in Morenci's ability to remain competitive on the world market. Declining copper prices of the early 1980s, led to the introduction of SX-EW technology to recover copper from low-grade oxide and secondary sulfide ores at Morenci. This trend culminated with the low copper prices of the late 1990s ($0.62 per pound in February 1999), resulting in the decision to close the Metcalf and Morenci concentrators and rely on low-cost, dump leaching operations as the sole source for copper production.

By the time of Freeport-McMoRan's merger with Phelps Dodge, the copper price had risen to $3.00 per pound. Viewing exploration as an investment, Freeport-McMoRan began an aggressive 7-year exploration program at Morenci. After increasing their recoverable copper reserves by 8 billion pounds within three years, management realized a huge resource was present at Morenci (Figure 40). This represented a unique opportunity. Already having permitting in place to mill 125,000-tons/day, development of this resource only required restoring Morenci's mining and milling capacity with modern energy-efficient technology (Fiscor, 2015).
In early 2012, Freeport-McMoRan completed a feasibility study to expand the copper production capacity at Morenci to more than 1 billion pounds annually. Construction of this project began during the fall of 2012. The centerpiece of this expansion program was a new 70,000-ton/day concentrator that is housed in the old Metcalf concentrator building. This enabled the Morenci operation to expand its milling capacity from 55,000 to 125,000-tons/day. Other aspects included expanded tailings storage capacity, additional mining equipment, and improvements to the community of Morenci. The modernized Metcalf concentrator was commissioned within budget and produced its first copper concentrate in May 2014. The Metcalf concentrator's second ball mill came on line in June 2014 and reached full capacity in August 2014. This expansion project was completed during the fall of 2015 at a total cost of $1.9 billion (Fiscor, 2015).

In May 2013, Freeport-McMoRan Copper & Gold, Inc. completed the purchase of Plains Exploration and Production Company (PXP), an oil company. This $16.3 billion transaction included assumption of $9.7 billion in PXP debt, payment of $3.3 billion in cash and issuance of about 91 million shares of stock valued at $2.9 billion (Freeport-McMoRan Copper and Gold, Inc., 2013). Over the last several years (2012-2015), Freeport-McMoRan also invested nearly $10 billion in major expansion projects at Morenci, Cerro Verde in Peru, Tenke Fungurume in the Democratic Republic of the Congo, and Grasberg in Indonesia (Freeport-McMoRan, Inc. 2015-2016). This combined with the steady fall in the price of metals and oil over the last several years have made it difficult for Freeport-McMoRan to meet its financial obligations.

In an effort to accelerate debt reduction and restore its balance sheet, Freeport-McMoRan, Inc. sold a 13% interest in the Morenci project to Sumitomo Metal Mining Company in May 2016 for $1.0 billion in cash. On completion of this purchase Sumitomo Metal Mining's interest in the Morenci project increased to 25% and Sumitomo Corporation retained a 3% interest. Freeport-McMoRan's interest in the project declined to 72% (Freeport-McMoRan, Inc., 2016).
Interesting Facts about the Morenci Project

Located at an elevation of 3,600 to 6,600 feet, Freeport-McMoRan's Morenci project encompasses land holdings covering approximately 68,250 acres. It includes 51,150 acres of patented mining claims and other privately owned lands, 14,050 acres of unpatented mining claims, and 3,050 acres of lands held under state or federal permits, easements and rights-of-way (Freeport-McMoRan, Inc., 2015-2016).

This operation employs a mobile mining fleet that has a capacity to move an average of 900,000 short tons of material daily, including 125,000 tons of mill ore, 75,000 tons of mine-for-leach (crushed) ore and 700,000 tons of run-of-mine (ROM) leach ore. There is little to no waste. This fleet includes 111 272-ton Cat 793 haul trucks and two 190-ton Cat 789 haul trucks that are loaded by 14 electric shovels with bucket sizes ranging from 34 to 74 cubic yards. Blast holes are drilled by 14 Atlas Copco drill rigs. Support equipment include graders, water trucks, dozers, rollers, and loaders (Anonymous, 2015).

Overall dimensions of the mined area are approximately 5 miles by 3 miles. The ores are mined on 50-foot benches, with final pit slopes ranging from 37 to 52 degrees. The elevation of highest bench is 6,600 feet above sea level. The ultimate pit bottom is expected to be at an elevation of approximately 2,755 feet (Freeport-McMoRan, Inc., 2015-2016). A semi-autonomous radar system provides an operations command center real-time slope stability data throughout the mine site (Anonymous, 2015).

Morenci's copper concentrates (34% copper) are shipped to Freeport-McMoRan's smelter at Miami, treated at the on-site concentrate leach facility, or sold to a third party for smelting or refining. Molybdenum concentrates (45% molybdenum) are shipped to one Freeport-McMoRan's molybdenum plants for further refinement (Anonymous, 2015).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Mining District</th>
<th>State</th>
<th>Years</th>
<th>Cu Production (lbs)</th>
<th>Percentage of Total Historical U. S. Copper Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bingham Canyon</td>
<td>Utah</td>
<td>1865-2015</td>
<td>42,289,734,000</td>
<td>16.43</td>
</tr>
<tr>
<td>2</td>
<td>Morenci</td>
<td>Arizona</td>
<td>1872-2015</td>
<td>36,757,807,000</td>
<td>14.28</td>
</tr>
<tr>
<td>3</td>
<td>Butte</td>
<td>Montana</td>
<td>1880-2015</td>
<td>22,261,799,000</td>
<td>8.65</td>
</tr>
<tr>
<td>4</td>
<td>Pima</td>
<td>Arizona</td>
<td>1888-2015</td>
<td>21,295,393,000</td>
<td>8.27</td>
</tr>
<tr>
<td>5</td>
<td>Inspiration-Miami</td>
<td>Arizona</td>
<td>1899-2015</td>
<td>17,215,827,000</td>
<td>6.69</td>
</tr>
<tr>
<td>6</td>
<td>Central (Chino)</td>
<td>New Mexico</td>
<td>1801-2015</td>
<td>15,306,691,000</td>
<td>5.95</td>
</tr>
<tr>
<td>7</td>
<td>Mineral Creek (Ray)</td>
<td>Arizona</td>
<td>1905-2015</td>
<td>14,033,000,000</td>
<td>5.45</td>
</tr>
<tr>
<td>8</td>
<td>San Manuel</td>
<td>Arizona</td>
<td>1886-2002</td>
<td>9,313,614,000</td>
<td>3.62</td>
</tr>
<tr>
<td>9</td>
<td>Eureka (Bagdad)</td>
<td>Arizona</td>
<td>1890-2015</td>
<td>8,253,999,000</td>
<td>3.21</td>
</tr>
<tr>
<td>10</td>
<td>Warren (Bisbee)</td>
<td>Arizona</td>
<td>1880-2013</td>
<td>7,922,958,000</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td>194,650,822,000</td>
<td>75.63</td>
</tr>
</tbody>
</table>

With the exception of 2009 and 2010, Morenci mine has been America's largest copper producer since 1984. Approximately 33.9% (1,061,200,000 pounds) of copper output from our nation's mines during 2015 was derived from the Morenci operation (Briggs, 2016).

Copper has been mined from the Copper Mountain (Morenci) mining district for 143 years. In terms of total historical production, it is the second largest copper producer in the United States, accounting for nearly 36.8 million pounds through 2015. This represents about 14.28% of total U. S. copper production from 1845 through 2015 (Briggs, 2016). Only the West Mountain (Bingham Canyon) mining district near Salt Lake City, Utah has yielded more copper (Table 3).

Extensive exploration activities are required to find and develop the ore reserves required to support future mining operations at Morenci. A recent drilling campaign was completed in August 2013. Since March 2007, this exploration and in-fill drilling program completed 868 drill holes, totaling approximately 1.7 million feet (Anonymous, 2015). Morenci's proven and probable reserves and minerals resources (mineralized material) are shown in Tables 4 and 5, respectively. As of December 31, 2015, sufficient reserves have been identified to continue operations at Morenci until 2038 (Freeport-McMoRan, Inc., 2015-2016).

<table>
<thead>
<tr>
<th>Proven and Probable Reserves</th>
<th>Reserves Short Tons</th>
<th>Cu %</th>
<th>Contained Copper Short Tons</th>
<th>Mo %</th>
<th>Contained Molybdenum Short Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill Ore</td>
<td>829,000,000</td>
<td>0.42</td>
<td>3,481,800</td>
<td>0.020</td>
<td>165,800</td>
</tr>
<tr>
<td>Crushed Leach Ore</td>
<td>424,000,000</td>
<td>0.54</td>
<td>2,289,600</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ROM Leach Ore</td>
<td>2,686,000,000</td>
<td>0.18</td>
<td>4,834,800</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total Reserves</td>
<td>3,939,000,000</td>
<td></td>
<td>10,606,200</td>
<td></td>
<td>165,000</td>
</tr>
</tbody>
</table>

Table 4. Mill, crushed leach and run-of-mine (ROM - i.e. uncrushed ore) leach reserves as of December 31, 2015 (Source: Freeport-McMoRan, Inc., 2015-2016). The term, "reserve" means that portion of the mineral deposit that can be economically and legally extracted or produced at the time of the reserve determination.

<table>
<thead>
<tr>
<th>Mineralized Material</th>
<th>Resource Short Tons</th>
<th>Cu %</th>
<th>Contained Copper Short Tons</th>
<th>Mo %</th>
<th>Contained Molybdenum Short Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mill Resource</td>
<td>659,000,000</td>
<td>0.28</td>
<td>1,845,200</td>
<td>0.020</td>
<td>131,800</td>
</tr>
<tr>
<td>Crushed/ROM Leached Resource</td>
<td>1,015,000,000</td>
<td>0.21</td>
<td>2,130,500</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total Resource</td>
<td>1,674,000,000</td>
<td></td>
<td>3,975,700</td>
<td></td>
<td>131,800</td>
</tr>
</tbody>
</table>

Table 5. Mill, crushed leach, and run-of-mine leach resources as of December 31, 2015 (Source: Freeport-McMoRan, Inc., 2015-2016). The term, "mineralized material" is defined as a mineralized body that has been delineated by appropriately spaced drilling and/or underground sampling to support the reported tonnage and average metal grades. However, mineralized material does not qualify as proven or probable reserves until legal and economic feasibility has been confirmed by a comprehensive evaluation of development costs, unit costs, grades, recoveries and other material factors.

Direct and indirect economic impacts of the Morenci project on the state of Arizona during 2013 totaled $989 million, including direct impacts of $490 million from compensation, vendor purchases and business taxes and indirect
impacts of $499 million from consumer spending by Morenci employees, supplier purchases and spending of state and local tax revenues. Direct employment at Morenci totaled 4,518, including 2,665 employees at Morenci and 1,853 employees working for vendors, who provided supplies or services to the Morenci project. An additional 6,697 indirect jobs were created by consumer spending by Morenci employees, supplier purchases and spending of state and local tax revenues (Anonymous, 2015).

The Morenci project operates in compliance with air and water quality permits administered by the Arizona Department of Environmental Quality. Best management and engineering controls are employed by Freeport-McMoRan to minimize the operation's impacts on the environment and maintain its status as a zero discharge facility. On-going efforts to support Freeport-McMoRan's sustainability program at Morenci include various recycling efforts, energy efficiency projects and habitat improvements for the Mexican free-tail bat, Townsend bat, and Rocky Mountain bighorn sheep (Figure 4). They have also conducted many remediation projects including cleanup around historical smelter sites in the Morenci and Clifton areas and closure of many historical mine shafts and adits throughout the Copper Mountain mining district (Anonymous, 2015).

![Image of bighorn sheep](image.jpg)

Figure 41. Some of the Rocky Mountain bighorn sheep, who live in and around the Copper Mountain mining district. Photo taken along Route 191, near the old town site of Stargo by David Briggs in August 2007.
Acknowledgments

The author thanks Freeport-McMoRan, Inc. and the Arizona Geological Survey for their permission to use many of the photos contained within this article. These photos have helped to illustrate what is described in the text.

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Appendix 1. Historical Timeline for Morenci Mining District

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1863</td>
<td>Copper and placer gold discovered by soldiers of General Carleton's Regiment of California Volunteers in January 1863.</td>
</tr>
<tr>
<td>1864</td>
<td>Henry Clifton lead a prospecting party to search for gold along the Gila and San Francisco rivers.</td>
</tr>
<tr>
<td>1870</td>
<td>Copper and placer gold rediscovered by a group of Silver City ranchers searching for horses stolen by Apaches.</td>
</tr>
<tr>
<td>1872</td>
<td>Robert and James Metcalf returned with a group of prospectors to prospect for gold along Gold Gulch. First mining claims staked in Morenci mining district. The Detroit Copper Mining Company was incorporated in July 1872. The Francisco Mining Company, a predecessor of the Longfellow Mining Company, was formed in August 1872.</td>
</tr>
<tr>
<td>1873</td>
<td>The Francisco Mining Company produced the first copper ingots at a primitive smelter located along Chase Creek during the spring of 1873.</td>
</tr>
<tr>
<td>1874</td>
<td>The Longfellow smelter was relocated to Clifton at the confluence of Chase Creek and the San Francisco River in early 1874.</td>
</tr>
<tr>
<td>1877</td>
<td>Water-jacketed furnaces introduced at the Longfellow smelter.</td>
</tr>
<tr>
<td>1879</td>
<td>The Coronado Railroad was commissioned by the Longfellow Mining Company in December 1879. It was the first mine railroad in Arizona.</td>
</tr>
<tr>
<td>1880</td>
<td>Southern Pacific Railroad completed to Lordsburg, New Mexico in October 1880, significantly reducing the cost of shipping goods to and from Morenci.</td>
</tr>
<tr>
<td>1881</td>
<td>William Church persuades Phelps, Dodge and Company to provide the financial backing required to develop Detroit Copper's holdings in the Morenci mining district. The Southern Pacific Railroad linked up with the Atchison, Topeka and Santa Fe Railroad at Deming, New Mexico in March 1881, becoming the second transcontinental railroad. In March 1881, the Morenci mining district became a part of Graham County, which had been created from southern Apache County and eastern Pima County.</td>
</tr>
<tr>
<td>1882</td>
<td>The Detroit Copper Mining Company commissioned a small smelter along the east bank of the San Francisco River in April 1882. The Arizona Copper Company purchased the holdings of the Longfellow Mining Company in September 1882. In November 1882, the Longfellow mine experienced a major cave-in.</td>
</tr>
<tr>
<td>1884</td>
<td>The Arizona and New Mexico Railroad was completed in April 1884, connecting Clifton with Lordsburg, New Mexico. Arizona Copper commissioned its new Clifton smelter in July 1884. Detroit Copper replaced its original smelter with a new facility at Morenci in September 1884.</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>1886</td>
<td>Detroit Copper established the first oxide concentrating plant in the Morenci mining district in May 1886.</td>
</tr>
<tr>
<td>1893</td>
<td>Arizona Copper developed a hydrometallurgical process to recover copper from oxide mill tails. Low-grade sulfide porphyry ores of the Clay ore body were discovered.</td>
</tr>
<tr>
<td>1896</td>
<td>Arizona Copper commissioned the Arizona's first successful sulfide concentrator in July 1896. The Bessemer converter installed at Detroit Copper's smelter in late 1896.</td>
</tr>
<tr>
<td>1897</td>
<td>In the spring of 1897, the Detroit Copper Mining Company became a wholly-owned subsidiary of Phelps, Dodge and Company. Dr. James Douglas became the president of the Detroit Copper Mining Company.</td>
</tr>
<tr>
<td>1898</td>
<td>Morenci Water Company was organized in October 1898 to provide a safe water supply to the town of Morenci.</td>
</tr>
<tr>
<td>1899</td>
<td>The Morenci Southern Railroad was formed in October 1899. William Boyce Thompson organized the Shannon Copper Company in November 1899.</td>
</tr>
<tr>
<td>1900</td>
<td>The Detroit Copper Mining Company commissioned its first successful sulfide concentrator, the West Yankie concentrator.</td>
</tr>
<tr>
<td>1901</td>
<td>The first successful treatment of low-grade, sulfide porphyry ores on a large scale occurred at Arizona Copper's Morenci operation in 1901. The Morenci Southern Railroad completed a narrow-gauge rail line in December 1901, connecting Guthrie and Morenci.</td>
</tr>
<tr>
<td>1902</td>
<td>Shannon Copper smelter was commissioned in May 1902.</td>
</tr>
<tr>
<td>1903</td>
<td>First systematic exploration program to evaluate the economic potential of the Clay ore body was initiated. Shannon Copper's concentrator was commissioned in March 1903. Longfellow mine was closed in 1903.</td>
</tr>
<tr>
<td>1905</td>
<td>Arizona Copper pioneered the use of electric haulage in its Humboldt mine.</td>
</tr>
<tr>
<td>1906</td>
<td>In-situ leaching methods employed to recover copper from the Medler mine. Arizona Copper's No. 6 concentrator commissioned at Morenci in July 1906. Major flood event occurred at Clifton in December 1906.</td>
</tr>
<tr>
<td>1908</td>
<td>Phelps, Dodge and Company, a partnership, was reorganized as Phelps, Dodge and Company, Inc. Dr. James Douglas was elected president. His son, Walter Douglas was appointed general manager of its western operations, which included the Detroit Copper Mining Company. Annual copper production from underground operations at Morenci peaked at approximately 77 million pounds.</td>
</tr>
<tr>
<td>1909</td>
<td>Greenlee County was created in March 1909 with Clifton being the county seat.</td>
</tr>
<tr>
<td>1910</td>
<td>Shannon-Arizona Railroad completed in February 1910, connecting its mines near Metcalf with its Clifton reduction facilities.</td>
</tr>
<tr>
<td>1913</td>
<td>Arizona Copper commissioned a new smelter along the east bank of the San Francisco River at Smelter Hill in October, 1913. It's older Clifton smelter was closed in December 1913.</td>
</tr>
<tr>
<td>1915</td>
<td>Differential flotation process was first employed by the Detroit Copper's West Yankie concentrator in September 1915. Completed the underground haulage system connecting the underground operation at the Coronado mine with the main haulage level of the Humboldt mine in 1915.</td>
</tr>
<tr>
<td>1917</td>
<td>The Detroit Copper Mining Company became the Morenci Branch of the Phelps Dodge Corporation in April 1917. Later that year, Walter Douglas succeeded his father, as president of the Phelps Dodge Corporation.</td>
</tr>
<tr>
<td>1919</td>
<td>Shannon Copper Company ceased operations on January 1, 1919. The Arizona Copper Company purchased the assets of the Shannon Copper Company in</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>October, 1919.</td>
<td>Phelps Dodge Corporation suspended all mining, milling and smelting operations at Morenci in September 1919 due to falling copper prices.</td>
</tr>
<tr>
<td>1921</td>
<td>Arizona Copper suspended all mining, milling and smelting operations at Morenci in May 1921. Phelps Dodge Corporation acquired Arizona Copper's Morenci assets in October 1921.</td>
</tr>
<tr>
<td>1922</td>
<td>Phelps Dodge resumed mining and milling operations at Morenci in early 1922.</td>
</tr>
<tr>
<td>1923</td>
<td>Phelps Dodge resumed smelting operations at Arizona Copper's smelter at Smelter Hill in May 1923. Mining operations were suspended at the Coronado mine.</td>
</tr>
<tr>
<td>1928</td>
<td>Phelps Dodge began a systematic 88,000-foot drilling program at the Clay ore body.</td>
</tr>
<tr>
<td>1930</td>
<td>Louis Cates succeeded Walter Douglas as president of Phelps Dodge in May 1930.</td>
</tr>
<tr>
<td>1932</td>
<td>Phelps Dodge suspended operations at all of its mining, milling and smelting facilities in May 1932 as a result of Great Depression.</td>
</tr>
<tr>
<td>1937</td>
<td>A decision to proceed with the development of the Clay ore body was made in June 1937. Pre-production stripping of the Morenci pit began in August 1937. Phelps Dodge resumed smelting operations at its Smelter Hill smelter in September 1937.</td>
</tr>
<tr>
<td>1938</td>
<td>The No. 6 concentrator reactivated to conduct metallurgical tests. Phelps Dodge permanently closed its smelter at Smelter Hill.</td>
</tr>
<tr>
<td>1941</td>
<td>Metallurgical testing ends at the No. 6 concentrator on December 31, 1941.</td>
</tr>
<tr>
<td>1942</td>
<td>The 25,000-ton/day Morenci concentrator was commissioned on January 30, 1942. The new smelter was brought on line on April 26, 1942.</td>
</tr>
<tr>
<td>1943</td>
<td>In response to the increased demand for copper during World War II, the production capacity of the Morenci operations was nearly doubled.</td>
</tr>
<tr>
<td>1946</td>
<td>Completed the Horseshoe Dam project along the Verde River, which allowed Phelps Dodge to access additional supplies of water for the Morenci project.</td>
</tr>
<tr>
<td>1949</td>
<td>A molybdenum recovery circuit was added to the Morenci concentrator in November 1949.</td>
</tr>
<tr>
<td>1953</td>
<td>Completed the Show Low Dam project along a tributary of the Little Colorado River.</td>
</tr>
<tr>
<td>1961</td>
<td>Phelps Dodge entered a lease/option agreement on the Western Copper property with the Hanna Mining Company in August 1961.</td>
</tr>
<tr>
<td>1965</td>
<td>Relocation of the town of Morenci began to make room for the expansion of the upper levels of the Morenci pit. Completed construction of the Blue Ridge Dam project on East Clear Creek, a tributary of the Little Colorado River.</td>
</tr>
<tr>
<td>1966</td>
<td>Phelps Dodge exercised its option to lease the Western Copper property from the Hanna Mining Company in 1966.</td>
</tr>
<tr>
<td>1969</td>
<td>Phelps Dodge made the decision to proceed with the development of the Metcalf ore body in June 1969.</td>
</tr>
<tr>
<td>1975</td>
<td>The first ore from the Metcalf pit was delivered to the Metcalf concentrator in January 1975.</td>
</tr>
<tr>
<td>1980</td>
<td>Open pit mining operations at Metcalf were suspended December 1980.</td>
</tr>
<tr>
<td>1981</td>
<td>Phelps Dodge purchased the Western Copper property in April 1981.</td>
</tr>
<tr>
<td>Year</td>
<td>Event</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>1982</td>
<td>All mining and milling operations were suspended from April 1982 until October 1982 due to depressed copper prices. Relocation of the Morenci town site was completed in 1982.</td>
</tr>
<tr>
<td>1983</td>
<td>Thirteen unions led by the United Steelworkers began a strike at midnight on July 1, 1983. The greatest flood in Clifton's history occurred on October 2, 1983.</td>
</tr>
<tr>
<td>1984</td>
<td>The unions were decertified in October 1984 with 95% of the Morenci workforce voting for decertification. The Morenci smelter was closed in December 1984.</td>
</tr>
<tr>
<td>1986</td>
<td>The National Labor Relations Board rejected appeals from the unions to halt decertification on February 19, 1986, officially ending the strike. Phelps Dodge sold a 15% joint venture interest in the Morenci project to Sumitomo Metal Mining Arizona, Inc. in February 1986. Conversion of in-pit haulage from rail to truck was completed during 1986.</td>
</tr>
<tr>
<td>1987</td>
<td>In June 1987 the Lower Chase Creek Dam was completed as a part of a flood control and storm run-off project. The first solvent extraction-electrowinning (SX-EW) facilities at Morenci were commissioned in September 1987.</td>
</tr>
<tr>
<td>1989</td>
<td>An in-pit crushing and haulage system was commissioned in February 1989, completely eliminating the need for rail haulage at Morenci. Announced plans to develop the Northwest Extension ore body in August 1989. Production of precipitate copper was suspended in 1989.</td>
</tr>
<tr>
<td>1994</td>
<td>A large resource of leachable material was identified at Garfield. Open pit mining operations were completed at the Morenci pit after 57 years of operation.</td>
</tr>
<tr>
<td>1996</td>
<td>The Morenci operation mined 1,327,800 short tons of material on May 26, 1996, a world record. The two 600-foot stacks of the smelter were toppled by a controlled blast on November 16, 1996.</td>
</tr>
<tr>
<td>1997</td>
<td>The 300-foot smelter stack at Smelter Hill was toppled by a controlled blast in February 1997. Morenci awarded ISO 9002 certification for its SX-EW operations. Annual copper production at Morenci peaked at 1,084,400,000 pounds.</td>
</tr>
<tr>
<td>1999</td>
<td>Milling operations were suspended at the Metcalf concentrator in June 1999 and it was permanently closed at the end of December 1999. Pre-production stripping of the Coronado deposit began in 1999.</td>
</tr>
<tr>
<td>2001</td>
<td>The Morenci concentrator was placed on care and maintenance status at the end of February 2001. In March 2001, the sole source of copper production at Morenci was derived from dump leaching. Pre-production stripping began at Garfield in May 2001.</td>
</tr>
<tr>
<td>2002</td>
<td>Open pit mining operations were completed at Northwest Extension.</td>
</tr>
<tr>
<td>2003</td>
<td>Pre-production stripping of the Western Copper deposit began in 2003. Morenci sets a world record cathode production record level of 844 million pounds.</td>
</tr>
<tr>
<td>2006</td>
<td>Milling operations resumed at the Morenci concentrator during the spring of 2006.</td>
</tr>
</tbody>
</table>
2007  Freeport-McMoRan Copper and Gold, Inc. acquired an 85% interest in the Morenci project through its merger with Phelps Dodge in March 2007. The Morenci concentrate leach plant was commissioned in October 2007.

2009  Milling and concentrate leach plant operations were suspended in February 2009 due to a decline in copper prices and deteriorating market conditions.

2010  Morenci concentrator resumed operations in March 2010.

2012  Commenced $1.9 billion Morenci expansion project designed to increase copper production by 225 million pounds, annually.

2014  Commissioned new Metcalf concentrator in May 2014.

2015  Completed $1.9 billion expansion project during the fall of 2015. The concentrate leach facility was brought back on line during the spring of 2015.

2016  Freeport-McMoRan sold a 13% interest in its Morenci project to Sumitomo Metal Mining Company in May 2016. The purchase price was reported to be $1 billion in cash.

Appendix 2. Ore Treatment Facilities at the Copper Mountain (Morenci) Mining District

<table>
<thead>
<tr>
<th>Operator Name</th>
<th>Facility Name</th>
<th>Dates of Operation</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longfellow Mining</td>
<td>Stone House Smelter</td>
<td>1873-1874</td>
<td>Along Chase Creek</td>
</tr>
<tr>
<td>Longfellow/Az Arizona Copper</td>
<td>Longfellow Smelter</td>
<td>1874-1884</td>
<td>Clifton</td>
</tr>
<tr>
<td>Detroit Copper</td>
<td>First Smelter</td>
<td>1882-1884</td>
<td>Smelter Hill south of Clifton</td>
</tr>
<tr>
<td>Detroit Copper</td>
<td>Second Smelter</td>
<td>1884-1919</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Detroit Copper</td>
<td>Oxide Concentrator</td>
<td>1886-1900</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Detroit Copper</td>
<td>First Sulfide Concentrator</td>
<td>1895-1900</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Detroit Copper</td>
<td>West Yankie Concentrator</td>
<td>1900-1919</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>Clifton Smelter</td>
<td>1884-1913</td>
<td>Clifton</td>
</tr>
<tr>
<td>Arizona Copper/Phelps Dodge</td>
<td>Smelter Hill Smelter</td>
<td>1913-1938</td>
<td>Smelter Hill south of Clifton</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>No. 1 Oxide Concentrator</td>
<td>1887-1914</td>
<td>Clifton</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>No. 2 Sulfide Concentrator</td>
<td>1896-1914</td>
<td>Clifton</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>No. 3 Sulfide Concentrator</td>
<td>1898-1909</td>
<td>Clifton</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>No. 4 Sulfide Concentrator</td>
<td>1900-1919</td>
<td>Clifton</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>No. 5 Sulfide Concentrator</td>
<td>1901-1911</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Arizona Copper/Phelps Dodge</td>
<td>No. 6 Sulfide Concentrator</td>
<td>1906-1941</td>
<td>Old Morenci</td>
</tr>
<tr>
<td>Arizona Copper</td>
<td>Oxide Leach Plant</td>
<td>1893-1914</td>
<td>Clifton</td>
</tr>
<tr>
<td>Shannon Copper</td>
<td>Shannon Smelter</td>
<td>1902-1919</td>
<td>Clifton</td>
</tr>
<tr>
<td>Shannon Copper</td>
<td>Shannon Concentrator</td>
<td>1903-1919</td>
<td>Clifton</td>
</tr>
<tr>
<td>Shannon Copper</td>
<td>Oxide Leach Plant</td>
<td>1916-1919</td>
<td>Clifton</td>
</tr>
<tr>
<td>Phelps Dodge</td>
<td>Morenci Smelter</td>
<td>1942-1984</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Operator Name</td>
<td>Facility Name</td>
<td>Dates of Operation</td>
<td>Location</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>----------------------------</td>
<td>--------------------</td>
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</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Morenci Concentrator</td>
<td>1942-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge</td>
<td>Old Metcalf Concentrator</td>
<td>1975-1999</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>New Metcalf Concentrator</td>
<td>2014-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Concentrate Leach Plant</td>
<td>2007-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge</td>
<td>Precipitate Plants</td>
<td>1937-1989</td>
<td>Various Locations</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Modoc Solvent Extraction</td>
<td>1992-present</td>
<td>SE of Modoc Mountain</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Metcalf Solvent Extraction</td>
<td>1987-present</td>
<td>Pit Area near Metcalf Town Site</td>
</tr>
<tr>
<td>Phelps Dodge</td>
<td>Southwest Solvent Extraction</td>
<td>1987-1996</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Central Solvent Extraction</td>
<td>1987-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Stargo Solvent Extraction</td>
<td>1998-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Central Electrowinning</td>
<td>1987-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Southside Electrowinning</td>
<td>1995-present</td>
<td>New Morenci</td>
</tr>
<tr>
<td>Phelps Dodge/Freeport-McMoRan</td>
<td>Stargo Electrowinning</td>
<td>2001-present</td>
<td>New Morenci</td>
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</tbody>
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