Chapter Nine

History of Smelting in Arizona

Introduction

This presentation is primarily concerned with copper ores; other types of ores have been smelted and some examples are noted.

Modern copper smelting is employed to produce metallic copper and a slag. Slag, a waste product, contains iron and siliceous constituents. Metallic copper and slag are produced from the mill concentrates. Concentrates are a damp mass of finely divided, ground material that consists of copper sulphide minerals, pyrite (the sulphide of iron) and a gangue (usually made up of silica and the silicates of aluminum). The smelting process is accomplished by pyrometallurgy, the kind of metallurgy that employs heat to cause chemical reactions through which the end products are obtained. Mining and concentrating are mechanical separations, smelting rearranges the elements and their compounds.

Early ores were oxides, carbonates, etc. that could be successfully smelted with crude equipment. As mining depths increased, these ores graded into siliceous ores and finally exclusively into sulphide ores. Thus the required type of smelting equipment changed, sometimes radically, as the ore changed. Many of these developments were made elsewhere and introduced to Arizona.

In the remote locations in which minerals were found nothing was readily on hand. Indians raided and plundered; labor was scarce; so were fuel, water, and materials of construction. Railroads were far away; transportation was on the backs of burros and mules or by wagons pulled by horses, mules, burros, or oxen. Thus transportation was expensive and the price for copper varied over wide ranges.

The period covered is from the beginning of mining in Arizona (unknown) to the start up of the Morenci Smelter of Phelps Dodge Corporation in 1942.

For this project all of the smelters have not been found. It has been stated, "Between 1880 and 1885 at least 53 furnaces were erected in Arizona alone".[58] Therefore, an attempt has been made to list the smelters and to enumerate some of the smelting problems and how they were overcome. Unfortunately, this project has turned up conflicts in dates and data. I hope I have not consistently chosen the controversial points of view.

There are three references to smelting or possible smelting before 1870: (1) The 1934-35 excavations of the Hohokam village at Snaketown resulted in the discovery of 28 copper bells (high-grade copper with a trace of silver). Dates were somewhere in 900-1400 A.D. Evidence in 1964-65 pointed to production in Mexico—not in Arizona as originally believed. (2) It was reported that the first prospectors who reached the Castle Dome district (Yuma County) in 1863 found ancient surface workings which followed veins of galena. These workings had been overgrown by native trees, but there were well worn trails from the mining pits to the ruins of crude adobe smelting furnaces on the banks of the Gila River, about 18 miles away. Indians may have packed the ores on these trails during the time of the early Spanish explorers (as early as 1540 A.D.). (3) An oral tradition was handed down that probably after 1694 and long before 1847 Mexicans selected the richest ores in the Ajo area and packed it on mules to a hand blast furnace they had erected at El Monte a spot in the Ajo Mountains, where there was water and wood. The copper matte was then packed down to Altar, Mexico, where it was sold.

Smelting Metallurgical Process

Welsh Process

The art of refining copper was, for many generations, a carefully guarded secret among Welsh furnacemen that was handed down from father to son. Labor skilled in the process could be obtained at low wages and the finest coal in the world cost no more than 25 cents per ton. It was cheaper to ship the highest grade ores and the high-grade mattes (about 60% copper) to Swansea, Wales to complete the process of obtaining copper metal.

The Welsh carried out their process in reverberatory furnaces which are shallow furnaces consisting of a hearth, side walls, end walls, and a roof. The furnaces were heated by coal burned in an enclosed firebox. This process treated copper ores and/or mattes in these furnaces by a series of roastings and fusions to raise the percentage of copper in the product to finally produce a blister copper. The process generally consisted of five parts.

I. Calcining the ore in a hand manipulated furnace until not more than 5% sulphur was left.
II. Fusion of the ore to form a matte of about 35% copper ("Coarse Metal").

III. Calcining the "Coarse Metal" in a hand manipulated reverberatory roaster.
IV. Second reverberatory fusion that resulted in a matte containing 75% copper ("White Metal").
V. Roasting and formation of "Blister Copper". The "White Metal" was fired gradually for several hours with an oxidizing flame. Finally the heat was raised and the whole charge was melted down. The blister copper was tapped. This metal obtains its name from the fact that, upon cooling, the occluded gas, seeking to escape from the molten metal, forms blisters on the surface of the "pigs" of metal. The blister copper contained 98% copper, but also contained impurities that must be removed to make the copper suitable for the market. Further refining was by blowing the molten blister copper with air to remove impurities and poling (green tree poles) to remove the oxygen. The steps of this process were far more numerous and variable than appears from this outline; the reactions were not clear cut.

Primitive "Adobe" Blast Furnaces

In 1599 Gonzalo Gomez de Cervantes decided to explain in detail how to erect a tiny blast furnace. In Guatemala these are called "chimbos". Materials readily available in nature are used. Large, fire-resistant, non-spalling rocks are used for the refractory base. The smelting zone is the hottest part of any furnace; there the corrosive effect of the molten litharge flux (lead smelting) causes the maximum damage. The bottom 25 inches of the furnace shaft walls, therefore, are to be of the same refractory rock as the base. The open top of the furnace shaft is only 50 inches above its base. Common "adobe" suffices above the smelting zone. The air blast hole is about six inches above the tap hole. It is assumed that most ancient furnaces were blown with an air blast from a pair of cylindrical bellows (like an oversized concertina) which were driven by a water wheel. In arid localities hand or foot operated bellows were probably used.

Alternate layers of ore or concentrate and wood charcoal are dumped into the top of the "chimbo". An iron bar is used to ream out both the tap hole and the air blast tuyere (hole). The molten lead trickles from the tap hole into a masonry basin. The furnaceman skims the slag from the surface of the molten lead, hot metal is ladeled into simple molds. The process was and is difficult to carry out and it is inordinately costly. Other major references are under "Bisbee" and "Clifton-Morenci".

Small Blast Furnaces—Brick Lined or Water Cooled

Primitive "adobe" type blast furnaces gradually evolved into blast furnaces with steel shells lined with firebrick (see "Clifton-Morenci") and then into water-jacketed furnaces (see "Bisbee" and "Clifton-Morenci").

By the early 1880's the small, water-jacketed furnaces were the solution to the needs of those in the copper industry. The 36-inch diameter iron shell was encased by a hollow metal jacket, inside which flowed cooled water. These replaced the costly and immovable fire brick lined furnaces. The furnace stood on four short pillars, was only nine feet or less high, could be unbolted, loaded on a wagon, and moved from site to site.

The Arizona ores first developed were oxidized or partially oxidized and frequently occurred in limestone. These ores were broken into pebbles and shoveled into the furnace—about 30 tons of copper ore per day along with limestone flux and charcoal and/or coke. The air blast rose through this column of materials. As these materials melted, two products formed: the copper (the heavier) was withdrawn from the furnace through two tap holes close to the bottom, the molten slag (the lighter) was withdrawn through two spouts a few inches higher than the tap holes. These holes were opened by piercing a hole through the clay stopping in the hole, this was done by means of a pointed steel bar. Flow of material was arrested by thrusting into the opening a plug of clay which had been stuck on the end of a button-headed stopper rod or "dolly". The black copper (about 6 tons of 96% pure copper per day) was received in a bullion mold.

The slag was received into a forehearth, mounted on wheels, through which the escaping furnace slag flowed. This slag carried with it drops of copper that did not settle out in the furnace. The molten slag filled the forehearth and crusted over but maintained a cavity, where drops of copper settled out. Slag overflowed at the spout at the opposite end of the forehearth into a slag pot.

Often the furnace slags produced in the early days from the oxidized ores were far from having the proper composition and they assayed high in copper on that account. But this copper was not lost, it had simply been placed in storage. With the advent of the railroads and the discovery of sulphide copper ores to mix with the oxide ores, these slag dumps were resmelted with most satisfactory results. Dr. James Douglas summed up the situation when he said, "We never produced a slag containing more than 2% copper but when we resmelted it, 3% was recovered". At the plant of the Arizona Copper Company at Clifton the slag was granulated and dumped into the San Francisco River which flowed along side the smelting plant. The copper contained in this slag was lost forever.

This small blast furnace method was replaced by the more efficient and cheaper methods of matte smelting either in larger blast furnaces or in reverberatory furnaces.

Blast Furnaces: Matte Smelting

Sulphide ores were first smelted in blast furnaces under oxidizing conditions to produce a matte consisting of sulphide which has been prepared by fusion. Copper matte consists of a mixture of cuprous sulphide (Cu_2S) and ferrous sulphide (FeS). As the matte forms, it takes up the gold and silver of the ore.

The larger blast furnaces were an excellent adaptation for coarse ores but they were not good for the treatment of fine materials and concentrates. The blast furnaces were gradually superseded by the larger reverberatory furnaces.

Reverberatory Furnaces: Matte Smelting

Up until the period 1879—1890 all reverberatory furnaces were similar to those used in Wales.

At Butte, Montana there were four periods of development of the reverberatory furnace. The first period started in 1879 with the construction of the first reverberatory furnace in Montana and is considered to have ended about 1890. The furnace hearth was 14 feet long by 9 feet wide and it used wood for fuel in a firebox. Ten tons of ore were processed in 24 hours. A matte of 60% copper was produced and was shipped abroad. The second period extended from about 1890 to 1904 when methods of operation improved and furnaces were considerably enlarged. The hearths were 25 feet wide by 50 feet long (85 to 100 tons per hour). The third period commenced with 1904 and ended about 1914. This period witnessed the development of the long reverberatory furnaces of today (up to 120 feet long) and there was further progress in the direction of continuous operations. Heating was, however, still done by coal which was burned in the fire box. Oil had been adopted as the fuel elsewhere but it was not available in Montana. The fourth period started about 1914 when firebox heating was replaced by coal dust and later by natural gas through burners. Oil, coal dust, and natural gas were superior to regular mined coal.

As early as 1906 the reverberatory furnaces at Morenci were used to smelt the flue dusts that were being collected, in increasing quantities, as the proportion of fine concentrates in the blast furnace feed became larger each year.

In 1911 Arizona Copper Company decided to abandon the smelter then in operation at Clifton and build a new plant based exclusively on the reverberatory furnace system. This smelter was completed in January 1914 and it was the first copper smelter in Arizona to be built without any consideration of blast furnaces.

About 1924 the copper smelting companies were confronted with the patent of George Cameron Carson, who claimed that he was the originator of the side-wall feeding reverberatory furnace used in smelting. Carson prevailed and in 1930, the various smelting companies agreed on a basis of compromise that avoided tedious litigation to determine the amount of damages.

Three Phase Smelting Operation

By 1933 more than 90% of the copper produced from porphyry coppers had come from a three phase smelting operation. (1) Roasting, (2) Reverberatory smelting, (3) Converting.

Roasting: The purpose of roasting is to burn off sulphur by heating pulverized ore (or direct smelting ore) in an ample flow of air. The quantity of sulphur present is reduced and the amount of matte that can be formed is less. No fusion or sintering takes place.

About 1903 roasting was done in long, coal fired brick furnaces with a single hearth on which ore or concentrates, charged in a layer three inches thick was stirred at 30 minute intervals by hand rabbles and gradually pushed to the discharge end. The modern type of roaster consists of a series of superimposed circular hearths on to the uppermost of which ore or concentrates is fed. Revolving mechanical rabbles on each hearth stir the charge continuously. Movement is from the periphery to the center on alternate hearths and in the opposite direction on the others. The product is called calcine.

Reverberatory Smelting: The calcines, concentrates, or ores were fed directly to a reverberatory furnace. The solid calcine, concentrates, or ores becomes a molten mass through which the waste material rises; this is discarded as slag. The matte settles to the furnace bottom and is removed for further treatment in the converter. The matte will contain 25% to 55% copper.

The effluent hot gases from the reverberatory furnace are used to generate steam in waste heat boilers. This steam is used to operate the low pressure blowers for air to blow the converters or to operate steam turbines to generate electricity.

Prior to 1938 the Clarkdale smelter, United Verde Branch, Phelps Dodge Corporation, developed a method to renew the interior, silica refractory surfaces of operating reverberatory furnaces by the pneumatic spraying of an aqueous suspension of finely divided particles of a refractory material. The total mixture bonds by fusion and has been successfully used to patch the arches, sidewalls and uptake walls and roofs. Furnace campaigns of one and one-half years and more were attainable.

Converting: The Welsh process for reducing copper matte to metallic copper was displaced by the rapid and inexpensive converting process which was being developed by about 1884.

Matte from the blast furnace or reverberatory furnace was transferred to a copper converter. The converting process consists of transferring molten matte to the converter; then siliceous ore is added as flux and air is blown through the molten bath. The air burns some sulphur from the copper (leaves as sulphur dioxide) and causes the silica in the flux to combine with the iron (oxidized to FeO) to form a slag. The slag is poured off to leave a bath of enriched matte (copper sulphide—"White Metal"). The remaining sulphur is burned off to leave practically pure copper metal. This "blister copper," poured from the converter, cannot be used without further treatment. Blister copper contains 99% copper but still contains small quantities of impurities as well as considerable quantities of precious metals. Anodes are cast from partially refined blister copper; these anodes are electrolytically refined to remove or to recover these materials. This processing step came into use about the early 1890's.

To carry out these matte-converting steps an adaptation of Sir Henry Bessemer's process to blow steel was tried. The first attempts were unsuccessful because the holes through which air was blown into the molten mass were in the bottom of the converter and these holes became clogged with chilled copper as soon as matte reduction started. The first successful application came in 1880 when Pierre Manhes of France placed the tuyeres above the floor of the converter so that a space was provided for the liquid copper to collect. To clear away obstructions which formed in front of the tuyeres (holes for air introduction) holes were drilled in the outside wall of the air chamber, directly opposite the holes in the shell, and lining so that these holes could be punched with a steel rod while the converter was in operation; the outer holes were kept closed, usually with wooden plugs. In 1884, at the Parrot

works in Butte, the first successful converter was installed in the United States.

These early converters were lined by hand with a wet mixture of crushed silica (85%) and fireclay (15%). Thus, the lining served both as a refractory to protect the converter shell and as a flux for the oxidized iron. These small vertical converters were charged with about two tons of matte and by the time the lining was nearly worn out they could accept four to five tons.

It was found that by supplying silica to the charge directly upon the surface of the molten bath, the converting operation could be carried forward with a basic lining and by 1911 the acid lining had been given up in favor of the basic lining.

Dr. James Douglas applied modern methods and devices as soon as they had been proved. He was the first to introduce electric power on a large scale in the mining districts of the southwest and he was the first in the United States to employ the acid lined trough or barrel type of converter (at Bisbee) by 1902.

Another important invention made about 1911 was the Dibblie ball-valve arrangement for punching tuyeres. When the punch bar is thrust into the hole in back of the ball valve, it lifts up the ball and allows the bar to be thrust through the tuyere, and as soon as the bar is withdrawn, the ball drops back into position and seals the hole to prevent the escape of air.

In the days of the blast furnace the converter slag was poured from the converter into small pots which were wheeled to a dump. The slag was reclaimed and treated in the blast furnace. When reverberatory furnaces came into general use, the fresh, molten converter slag was transferred back to the reverberatory furnace.

Individual Smelters—Cochise County

Benson

As of 1882 in Arizona and New Mexico there were a number of deposits of lead ores being developed. These ores were rich in lead but generally poor in silver. Steps were being taken in different places to smelt these ores, using the lead as a carrier for silver. The two principal lead smelters in Arizona during 1883-85 were the Benson smelter and the smelter owned by the Tombstone Mill and Mining Company, located at Millville near Charleston.

The Benson Mining and Smelting Company operated a smelter at Benson, Arizona. The smelter was initially blown in on September 28, 1882, and after a little more than two years of operations, it was shut down and shipped to Mexico.

Johnson Mining District (East of Benson)

At the Peabody mine in 1881 copper bearing ore was being piled on the mine dump awaiting the erection of a 30-ton smelter that had been manufactured by the Pacific Iron Works of San Francisco. This smelter of the Russell Silver and Gold Mining Company was erected at Russellville and began operations in May 1882. During the summer, in spite of the limited water supply, the Russell smelter turned out four tons of copper bullion every day.

In February 1883 the Cochise Copper Company moved the smelter to a point only 150 feet from the entrance to the Peabody mine. About one-half mile from the smelter a new town was located, called Johnson. On moving the existing 30-ton furnace, another of the same capacity was ordered, but the furnaces were sold and moved away after the mine closed in 1884.

The Arizona United Mining Company decided to build its own smelter at Johnson. This smelter was a 125-ton furnace which was blown in October 10, 1909. The smelter lasted a few months and was abandoned after mining was suspended in May 1910.

Bisbee

Just west of Castle Rock near a spring (along the present main street) three men constructed a primitive furnace about April, 1878. This furnace was a mass of adobe masonry about six feet tall. A couple of American round bellows were affixed at the ends of the air ducts, and at the other end a crucible was dug into the earth. Oxidized lead ores were to be smelted. Charcoal and ore in sufficient quantity to maintain a compact mass were placed into the furnace. As the ore melted, its metallic content, as well as the slag, trickled out. Charcoal was made from oak, mesquite, or pine. Such furnaces could only be used where ore was self-fluxing with sufficient iron and limestone to make an easily smelted slag.

By this laborious method 600 pounds of lead-silver matte, in 60 to 80-pound cakes, was smelted every four to six hours. The furnace could not produce enough matte to pay the transportation costs.

On April 9, 1880, interests were purchased in the Copper King and Copper Queen claims. John Williams, a Welshman from Swansea, and his two sons (Louis and Ben), contributed the knowledge needed to smelt the exceedingly rich copper ores from these claims. In 1852 in Drontheim, Norway, the elder Williams had introduced to the world the first water-jacketed furnace. Although not entirely an original idea, this furnace revolutionized the reduction of oxidized and siliceous ores. The addition of a water jacket made the furnace virtually indestructible and eliminated the use of firebrick in furnace construction. By 1880 the furnace was being mass produced in various sizes by the Pacific Iron Works of San Francisco under the trade name of Rankin and Brayton. The Rankin and Brayton furnace spelled success for the Copper Queen. The 36-inch diameter, water-jacket furnace cost $11,000; it had a capacity of 30 tons, depending on the fusibility of the charge, strength of the air blast, and the water supply.

Five car loads of English coke were brought from San Francisco to be mixed with the locally produced charcoal; the railroad was 60 miles away at Benson. The smelter was finished by mid-August 1880. It was connected to the Malvina spring near Castle Rock and brought to operating temperature. An insufficient flow of water from the spring caused the first furnace run on August 20, 1880, to fail. A month later, with a single fusion, the smelter was producing a pig of black copper, weighing about 180 pounds, every 15 minutes. This ran 94–96% copper.

For months the smelter devoured thousands of tons of ore that ran 23% copper. The vast volume of ore and the

ease with which it was mined soon taxed the single water-jacket furnace. Another Rankin and Brayton furnace was added late in 1880. Production soared to nearly 20,000 pounds of copper per day, if fuel and water remained constant. Plans were being made to pipe water from the San Pedro River; these were changed when water was struck on the 300-foot level of the mine.

Molten slag, containing the waste rock from the furnace, was formed into building blocks and spread out in the sun to cool and cure. These were sold to build houses and business structures.

Because the Copper Queen monopolized the only source of water with enough volume to cool a refinery, the Neptune Mining Company smelter was established 15 miles away on the San Pedro River in 1880. The town of Hereford was laid out. This 30-ton, water-jacket furnace was designed by August Rahl. The Neptune's lens of copper carbonate soon pinched out; operations ceased.

Phelps, Dodge and Company purchased the Copper Queen Mining Company and the merged properties would operate as Copper Queen Consolidated Mining Company; incorporation took place on August 6, 1885.

By 1885 the smelter was forced to look to Colorado Fuel and Iron Company near Trinidad to obtain adequate fuel (coal and coke).

Dr. Douglas proposed the revamping of the Copper Queen smelter. A larger, more economical smelter was erected on a bench of land one-fourth mile east of the original Copper Queen smelter. In May 1887 four 36-inch diameter, water-jacketed furnaces were blown in. This was a coke-burning smelter that was able to produce more copper of a greater purity due to the higher heat generated by the coke. One million pounds of copper per month at 12½ to 14½ cents per pound went to Paris brokers for a period of three years (these French speculators were trying to corner all the international copper market). Debts were quickly liquidated. By the year end of June 30, 1893, copper bullion shipments ranged around 5,000 to 6,000 tons annually. For every ton of copper shipped out about two tons of coke and one to two tons of bituminous coal had to be hauled in. With steady output of copper bullion and the receiving of coke the need for a railroad to connect Bisbee with the outside world was increasing.

About this same time (1894) a sizeable enlargement of the second smelter was carried out (called the third smelter).

In the early years the rich oxide and carbonate ores (20-25% copper) were mainstays of production. As the shafts were extended downward, the oxide ores graded into sulfide ores, which detracted from the quality of the copper produced at the smelter. In 1893 large bodies of sulphide ores discovered on the lower levels became the chief source of production. As early as 1886, a matte began to float on the surface of the copper ingots and this jeopardized the selling price.

When large bodies of compact chalcocite ores were developed, the Copper Queen was forced to entirely revamp its smelting operations; direct smelting was abandoned, matte was then made and reduced in converters.

The smelting plant finally adopted consisted of four oval shaped, water-jacketed blast furnaces: 42 inches by 120 inches. Two two-ton tilting wells, arranged in tandem for each furnace, conveyed molten matte to the converters. The average daily capacity of each furnace was about 160 tons; each converter could reduce 30 to 40 tons of 45% copper matte to metallic copper (the end product averaged slightly over 99% pure). Regardless of this extensive revamping, this third smelter was obsolete in four years because it could not process the large volume of copper ores and could not meet the insatiable appetite of the country for copper—it was the dawn of the electrical age. In 1901, a fifth furnace along with another stand of converters had been added. However, it was time to move and to abandon this smelter.

For about a decade (1891-1901) Copper Queen Consolidated Mining Company (Phelps Dodge) was the only viable mining and smelting enterprise in Bisbee. By 1902 the Calumet and Arizona Mining Company had established itself as one of Bisbee's great copper producers.

Douglas

When it became necessary to relocate the Copper Queen smelter, various localities were studied. A few months before May 1900 Dr. Douglas found a location for his enlarged smelter and for a related townsite about twenty-five miles east of Bisbee. There was an abundant supply of water; the land was available for a fair price. In the fall of 1901 plans for the Copper Queen smelting plant were announced.

In 1901 an entirely new smelting plant was begun on the 300-acre site by Copper Queen. In December 1901 Calumet and Arizona decided to build a smelter adjacent to the one of Copper Queen. The Copper Queen people had a less immediate need for their new smelter than the Calumet and Arizona people. Calumet and Arizona produced their first copper bars on November 15, 1902. The Copper Queen smelter started up on March 9, 1904. After 25 years of operation, the smelter at Bisbee closed on July 24, 1904.

The five smelting furnaces at the Copper Queen had a capacity of 10,000,000 pounds of copper per month. There were also four barrel-type, acid-lined converters. The smelter's cost was $2,500,000. The blow-in of the smelter was a milestone in the Copper Queen history. From a single water-jacket furnace no higher than a man, the Copper Queen smelting plant had grown into the most modern structure of its kind in the world.

Increased smelter production consumed large quantities of coke. In order to assure a reliable supply of this fuel, Phelps, Dodge and Company, in 1905, purchased the coal mines in Dawson, New Mexico (these operated as Stag Cañon Fuel Company). The coke ovens operated until 1926, when Arizona smelters discontinued the use of coke as their principal fuel; oil became the principal fuel.

Needs of World War I and the unprecedented domestic demand for copper caused Phelps Dodge to drive its blast furnaces at Douglas at the utmost speed, and also smelted 600-700 tons of ore per day in the modern reverberatory furnaces that had been recently added. In January 1918 Phelps Dodge smelted 20,630,272 pounds of fine copper.

In 1927 Phelps Dodge Corporation built a flotation plant of 150 tons daily capacity to treat lower grade lead ore; at Douglas they installed a lead smelter of 200 tons daily capacity. This lead smelter closed in April 1930.

Probably one of the most novel banquets ever held in the mining and smelting industry took place February 26, 1927 in the base of the new smelter stack of Phelps Dodge Corporation at Douglas. The new stack was 350 feet high. Those who attended the banquet sat around a circular table in the base of the stack.

Here it is necessary to return to events relating to the Calumet and Arizona Mining Company.

In 1913 the old smelter of C & A was replaced by a new one at a cost of $2,000,000. On July 2, 1913 the first unit was blown in; when capacity was reached, 3,000 tons of ore could be treated each day.

Slag from copper ore smelting produces one of the best forms of ballast for stable railroad beds. By 1905 the C & A slag dump was large enough to be used for this purpose.

During the depression copper prices steadily declined from ten cents a pound at the end of 1930 to an all time low of less than five cents in March 1933. Phelps Dodge and Calumet and Arizona announced a merger which was approved by the stockholders in September 1931. Upon the merger in 1931 Phelps Dodge shut down the Copper Queen smelter and dismantled it. They moved all smelting operations to the Calumet and Arizona smelter (this became the Douglas Reduction Works of Phelps Dodge Corporation). By January 1937 the price of copper was near thirteen cents a pound—the end of the depression for the copper mining industry.

In 1938 there were four reverberatory furnaces with inside dimensions of 26 feet wide by 107 feet long; there were four Peirce-Smith converters. The furnaces average 1,000 tons of solid charge per day.

Gila County

Globe—Miami

In the spring of 1876 a small furnace was nearing completion in Globe City along Pinal Creek. At Wheatfield, further down Pinal Creek, there was another furnace. In Globe City the Carrie and True Blue Claims had been purchased by four partners, who ordered a 30-ton furnace from San Francisco; smelting began on September 27, 1881. This was the first water-jacketed furnace in the district. Smelting was halted four weeks later.

The Old Dominion mine (3½ miles north of Globe City) was sold to the Old Dominion Copper Mining Company on December 11, 1880. They also purchased the New York and Chicago mines southwest of present day Miami. Two 30-ton furnaces were erected in nearby Smelter Wash. By March 1882 small amounts of copper were being turned out. A small settlement near the mine was called Bloody Tanks. This plant treated siliceous ores from the Carrie claim. In order to obtain the necessary flux, arrangements were made to pay $1.00 per ton for ironstone from the Old Globe claim outcrop; this material happened to contain more copper than the Carrie ore. Thus the value of the Old Globe claim was discovered.

Closer to Globe City the Buffalo Mining and Smelting Company began operating a small furnace in December 1881 to treat ore from the Buffalo and Hoosier mines. The Hoosier mine became part of the Long Island Copper Company which fired its smelter in October 1882. Near Globe City the Old Globe Copper Company took delivery of a 30-ton furnace in the spring of 1882. The Old Dominion management recognized that their mines were almost worthless so they purchased the rich properties of the Old Globe Copper Company in September 1882. The two Old Dominion furnaces were moved from the Bloody Tanks area to join the existing Old Globe smelter. All three furnaces were operated by John L. Williams, brother of Ben and Lewis Williams of Bisbee. These furnaces were located below the Globe Ledge claim. This smelter site is now beneath the white sands (mill tailings) that can be seen along the road between Globe and Miami.

Another enterprise, the Takoma Copper Company, leased the smelter at the Carrie claim and began smelting in February 1883.

The high cost of wagon haulage of coke from the Southern Pacific railroad at Willcox (140 miles) was a heavy burden. As copper prices dropped, the Buffalo, Long Island, and Takoma operations shut down. By the summer of 1883 Old Dominion was the only working copper property around Globe. The Old Dominion suspended operations for five months in 1885. It went bankrupt and smelting ceased. The Old Dominion Copper Company of Baltimore City was incorporated on January 28, 1888. By the end of 1891, ten years of Old Dominion copper production totaled 50,000,000 pounds. The mine had proven profitable; the huge debt was paid off. A new smelter with three new furnaces was blown in in January 1892. These blast furnaces had a capacity of 185 tons to the charge. The existing ore yielded 11-12% copper per ton. During May, 1895, the Lewisohn interests of New York purchased the Old Dominion Copper Company of Baltimore City. As of July 9, 1895 they formed the Old Dominion Copper Mining and Smelting Company. Two weeks before Christmas of 1895 the renovated Old Dominion smelter was blown in. Because of some construction work the United Globe (Buffalo) smelter was not blown in until January 1896.

To take advantage of the future lower shipping costs the Old Dominion had been accumulating a vast quantity of copper at the smelter while awaiting the railroad. In January 1899 they began to load the railroad cars (25 tons per car); in all there were 20 cars of copper (1,120,000 pounds). This was said to be the largest single shipment in Arizona; it probably was until the 660 ton shipment from Clifton in September 1902. Water in the Old Dominion mine became a serious problem in 1902 and 1903. Old Dominion Copper Mining and Smelting Company and United Globe (Buffalo) merged to become the Old Dominion Company.

The new Old Dominion smelter was located on the hill east of and above the existing smelter. The old smelter went down in August 1904; this had been preceded by an explosion of the No. 2 furnace in the evening of July 27. No one was hurt but three men were tossed into the air. The new smelter was ready on September 26, 1904; it turned out 2,000,000 pounds of copper in November 1904. Before the new smelter was built only copper matte was produced; it was sent to El Paso for treatment. In 1907 the Old Dominion was running four furnaces. The No. 5 furnace was blown in on July 10. The No. 5 furnace made it possible to produce 3,000,000 pounds of copper per month. No. 6 furnace was being built. In the six years

ending with 1908 Old Dominion spent $2,491,000 (this included the new smelter).

The rising mine output encouraged the Arizona Commercial Copper Company to build its own smelter. The 500-ton smelter (near the Eureka shaft) with its 125-foot stack was blown in on October 15, 1909. The smelter shut down in April 1910. The ore yielded only 4% copper. The water jackets of the $260,000 furnace proved defective. Though the manufacturer assumed full responsibility and rewelded the water jackets at no cost the smelter never operated again.

At the Old Dominion copper content fell each year (4.16% copper in 1925, 2.27% in 1930). There was a heavy flow of water into the mine. The mine was closed in December 1931. The Old Dominion Company smelter was shutdown forever on November 20, 1924.

Over in Miami the Miami Copper Company was formed November 30, 1907. Inspiration Consolidated Copper Company was organized on December 18, 1911 to combine the properties of Inspiration Copper Company and the Live Oak Development Company. The Black Warrior mine was purchased in 1912; the New Keystone Copper Company in 1914.

Miami Copper Company concentrated its first ores in 1911. The ore was 2.5% copper. During the first two years the concentrates were sent to Cananea Consolidated Copper Company in Mexico. The Mexican revolution required a change. The concentrates were shipped to the International Smelting and Refining Company smelter at Toole, Utah, starting on April 22, 1913. Inspiration Consolidated Copper Company began concentrate production in 1915.

The rising output from these two mines warranted a large smelter that was closer to Miami than Cananea or Toole. Late in October 1913 International Smelting and Refining Company purchased 32 acres from Miami Copper Company for the smelter site. Ground was broken in December 1913. As work on the smelter was in progress (April 1914), the Anaconda Copper Mining Company purchased the assets of the International Smelting and Refining Company. The name was changed to International Smelting Company; it reverted to its original name in 1934. In July 1915 the smelter was placed into operation. The cost of the smelter was $3,000,000. Blister copper was refined either at the Raritan Copper Works in New Jersey or the Phelps Dodge Refinery in El Paso. Inspiration's share of blister copper was refined either at its own plant in Inspiration or the Raritan Copper Works. The annual capacity was over 200,000,000 pounds of blister copper.

Dr. Louis D. Ricketts was chiefly responsible for the design and construction of the smelters at Arizona Copper (Clifton-Morenci); Calumet and Arizona (Douglas); and International (Miami). He set about to build a smelter that would attain 97% of the copper in the concentrates from Miami and Inspiration in the form of wire bars. Two potential sources of the loss of copper and the means adopted to eliminate them were: (1) Mechanical handling losses of very fine concentrates—both before and after they were dried in the Wedge roasters. There was lots of wind to easily scatter the rich concentrates over the desert landscape. To overcome this specially designed closed cars were provided; spreading beds, belt conveyors, and other units of the plant were carefully housed; (2) Dust losses in flues and stacks leading from the roasters (used only for drying) and the converters. Two Cottrell electrostatic treaters were installed; one to treat the converter gases and one to treat the gases from the roaster (dryers). This was the first Cottrell plant to be erected in Arizona to recover dust from a copper roasting operation. After the plant had been in operation about six months, the executives observed that actual shipments of blister copper fell a long way below 97% of smelter intake even after allowing for the measurable tonnage known to be "in process" at the plant. Ricketts reassured them by explaining the many ways in which a new metallurgical plant absorbs metal. Ore, calcines, matte, and blister copper find dozens of voids and crevices to fill up; furnace linings absorb copper; metal hides in places from which it would not pay to recover it while the plant is running, even if it were possible to do so. But these accumulations, after the first few months, cease to grow. At the end of 30 months the smelter had produced over 200,000 tons of copper. This yield was 2,600 pounds short of 97% recovery; as time went on, 97% recovery was slightly exceeded.

The International Smelter was the second smelter in Arizona to be built without any consideration of blast furnaces. In 1927, following the successful use of a wet feed charge to a reverberatory furnace by A. D. Wilkinson at Cananea, a trial at Miami was decided upon. The practice has been carried on and developed. The reverberatory furnace plant consisted of four furnaces (three were 21 feet wide, one was 25 feet wide, all were 120 feet long). A drag chain conveyor system was the best way to feed wet charge to the reverberatory furnace. A thin stream of concentrate was dropped through several holes in the furnace arch at once; this "trickle feed" flooded the furnace bath and made it possible to increase the size of the charge placed into the furnace at one time. Molten converter slag was returned to the furnace through a launder. The action of the converter slag was very marked in the furnace at times; the reaction was sufficient to cause a violent boiling in the bath. This boiling action materially assists in the mixing of the surface charge with the molten bath and undoubtedly assists the smelting rate.

Christmas

To hold the claims in the area, the San Carlos Mining Company was incorporated on April 17, 1884. A small smelter was built but some months after operations began the Federal Government ordered everyone off the area because it was within the San Carlos Indian Reservation. There also was a small smelter across the Gila River in the Saddle Mountain Mining District; it was too small to be operated profitably. On December 22, 1902 the Christmas area was withdrawn from the Reservation. Claims were again located and transferred to Saddle Mountain Mining Co. The old smelter at Christmas was given a five day test in January 1905. After obtaining favorable results, the old 30-ton furnace was dismantled; it was replaced with one five times larger. The new furnace was blown in in August 1905. Coal lands were acquired in the Deer Creek area to provide fuel for the smelter. A beehive coke oven was built for test purposes in the spring of 1907. By July

1907 the smelter was shut down because high freight rates made it financially impossible to ship the copper matte to the Humboldt smelter near Prescott.

Ray—Hayden

Ray is in Pinal County; the present related mill and smelter are in Gila County. In June 1899 the Ray Copper Mines Ltd. was organized, largely with British capital. They established a town called Kelvin on the Gila River, where a 250-ton concentrator was erected. The ore turned out to be slightly more than 2% instead of the anticipated 5% copper. In 1909 a concentrator site was selected near Winkleman, fifteen miles up river from Kelvin. A new town (Hayden) was established at this concentrator location and a smelter was also to be built here. Ray Consolidated Copper Company held off on the smelter, and concentrates were to be shipped to American Smelting and Refining Company at their El Paso smelter. This added more than one-cent per pound to the cost of the copper. Before the end of 1909 negotiations were closed whereby American Smelting and Refining Company (A. S. & R. Co.) took over the smelting project and received a long term contract to smelt the concentrates. This arrangement was a cost plus plan: the metallurgical and cost records of the smelter were open to the Ray Consolidated Copper Company officials. Profits were to be based on a fixed margin over and above costs. This was arranged to leave a financial incentive for A. S. & R. Co. to obtain the best possible metallurgical results consistent with low operating costs. The smelter was completed in 1910 at a cost of $3,000,000; concentrate shipments started in 1911. The blister copper was shipped to the A. S. & R. Co. refinery at Perth Amboy, New Jersey.

Graham County

Aravaipa District

This mining district is in the western part of Graham County and south of Stanley Butte. A small smelter was reported to have been built here in the 1870's by Col. C. W. Birdwell.

Greenlee County

Clifton—Morenci

A group including Henry Leszinsky organized the Francisco Mining Company on August 28, 1872. Their claims included the Longfellow and the Metcalf.

Since the railroad was 1,200 miles distant, it would be too costly to ship the rich ores to a port for shipping to Swansea, Wales. Smelting success could only be possible if smelting could be done on the spot. Eugene Goulding, a partner, had some smelting experience at Silver City, New Mexico, and developed a smelting method to be built locally.

In Chase Creek, below the Longfellow mine and before reaching Clifton, a small Mexican style furnace was built; due to its materials of construction it was known as the Stone House. Quartzite was used for rock, kaolin for fireclay, and charcoal for fuel. Bellows created from cowhides provided the air blast. The Stone House smelted the 20% copper carbonate ores at the rate of one ton per day. Due to their construction these furnaces never lasted longer than 36 hours but they were not difficult to rebuild. The smelting process proved costly because of the constant labor for rebuilding.

As the fall of 1873 opened, the picture brightened. By carefully selecting the sandstone from the Mimbres district in New Mexico and using it in the furnace construction, the life of the furnace was lengthened to 10 to 14 days. Early in October Leszinsky secured an experienced smelter man from Mexico. By the end of October 1873 the single Mexican style furnace was turning out 1,000 pounds of copper every 24 hours and another furnace was under construction. Operations were still inefficient; nearly one-third of the values ended up on the slag dump; consumption of charcoal was excessive—not more than three pounds of ore were being smelted per pound of charcoal.

In 1874 the smelter was moved two miles down Chase Creek, almost to its intersection with the San Francisco River. The hand bellows were to be replaced by mechanical blowers which were to be powered with a water wheel; water was to be diverted from the San Francisco River. With these blowers and four furnaces the output of copper was to be doubled to 2,000 pounds per day. By April 1874 eight furnaces had been completed to insure that four furnaces were in operation while four were undergoing repairs.

In June 1874 construction began on a large ten-ton reverberatory type furnace that was expected to end the problems for all time. An experienced metallurgist came from a Baltimore smelter. He promised to build them a smelter the "likes of which they had never seen before". In the next few months 10,000 fire clay bricks for the shell of the new furnace were laboriously baked in the existing copper furnaces. Finally, the last brick was in place. Then it was a pathetic story, the furnace lasted 24 hours; it had melted to a burnt heap of brick. It had taken eight months and $20,000 to build this furnace but despair probably goaded Leszinsky into continuing. He imported brick from Germany at a cost of $1.00 each for the furnaces. Even with the high grade copper ores the process did not work well enough to justify the expense.

The mining companies continued to build Mexican type furnaces and soon managed to pay expenses. These furnaces were turning out, by the summer of 1875, 6,000 pounds of copper per day. From 1874 to 1913 a series of smelters were located at this same site; each one was larger and more efficient.

The short life of the copper furnaces had always been a problem. After many experiments the solution was born in a moment of irritation in 1876, when Leszinsky ordered a copper plate to be placed as a temporary backing of a furnace wall. The repair took on an appearance of permanency as the cooling effect of the air on the outside of the plate prevented the heat of the molten copper and slag on the inside of the furnace from melting the copper plate. Because of its long life this furnace wall was called "The Century". The copper plate did a good job but additional cooling once in a while was required—the plate was sprayed with water. This resulted in gradual destruction of the plate and caused the furnace to shutdown. This weakness was overcome by casting water cooled jackets which could be bolted together and used in place of the copper plates.

Another improvement, worked out at the same time, was removing slag from the molten copper. By pouring the copper and the slag from the furnace into a clay-lined, pre-heated metal pot, the slag rose to the surface and was then poured off. Excellent results were gained as the remaining copper could be poured into molds of thin copper, this was 95% copper. These were the first bars of copper cast in Arizona from the smelting of copper ores.

By 1878 the Longfellow mine smelting furnaces were turning out 8,000 pounds of copper per day.

At first Leszinsky had used locally burned charcoal for smelting the copper ores. The trees from along the Chase Creek hillsides were swept clean for smelter fuel. In the Burro Mountains (80 miles away) a charcoal camp was formed and a second source of fuel was the mesquite groves along the Gila River. Charcoal never was really satisfactory for the blast furnaces. It slowed up the process of smelting and reduced the metallic iron from the ores which combined with the copper to make impure bullion. Charcoal did have the advantage of making cleaner slags, as was found later when coke replaced charcoal.

When the Southern Pacific Railroad reached Lordsburg, New Mexico, on October 18, 1880, the source and type of fuel for the smelting furnaces was radically changed. Coke now came by railroad to Lordsburg; a San Francisco importing firm had arranged to import the coke. This new fuel worked wonders; higher smelting output was the result. The furnaces began to turn out 15,000 pounds of black copper daily.

In April 1877, Gleason and Sweeney acquired claims in the area. Several weeks later, July 1877, their smelter was fired up, and in September 1878 the operations were abandoned.

In 1882 the Leszinsky brothers sold the Longfellow related operations to the Arizona Copper Company, Ltd. (a Scottish Corporation).

In September 1883 the Arizona Copper Company selected the site for their new smelter at the mouth of Chase Creek. Instead of the Longfellow smelter location close to the creek, two benches were hacked out of the hillside for the railroad tracks and smelter. The magnificient new plant was approaching completion in June 1884 with three Fraser and Chalmers, 60-ton furnaces and two 40-ton furnaces made by Pacific Iron Works. Three water-powered turbines were an important part of the smelter. One turbine powered five Baker blowers for the furnaces; another was for the ore crushers; and the third operated the pumps. Smelting began on July 1, 1884. With a rating of 250 tons per day this plant marked the beginning of a new era in the history of Clifton.

James Colquhoun came from Edinburgh, Scotland (head office of Arizona Copper Company, Ltd.) in 1883 as an assayer and mining engineer; he became Smelter Superintendent.

In 1892 copper was selling for ten cents a pound. William Church (Detroit Copper Company) was forced to shut down. The Arizona Copper Company was about to follow suit when James Colquhoun was made Manager and he was authorized to build a leaching plant. The plan was to leach with sulphuric acid (made on the spot) the tailings produced from a porphyritic ore containing oxide, carbonates, and silicate of copper. $100,000 was appropriated ($52,000 of this was the estimated cost of the acid plant). To whatever extent the leaching operations proved profitable the net result would be on the right side of the ledger. The output of copper was increased 40% and the cost was reduced by two cents per pound. This crude leaching plant was the salvation of the Arizona Copper Company.

The Copper King Mining Company blew in their smelter on January 12, 1891, and operations ceased in 1892.

At the beginning of 1901 a complete remodeling of the Arizona Copper Company smelter at Clifton was started to carry smoke and dust away from the town. A tunnel was to be driven into the cliff behind the smelter (this would act as a dust chamber); from the tunnel a vertical shaft would rise to an exhaust stack on top of the cliff. Each blast furnace was 20 feet long (then the largest furnace engaged in copper smelting); the capacity was 500 tons per day. Within five years this smelter was out of date due to a change in the character of the ore.

The Morenci Copper Mines, Ltd. (100-ton concentrating and smelting plant) and the Clifton Arizona Copper Company, Ltd. merged with the Clifton Consolidated Copper Company of Arizona, Ltd. in 1901.

Slag from the Arizona Copper Company smelter was hauled up Chase Creek on a narrow gauge railroad and the little cars, shaped like pots, dumped the slag along the banks of Chase Creek (this can be seen today).

The Arizona Copper Company stockholders approved a bond issue in the fall of 1911 to finance a new modern reverberatory furnace smelter designed by Louis D. Ricketts. This smelter was to be located two miles below Clifton and would include converters, roasters, and a dust chamber. In August 1913, when this new smelter was phased in, operation of the 1901 Clifton smelter was gradually reduced and finally terminated on December 31, 1913. This new smelter was a milestone for it marked the end of a 40-year record of expansion and modernization for the Arizona Copper Company.

On October 9, 1919 the Shannon Copper Company sold its properties at Metcalf and Clifton to the Arizona Copper Company. Arizona Copper Company was unable to continue the operations in 1921, after the copper market prices collapsed, and sold all of its holdings to Phelps Dodge Corporation. Up to that time the Phelps Dodge interests in this area had only been in the Detroit Copper Mining Company, which operated mines in and around Morenci. The smelting plant operated by the Arizona Copper Company was more efficient and modern than that of the Detroit Copper Mining Company so the Detroit smelter was shutdown and dismantled. The new Morenci High School was built on the site of the Detroit Copper Mining Company smelter. Phelps Dodge operated the Arizona Copper Company smelter until 1932 and in the early 1940's this smelter, except for the stack, was torn down. The stack still stands today.

In January 1942 production started from the Morenci open pit mine. A concentrator and a smelter to handle the mine ores were constructed at the mouth of Morenci

Canyon about two miles from the mine. The smelter poured its first copper anodes in April 1942. Concentrates were direct-charged to the two reverberatory furnaces (110 feet long by 31 feet 3 inches wide, inside dimensions). The furnaces were designed for 650 tons of charge per day. Matte was transferred to the three Peirce-Smith converters which were 13 feet in diameter and 30 feet in length. Copper from the converters was transported to two tilting, holding furnaces, 13 feet diameter by 25 feet long, that were used to process the copper for casting. One 40-foot diameter casting wheel with 26 copper molds was used to cast 700 pound anodes. These anodes were shipped to the electrolytic refinery of Phelps Dodge Corporation in El Paso, Texas.

Detroit Copper Mining Company

William Church came to Joy's camp (now Morenci) in 1874. He organized the Detroit Copper Mining Company which by 1880 had developed enough ore to warrant a smelter on the San Francisco River bank at a point three miles south of Clifton and six miles from the mine. A small smelter was built, and equipped with two 36-inch diameter furnaces. The air blast for smelting came from a water driven blower. In two years it produced $700,000 worth of black copper.

Excessive transportation costs made it advisable to move the smelter to the mine at Morenci. The mining claim (Copper Mountain) was near the Longfellow properties. Morenci had little water and the cost to pipe the water six miles and over a 1,300-foot ridge was prohibitive for them so the management of Detroit Copper Company approached Phelps, Dodge and Company. A loan did not come forth but Phelps Dodge took an interest in the Arizona adventure. Dr. James Douglas was engaged to examine Church's Morenci holdings. After a favorable report the Phelps Dodge partners agreed to finance Church's proposed development up to $30,000 in return for a block of Detroit Copper Mining Company stock. In January 1884 grading began for the Detroit Copper Company smelter close to the mines on Copper Mountain. Subsequently, the two furnaces from near the San Francisco River were moved to Morenci; a third furnace was added so a spare would be available. This smelter was blown in in September 1884, but smelting results were disappointing.

The smelting of black copper in these small furnaces was more difficult than it seemed, they froze up on the slightest provocation; they regularly lost too much copper in the slags which went to the dump. Dr. Douglas suggested that the furnace charges might be improperly mixed. By using the proper furnace mixtures the copper ores were smelted with efficiency and quality for the first time.

In the spring of 1897 Church sold his stock to Phelps, Dodge and Company.

Disaster struck the Detroit Copper Mining Company on June 29, 1900. Molten slag was carelessly poured into a pot containing shavings and cotton waste; this touched off an explosion in the smelter. The surrounding structural supports caught fire. The Detroit smelter and its five stacks became a mass of ruins. It was over a month before the furnaces were operating again.

In 1917 Phelps, Dodge and Company revised its corporate structure. The name of the affiliated Copper Queen Consolidated Mining Company was changed to Phelps Dodge Corporation. The properties of Detroit Copper Mining Company of Arizona were transferred to the new Phelps Dodge Corporation. As of April 1, 1917 this became the Morenci Branch of Phelps Dodge Corporation.

In 1921 the Arizona Copper Company (including the Shannon Copper Company) was purchased by Phelps Dodge Corporation. Therefore, by 1922 all major properties in the Morenci area became the Morenci Branch of Phelps Dodge Corporation.

Shannon Copper Company

The Shannon mines were at the summit of Metcalf Mountain (800 feet above Metcalf) and Shannon Copper Company was incorporated November 13, 1899. Space for a concentrator and a smelter together with their related tailings dams and slag dumps did not exist in the narrow confines of Chase Creek Canyon and there was not enough water. There was space for a reduction works about ten miles south of the mine and south of Clifton along the banks of the San Francisco River.

In May 1901 Philip Wiseman, General Manager, went to Chicago to purchase two water-jacketed furnaces. Excavation for the smelter was underway in November 1901. On May 5, 1902 the new smelter started to operate. The smelter product was castings of black copper. Supplies of rich ore were depleted a few months later and the smelter was closed on September 27, 1902. The smelter resumed operations, after a concentrator was placed in operation, on March 10, 1903. After its ore reserves were depleted the Shannon Copper Company ceased operating its smelter in 1918, and in 1919 it sold to the Arizona Copper Company.

La Paz County

Swansea

Richard Ryland discovered the Planet Mine ten miles northeast of the future site of Swansea (thirty miles east of Parker in the Buckskin Mountains) in 1862. The ores assayed as high as 60% copper. San Francisco investors erected a $100,000 smelter at the Colorado River landing of Aubrey (in Mohave County), but prosperity was short lived. Fifteen years later the Mathilda Mining Company of San Francisco erected a new water-jacket furnace and tried to smelt the Planet ores. This also was unprofitable. In late 1907, the promoters of the area brought in George Mitchell, a metallurgist from Swansea, Wales (Swansea, Arizona, was founded in 1908). In 1908 he incorporated the Clara Consolidated Gold and Copper Mining Company. To reduce his ores he brought in his own furnace: the Mitchell Economic Hot Blast Furnace was the most advanced thing of its kind in the 1890's. This furnace was for a 350-ton plant. He had bigger ideas; by the winter of 1908 he decided to build a 700 ton capacity smelter complete with converters. On May 2, 1910, the furnace was blown in and the Mitchell smelter soon earned a reputation as a coke consumer, not a sulphide ore reducer. Copper was produced for over fifteen cents per pound while the market price was twelve cents.

French stockholders incorporated Swansea Consolidated Gold and Copper Mining Company and took over the Clara Consolidated Gold and Copper Mining Company. The capacity of the smelter was increased. Included in the construction was a $60,000 reverberatory furnace to bring the smelting capacity to 1,000 tons per day. A copper price rise in 1912-13 made the operations profitable. By March 1913 copper prices had dropped and the company entered into bankruptcy.

Silent

The Trigo Mountains are near the Colorado River. The Silver and Eureka Mining District is in the southern part of these mountains and is bounded on the east by the Yuma Wash and on the west and south by a bend in the Colorado River. The town of Silent (named after the Silent Claim) was established near the Red Cloud mine. These claims provided an argentiferous galena ore. A small smelter was built at Silent in 1880. It operated only intermittently for about three years. In 1883 the owners of the Black Rock mine erected a small furnace at the Colorado River. They turned out lead bullion at the rate of one ton per day by June 1883. The length of operation is not known.

Pima County

Ajo

A group of lumber and clothing merchants were looking for a new process to treat their copper ores. Professor Fred L. McGahan was an ingratiating little Irishman. When he started to talk about how he could save the copper, he lulled his victims into a trance of greedy ecstacy. A contract was signed with McGahan early in 1906 to build his "vacuum smelter". As it was being built, it was a marvelous piece of equipment. His marvelous discovery was that when air was pumped out of the furnace and ore was fed into the furnace with a little fuel oil and just enough oxygen to burn it, he could regulate the temperature so accurately that all of the elements in the ore would be melted one by one. First the gold would melt and sink to the bottom, where it could be drawn off through the lowest spigot. The next spigot was for silver, etc. At the top were spigots for oxygen and hydrogen gas. After the furnace was once started, the hydrogen could again be burned with the oxygen; thus, the furnace could get along with out any outside fuel.

A furnace was also being built for the Gold of Ophir Company in Los Angeles. The Ajo group lighted the first fire in the Los Angeles furnace. McGahan explained that a slow fire must be kept up for 24 hours in order to prevent cracking of the steel shell. McGahan did not return. At his hotel they found a letter from him saying that $34,000 and expenses they had paid so far were far too little for his great invention. If they would pay him $50,000 more and a lot of New Cornelia stock, he would return and blow in the smelter. The awful truth burst upon the Ajo group; their faith had been rewarded by the loss of their money and their friends' money.

Arivaca

Smelting was probably carried out in this area in the 1850's and 1860's.

Rosemont

The Rosemont Mining and Smelting Company smelter in 1885 was receiving ore via pack animals from Helvetia on the north side of the Santa Rita Mountain. This was a 60-ton smelter; it probably reached its peak from 1891 to 1895. The Tip Top smelter was located east of Rosemont during the same period.

Helvetia

Thirty miles south of Tucson in the foothills of the Santa Rita Mountains a group successfully worked the Old Frijole mine. The copper ore was smelted a few miles away by the Columbia Copper Mining Company. The Helvetia Copper Company was formed on March 3, 1899 to manage these properties. During 1900 the furnace was reported to be pouring 50 tons of copper on some days, but a fire wiped out the furnace on December 7, 1900. Copper prices were so good they did not hesitate to secure a replacement—blown in May 1, 1901. The smelter went down in May 1906; it was again revived in 1908, but it proved to be inadequate.

Mineral Hill–Twin Buttes Area

In 1880 Col. C. P. Sykes purchased the San Xavier mine and the San Xavier Mining and Smelting Company was organized. To treat the ores a small blast furnace was erected on the Santa Cruz River nine miles south of Tucson; this operation was not successful. Near the San Xavier mine were the Azurite properties, where a significant strike was made in November 1895. In 1898 a second-hand smelter (water-jacketed furnace of 30-ton daily capacity) was built by the Azurite Copper and Gold Co. at the Mineral Hill Mines; it produced copper for about one year.

During the latter part of 1911 the Twin Buttes Mining and Smelting Company organized the Pioneer Smelting Company which began construction of a 150-ton smelter at Camp Corwin (about 1½ miles west of Sahuarita) on the Twin Buttes Railroad that ran between Twin Buttes Camp and Sahuarita. The smelter operated well but failed to make money. It operated from May 1912 until the following spring.

In 1916 the Mineral Hill Consolidated Copper Company enlarged the old Azurite Copper and Gold Company smelter; it produced for three years and closed again.

Tucson

In 1875 Tully, Ochoa and Company were operating two smelting furnaces in their Tucson corral at Ochoa and Stone. They reduced ore from their own copper mine in the Santa Rita Mountains as well as that of other mines in the region. There are references to a two stack smelter in Tucson in the period 1891 to 1895 and to a smelter on Los Reales Road, east of the Santa Cruz River.

The Total Wreck mine in the northeast part of the Empire Mountains produced wulfenite concentrates in 1917 and 1918. Some of these concentrates were shipped to Molybdenum Products Company in Tucson. During the first part of 1917 this firm treated the wulfenite in a reverberatory furnace with soda ash to make a sodium-molybdate slag and metallic lead. Later a blast furnace was put up and the same products were made in it. For a time it was difficult to sell either the concentrates or the

sodium molybdate. Ferro-molybdenum was made in small electric furnaces manufactured at the plant.

Silverbell

Mining dates back to 1865 in this general district which is 40 miles northwest of Tucson. The oxide copper ores contained minor silver-lead values. Six miles southeast of old Silverbell the Young America claim in the Silver Mountain Mining District was productive enough to justify the installation of a small smelter in the summer of 1874. In June 1881 others did some mining and some smelting in this area, and in 1900 a larger smelter was erected. (Refer to *Sasco.*)

Cerro Colorado Camp

There was some smelting in the 1850's and 1860's at this camp.

Pinal County

Butte City

The Pinal Copper Company was formed on December 22, 1880 to develop the Ray and other mining claims. A 30-ton, water-jacket furnace was purchased, installed down by the Gila River, and blown in May 11, 1881. The Pinal Consolidated Mining Company mined lead and silver ores in the Mineral Hill District. About eleven miles down stream from Kelvin was Butte (City). This was the site of a smelter for these ores. A standard 30-ton furnace was installed, but only ran a short time in May, 1882 because of a lack of fuel. To secure charcoal for smelting, five stone beehive ovens were built. The kilns were fired with native wood gathered from the river banks and on the hillsides. With this new source of charcoal, the smelter turned out 2,000,000 pounds of lead and silver during the first six months of 1883. After a litigation problem in 1885 everything salvageable was removed from Butte.

Skinnerville

This community, five miles east of Ray, awakened in 1900; it was renamed Troy four years later. The first bar of copper was produced by a 60-ton smelter near Troy on June 17, 1902, and it operated some in 1903.

Florence

Around 1876 there were two smelting furnaces at Florence. There is a reference that ore from Globe (City)—Wheatfield area was sometimes taken to this smelter.

In the Superior area the Silver King mine ore minerals were cerargyrite, argentite and native silver. Ore, when sorted, ran $2,000 per ton. To treat this ore a small furnace of the cupel type was erected at Florence about 1875. The pig lead to collect the silver was obtained from the Mowry mine in the Patagonia Mountains.

Belmont (Queen Creek Area)

Ore mined here for silver and gold values was treated in a custom stamp mill near Pinal (at base of Picket Post Butte). After the Silver King Mining Company mill was constructed, the older mill was closed because at the new mill provisions had been made to roast the ores; this process aided materially in recovering the precious metals.

Superior

In 1914 the Superior mine ores (some as rich as 50% copper) were hauled by wagon to the railroad to be transported to the smelter at Hayden (A. S. & R. Co.). In 1921 a study indicated that with the increased freight rates and higher smelting charges the Magma Copper Company was warranted in building its own smelter close to the mines at Superior. The smelter and the proposed standard gauge railroad would save two-cents per pound of copper produced (in 1923 copper was selling for around 14 cents). The smelter was completed in April, 1924; its original capacity was 500 tons of dry charge in 24 hours. Concentrates were piped to the smelter and filtered to produce concentrates with 11-13% moisture. After 58% to 60% of the sulphur had been removed by the roasting process, the resulting calcines were taken to the reverberatory furnace. Matte was 32-34% copper. There were two 12-foot diameter Great Falls converters. Converter slag was returned to the reverberatory furnace. The blister copper (98.98% copper in 1942) from the converters was cast into blister bars on one casting machine. These blister bars were shipped in railroad cars to the refinery in the east; they contained 27 ounces of silver and 0.65 ounces of gold per ton.

Total cost of constructing the smelter to March, 1924 was $1,907,776.30.

Sasco

The Imperial Copper Company was incorporated in 1903. It bought the old Silverbell mine and launched a smelter (Southern Arizona Smelting Company) in 1907. The first 350-ton furnace was blown in on February 1, 1908. Three months later the second furnace was fired up at Sasco (the name of the townsite was derived from the corporate title). In April 1909 the Sasco smelter was turning out almost 1,000,000 pounds of copper per month. Continual low copper prices and the exhaustion of the better grade ore bodies caused Imperial Copper to shut down August 15, 1910. The smelter was dismantled in the late 1920's. (Refer to *Silverbell.*)

Santa Cruz County

There were numerous small smelters in Santa Cruz County. Details on these units are not readily available so most will merely be noted herein:

Lochiel: one-fourth mile north of the Mexican border: about 100 tons of slag; one-fourth mile southeast of Lochiel: about 20 tons of slag.

San Rafael Grant: immediately south of there is about 300 tons of slag.

Washington Camp: Doco lode: about 1,000 tons of slag (copper) from the reducing plant for Duquesne Mining and Reduction Company was located here.

Montosa Canyon: about 100 tons of slag (copper).

Crittenden Townsite: A. J. Stockton established a short lived smelter in the suburb of Cranktown in 1887. Marder Luse & Co. (a Chicago maker of printing office type) established a smelting furnace in Crittenden in the spring of 1888 to treat ore from its lead mines in Mexico. After several years the lead smelter became idle, but produced about 500 tons of slag. In 1894 the furnace was sold and taken to Mexico.

Rollin C. Richardson and C. C. Fitzgerald acquired control of the Hardshell mine, at Harshaw, and the Flux mine

in the summer of 1896. Three miles south of Crittenden these men began to erect a smelter. This new smelter drew nearly all of the population from Crittenden. The smelter was not a success. This smelter area was called Rollin; after three years (November 1899) its name was changed to Patagonia. Slag on Smelter Avenue is about 200 tons.

Mowry: A smelter in the 1860's produced about 200 tons of slag; a smelter about 1910 produced about 5,000 tons of slag. Ores from the Mowry mine were lead-silver.

Duquesne: There was a reduction works located here; early 19th century Mexican miners built adobe smelters in this area.

Tumacacori: On the Mission grounds there are about 200 tons of slag.

Salero Camp: A smelter in the 1850's and 1860's.

Nogales: There was a lead smelter on Smelter Street: about 500 tons of slag.

Wrightson District: Mansfel Manufacturing Co. had a 30-ton matte smelter. Date unknown.

Ruby—Oro Blanco District: The Ostrich mill was equipped with a roasting furnace to treat refractory sulfide ores which contained gold. This plant was built during the early 1880's; it was operated by the Orion Company on ores from the Montana and Warsaw mines.

Yavapai County

Jerome—Clarkdale

The first claims were located in the Jerome district in 1876. At this time the nearest railroad terminal was hundreds of miles distant at Abilene, Kansas.

In 1882 the United Verde Copper Co. was organized by Fred Thomas, an engineer from San Francisco. A 36-inch, water-jacketed furnace with a capacity of 40 to 50 tons of ore per day was shipped from Chicago to Ashfork (the Atlantic and Pacific Railroad had extended its line through Arizona in 1882). The furnace was set up where the open pit is now; it was blown in on August 1, 1883. For the furnace a cooling water supply was provided by a pipeline from a spring two miles away. Coke was received from New Mexico. Oxidized copper ores were smelted. Black copper (known as "bullion"—it was 94% copper; any matte was 60% copper) bars were sent to the refinery on the east coast. From this little furnace, in 300 days operating time, was poured more than 4,000,000 pounds of copper that was worth nearly $800,000, and this copper contained 235,000 ounces of silver. The smelter closed in 1884, because even 20 or 30% copper ore was of no value in such a remote camp when copper was less than 10 cents per pound.

In 1887 a second furnace was erected. As ores were becoming leaner in copper and tending toward sulfides—these ores required the extra step of roasting.

In 1885 William Andrews Clark, ex-U. S. Senator from Montana, found on the books of Orford Copper Co. numerous shipments of matte from the United Verde mine. The mattes were extremely rich in gold and silver. Clark visited the area and proceeded to buy up outstanding stock in 1888. In the fall of 1888 ores were again being smelted in the little two-furnace plant in the gulch above Jerome. These were two 50-inch blast furnaces of cylindrical, water-jacketed type with annual capacity of about 15,000 tons.

In 1894 a smelter with a capacity of 3,500,000 pounds of copper per month was built. The blast furnaces were 48 inches by 120 inches, but in 1895 were converted to 48 inches by 240 inches. This plant was also built over the mine workings and slowly it became endangered by the settling of the mined ground. Roasting heaps, like those at Rio Tinto, were used to burn the sulphur out of the ore.

Between 1900 and 1911, the United Verde operation produced, and the smelter treated, about 230,000 to 300,000 tons of ore per year. The smelter consisted of four blast furnaces and four converters. The demand for increased capacity and for facilities for treating lower grade ores could not be satisfied at Jerome because of topographic limitations and the caving of the ground due to mining operations.

Preliminary investigations of possible sites for a new smelter were undertaken in 1910. The location of the Clarkdale smelter (as built on the Verde River about six miles from Jerome) lent itself most satisfactorily to all aspects of the problem: adequate water supply, good drainage; ample sand and gravel deposits for construction purposes; a fairly large and satisfactory deposit of clay suitable for building brick; easy access to tracks of the Verde Valley Railroad as then proposed; sufficient area at a satisfactory elevation for slag disposal and other related features.

Ground was broken in 1912 and the first furnace was blown in on May 26, 1915. The rated capacity of the new smelter, as designed and built, was 4,500,000 pounds of copper per month with 5% copper ore.

The smelter at Jerome had used blast furnaces exclusively; apparently it was the intention that even in the new Clarkdale smelter the blast furnaces would be the most important producer of matte; the reverberatory furnaces would be used mainly for the treatment of flue dust, fine ores, and converter slag. The blast furnace process at Jerome left the treatment of fines, flue dust, and converter slag unsolved. These problems, together with the growing popularity of matte smelting in reverberatory furnaces, which were equipped with boilers, caused the management to add reverberatory furnaces when the Clarkdale smelter was built.

The four blast furnaces were 48 inches by 320 inches. The six, eventual, reverberatory furnaces were blown in July 1915, October 1916, December 1916, June 1920, September 1920, and March 1928.

Roasters prepared the direct smelting ore and the concentrates for matte smelting in the reverberatory furnaces. Only about 10% or less of the roaster feed at that time consisted of flotation concentrates (15% copper, 5% SiO_2, 30% iron).

There were originally stands for four 12-foot diameter Great Falls converters; there were eight converter shells. By 1930 there were eight stands and fourteen shells.

The converters treated matte from the blast furnaces (20% copper) and from the reverberatory furnaces (35% copper). Most fluxes were not ideal but had to be used due to their high gold and silver values. The converter charges were blown to blister copper.

About 1910 practice in several plants had demonstrated

superiority of a basic converter lining of non-fluxing material and the addition of fluxing material through the mouth of the converter. Owing to patent litigation United Verde had used acid linings during 1925 and 1926. They had perfected a mechanical means of tamping these linings. United Verde undertook experiments to substitute monolithic tamped linings of periclase (a dense crystalline grain—88 to 92% MgO) to replace linings of manufactured magnesite brick. Trials evolved into use of periclase, fireclay, and sulphuric acid or periclase, molasses, and sulphuric acid. Early in 1930 all converting was carried on in shells with tamped periclase linings.

The Clarkdale smelter underwent progressive changes and expansion. In 1923 all records were broken when in excess of 1,100,000 tons of ore were processed.

In 1930 everywhere reverberatory furnace smelting was in use, and all ore for direct smelting was crushed to about ¼-inch size. This contrasted with the feed of 4 inches by 1½ inches that was used in the blast furnaces.

In February 1935 the United Verde Copper Company was acquired by Phelps Dodge Corporation. The United Verde mine and smelter had ceased to operate in 1931. Operations were resumed early in 1935 by Phelps Dodge Corporation. In 1941 the Clarkdale smelter treated the equivalent of 1,150,000 tons of ore (from Jerome underground, from custom smelting, and from Bisbee). During 1942 they handled copper bearing residues and scraps to relieve the eastern smelters of the excessive supplies of these materials.

Jerome—Clemenceau, United Verde Extension Mining Co.

Shortly before the outbreak of World War I (1912) James S. Douglas (Rawhide Jimmy), son of Dr. James Douglas, and associates organized a company and acquired a property known as United Verde Extension. This was adjacent to Senator Clark's famous mine. On December 20, 1914 at the 1,200 foot level an exploratory drift struck a five foot thick vein of 45% copper. The United Verde Extension smelter was built at Clemenceau (south of Cottonwood), in a hurry, during World War I at a cost of $5,122,445. On May 25, 1918 the smoke stack for the smelter reached a height of 425 feet (the highest stack in the world on that date). It started production in 1918. In the next few years the mine yielded a profit of $50,000,000. The mine was mined out by 1938.

Mayer

A short distance north of Mayer was the Rigby Spur on the Prescott and Eastern Railroad. The Rigby Reduction Company plant was on the slope above Big Bug Creek. It processed ores for a few years but fell prey to the large ore processing plant at Humboldt. The buildings and machinery were salvaged and removed.

One-half mile south of the Mayer depot was the Treadwell spur. The Treadwell Mining Company operated a smelter and several nearby mines. This smelter was completed in 1905 but proved ineffective and did not compete well with the huge Humboldt plant. It was later rebuilt and called the Great Western Smelter. This smelter started up March 12, 1917 and smelted at the rate of 200 tons per day. It produced fifteen tons of copper matte per day during the first week, and the matte assayed 40% copper; $40 per ton in gold; $20 per ton in silver. When the second unit of 500 tons was completed, the product would be blister copper. It operated intermittently for a few years and was then dismantled. Along Highway 69 south of Mayer the smokestack of a long-vanished smelter stands on a hill.

Humboldt

Between 1876 and 1884 a 20-ton furnace on the Agua Fria River smelted $350,000 worth of silver from the small but rich Silver Belt mine.

The Valverde Smelting Company purchased a mill site one and one-half miles east of the railroad. They constructed a large smelter and obtained a railroad spur. By the end of 1899, it was in operation with daily capacity of 250 tons. Plans were unveiled in 1904 to double its size, but expansion plans met a fiery end on September 28, 1904, when flames engulfed the smelter. The site was dormant for almost a year while financiers and investors created a new company and formalized construction plans for a new smelter. The new plant was funded by Arizona Smelting Company and construction began in September 1905. This smelter was much larger and more efficiently planned than the original one. It was the largest custom smelter in the territory. On August 18, 1905 the new community was christened Humboldt. The great demand for copper during World War I enabled nearly 1,000 tons of ore to be processed each day. More than 2,000,000 pounds of pure copper left the smelter each month. After World War I a glut of copper flooded the markets; metal prices dropped and the smelter closed.

The Southwest Metals Company reopened the smelter during the 1920's to reduce ore from their mines at Walker, but the depression closed the plant again.

The Iron King Mine reopened in the 1930's but Humboldt did not resurge. Very little of the ore mined at Iron King was processed at Humboldt as the old smelter was not equipped to handle the complex ores from the mine. Some of the old smelter facilities had been removed as early as 1927; most of what remained was dismantled ten years later. A smelter smokestack of Arizona Smelting Company still stands.

Howells

This town is located 6½ miles south of State Route 69 at a point 4 miles east of Prescott; it is less than a mile down Lynx Creek from Walker. Lead and silver ores were discovered here in the 1870's. In 1882 John Howell selected a site along Lynx Creek and built a two stack smelter. The high cost of hauling coke, 60 miles from the railroad, made the operation unprofitable. In less than a year $173,825 worth of lead and silver were produced and then the smelter shut down.

Curtiss (Arizona City)

This town is one-half mile south of State Route 69 at a point 28 miles east of Prescott; it is two miles northwest of Mayer. T. W. Boggs discovered outcrops of copper near the banks of Big Bug Creek in the early 1880's. Phelps

Dodge purchased the claims and built a 50-ton smelter on the creek between the mines. Smelting began in 1889 and it stopped in 1893.

Stoddard

This town was on the north side of the Agua Fria River, six miles north of Mayer. During 1882-83 rich carbonate ores were mined on the north slope of Copper Mountain. These ores were taken to the newly erected 40-ton furnace smelter built at Stoddard Camp; the operation closed abruptly in 1884 due to its isolation and the low copper price.

Yuma County

Castle Dome District

This district is 35 airline miles northeast of Yuma and about six miles by graded road east from the paved highway that goes from Yuma to Quartzsite.

Yuma

In 1875 Captain Nagle erected a small furnace at Yuma. After completion of the Southern Pacific Railroad between Los Angeles and Yuma in 1876, this smelter was unable to compete with the Selby smelter near San Francisco. The Yuma smelter probably handled Castle Dome area ores; because of its freedom from arsenic and antimony the lead produced commanded a premium for white lead manufacturing.

ADDENDA

Recovery of Mercury

Of all metals, quicksilver (mercury) is probably the most easily recovered from its ores, as it can be volatilized at a comparatively low temperature (about 680°F), and thus separated as a vapor from nearly all other substances present in the ore. Metallic mercury is then easily obtained by condensation and is marketed in 75-pound flasks. The process outline is simple but control of operations to obtain the maximum production with minimum cost presents difficulties and requires experience.

The Scott furnace was built in sizes to handle from 10 to 80 tons of ore in 24 hours. This masonry structure required special skill to build. Wood, coal, or oil was burned in a firebox; it was not mixed with the ore. A Johnson-McKay retort was also used for the recovery of mercury.

La Paz County

Southwest of Quartzsite was a mercury mine location in the Dome Rock Mountains. The Scott furnace with 6 condensers, in 1908, produced 100 to 140 flasks from 2,000 tons of ore; in 1914 a Johnson-McKay retort treated 50 tons of ore for 16 flasks.

Yavapai County

At Copper Basin southwest of Prescott two or three flasks of mercury were produced in a homemade retort near the mine in 1904.

Maricopa County

The Phoenix Mountains are 11 miles north of Phoenix. A 5-pipe Johnson-McKay retort was crudely constructed and evidently not very efficient. In 1924 some ore was treated and two flasks of mercury were produced.

Gila—Maricopa County

In the Mazatzal Mountains northeast of Phoenix mercury ores have been found on Alder Creek, Slate Creek, and Sycamore Creek. On Alder Creek a 12-pipe Johnson-McKay retort was built (two tons of ore per 24 hours); 75 flasks were produced before 1925 and 24 flasks in 1925. On Sycamore Creek a one-pipe retort was crudely built; a few flasks were produced by 1927.

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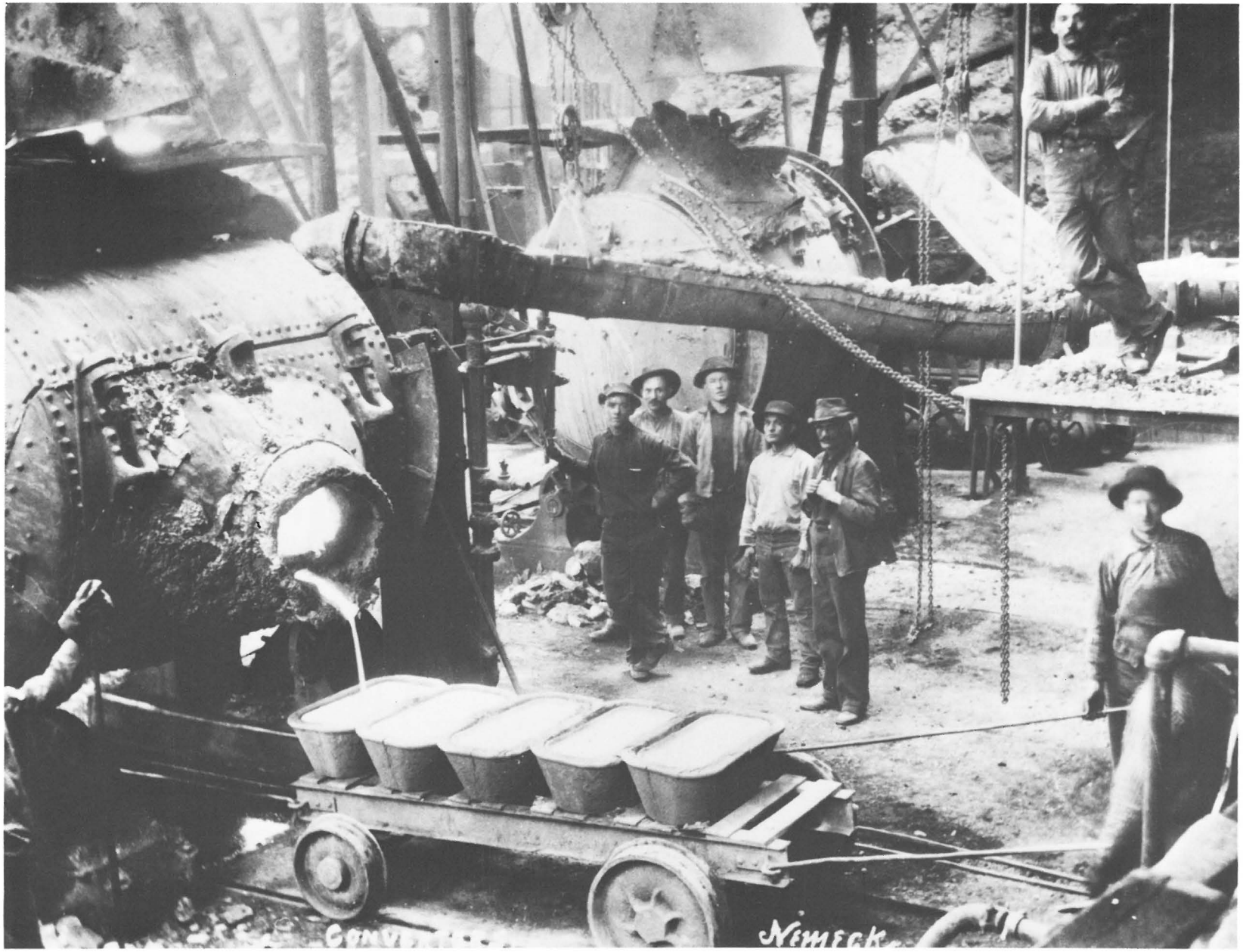
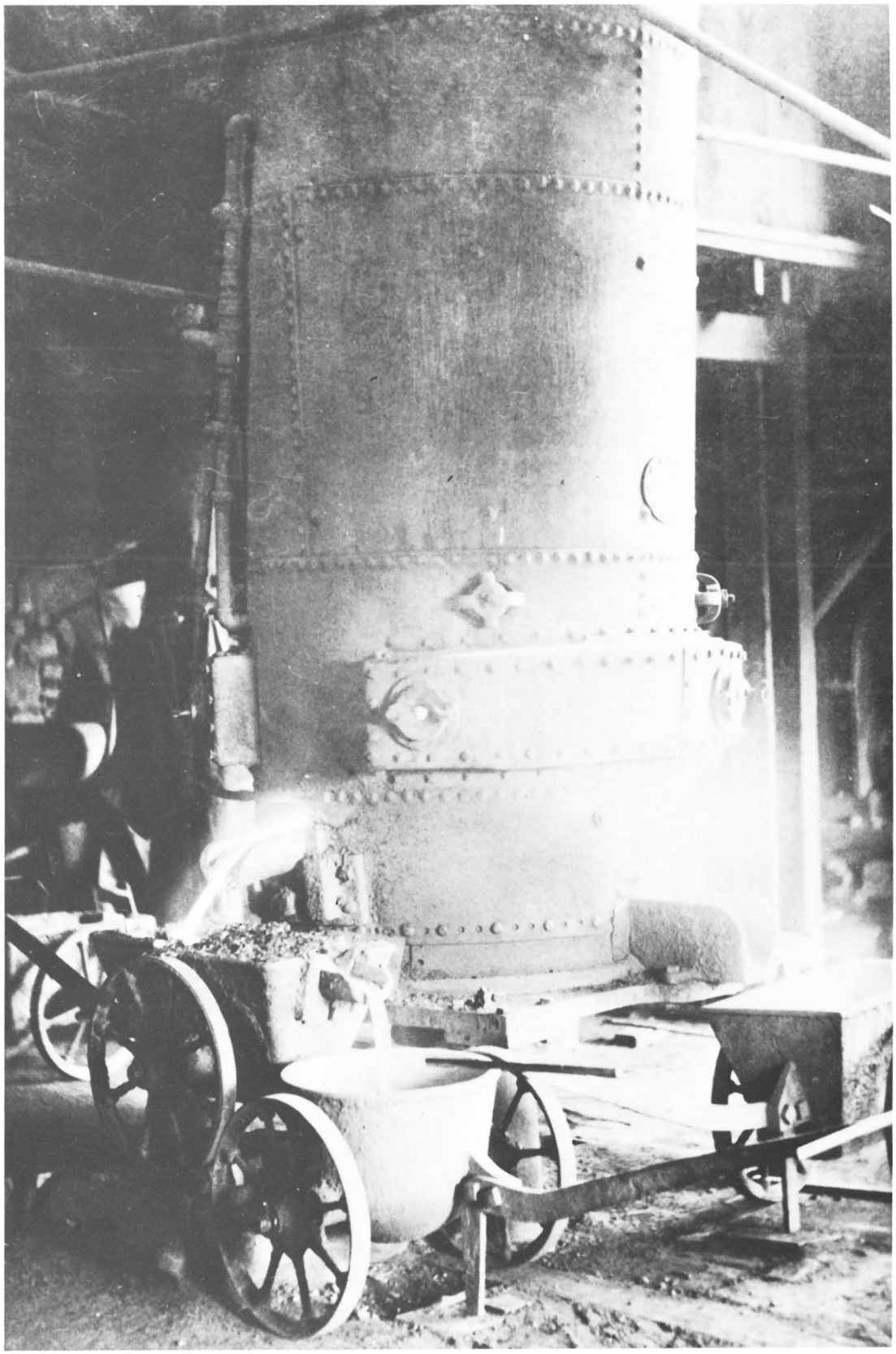
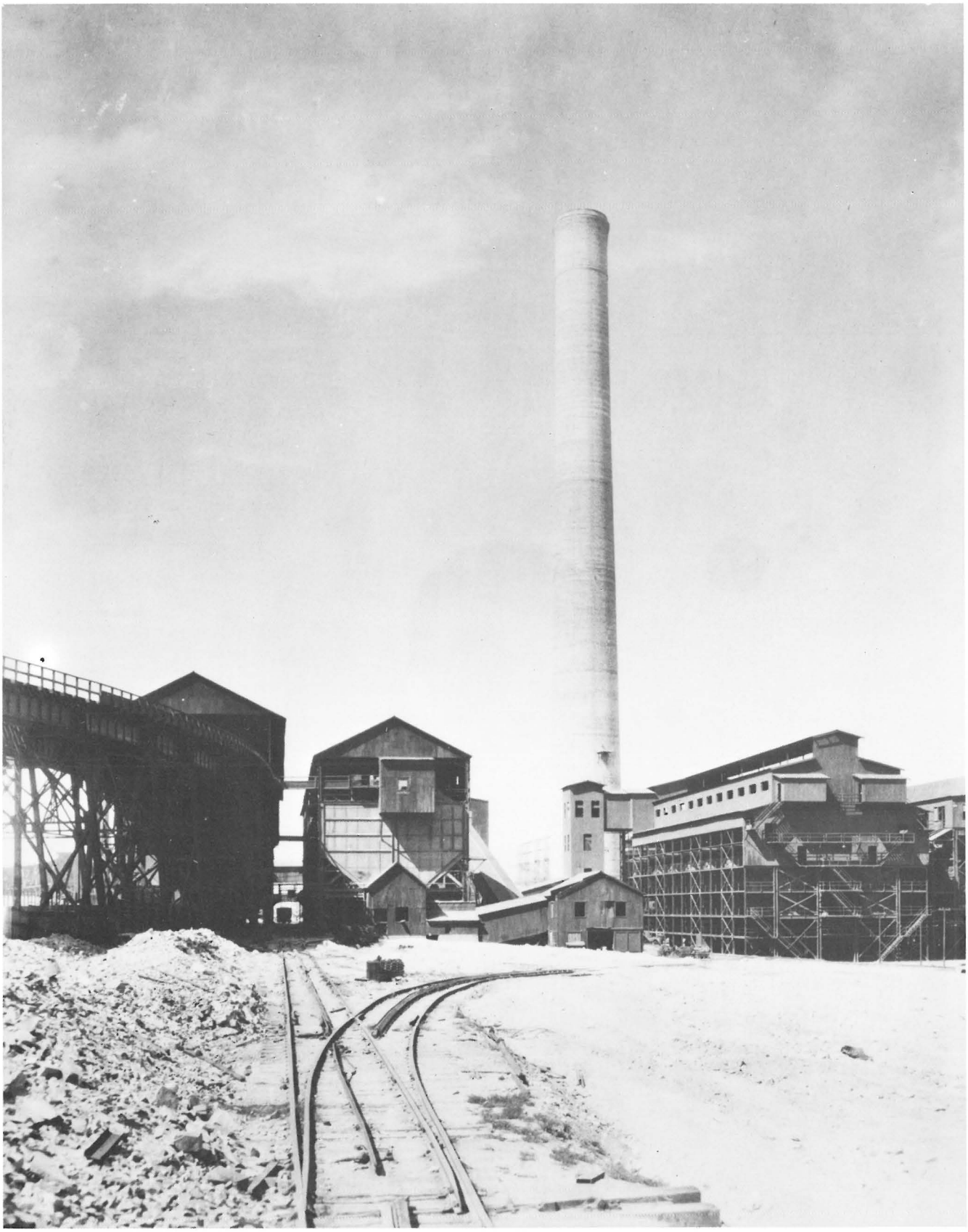


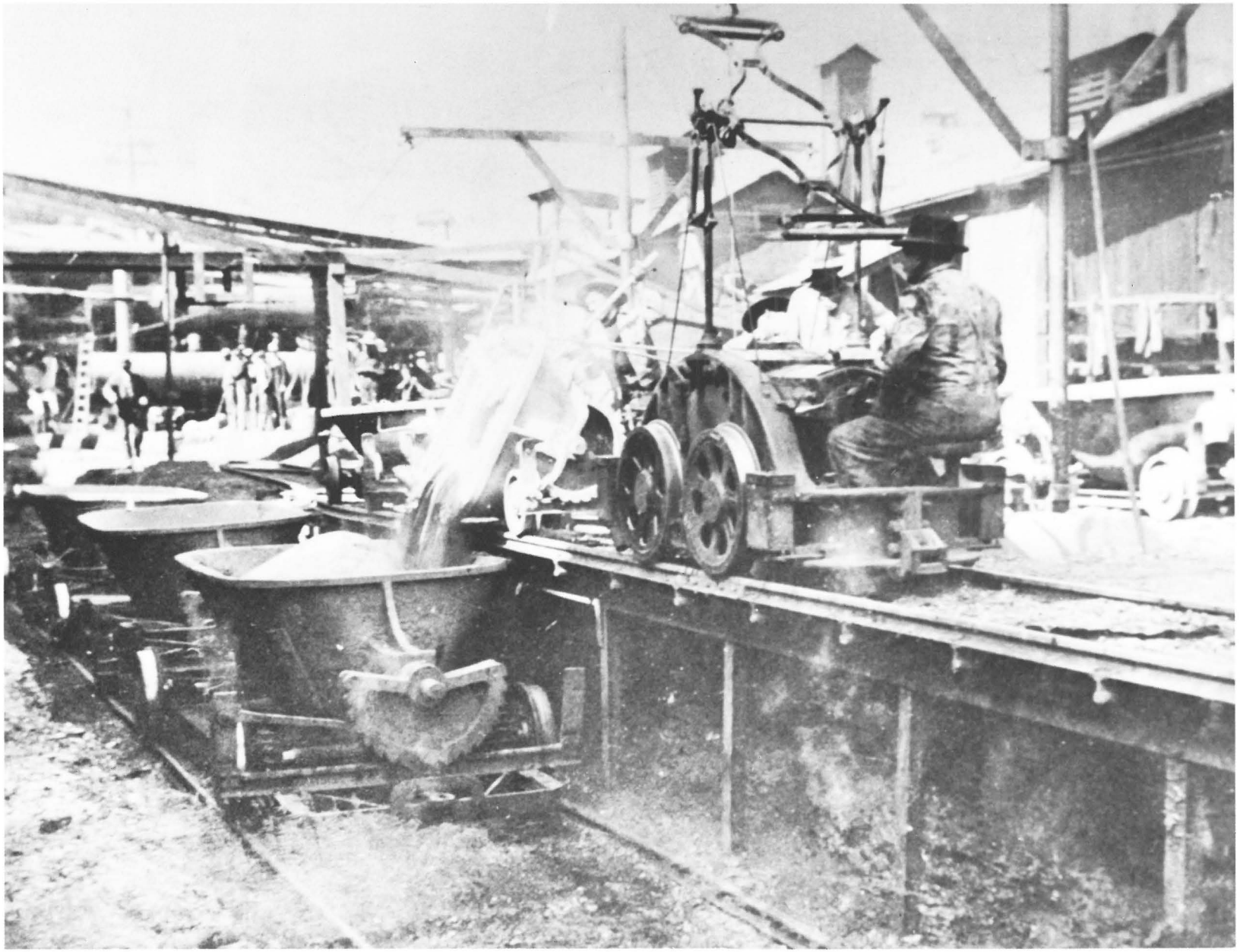
Copper Queen Consolidated Mining Co. (Phelps Dodge & Co.) Third Bisbee Smelter, 1898. Horizontal, barrel type converters designed by Dr. James Douglas. Converter is pouring blister copper into rail-mounted hand-pulled car. *Sweet Collection, Courtesy of Bisbee Mining and Historical Museum.*



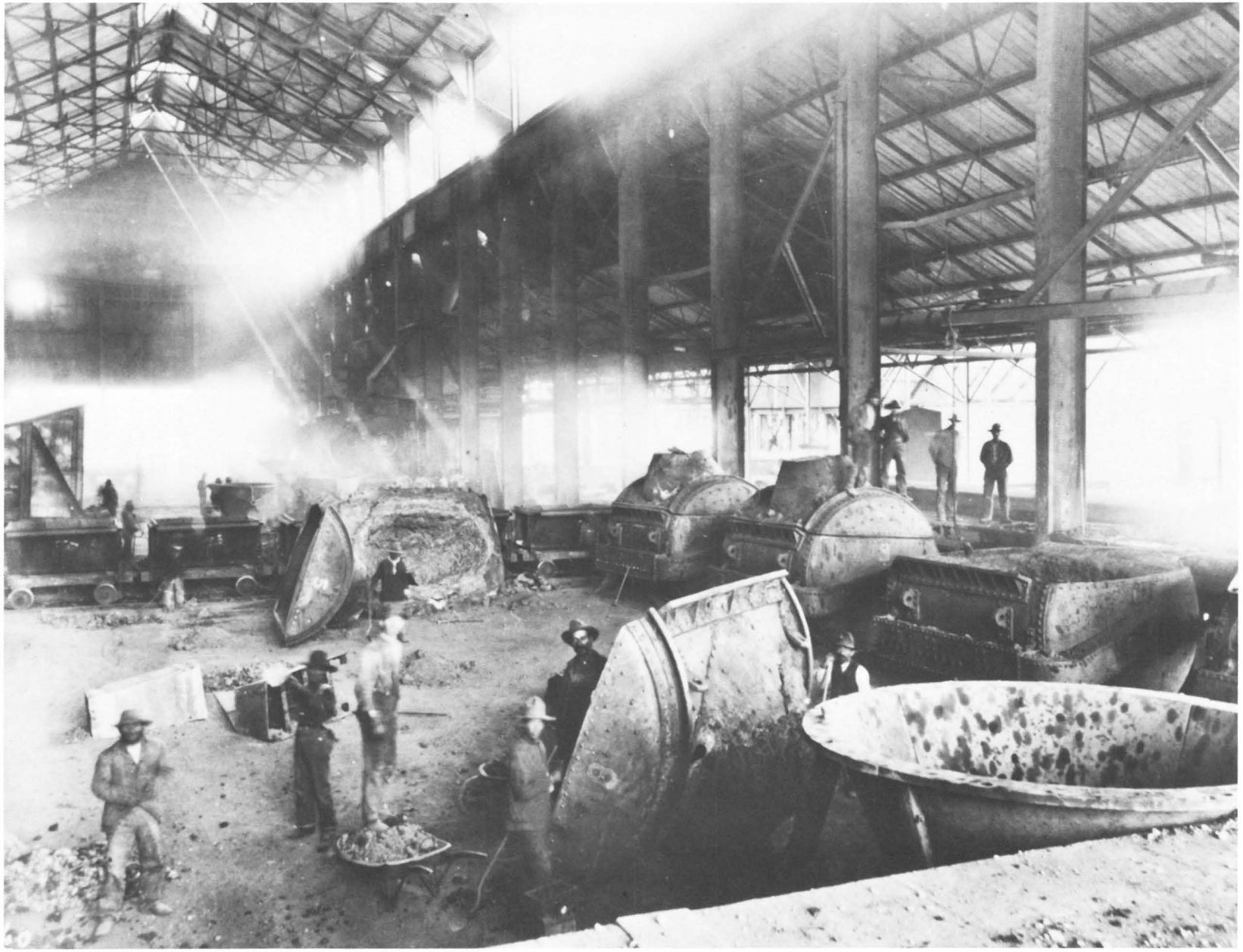
Copper Queen Consolidated Mining Co. (Phelps Dodge & Co.) Second Bisbee Smelter (1885-1889). 36" diameter furnace—30 ton capacity. Slag is being skimmed from the furnace. *Courtesy of Arizona Historical Society.*



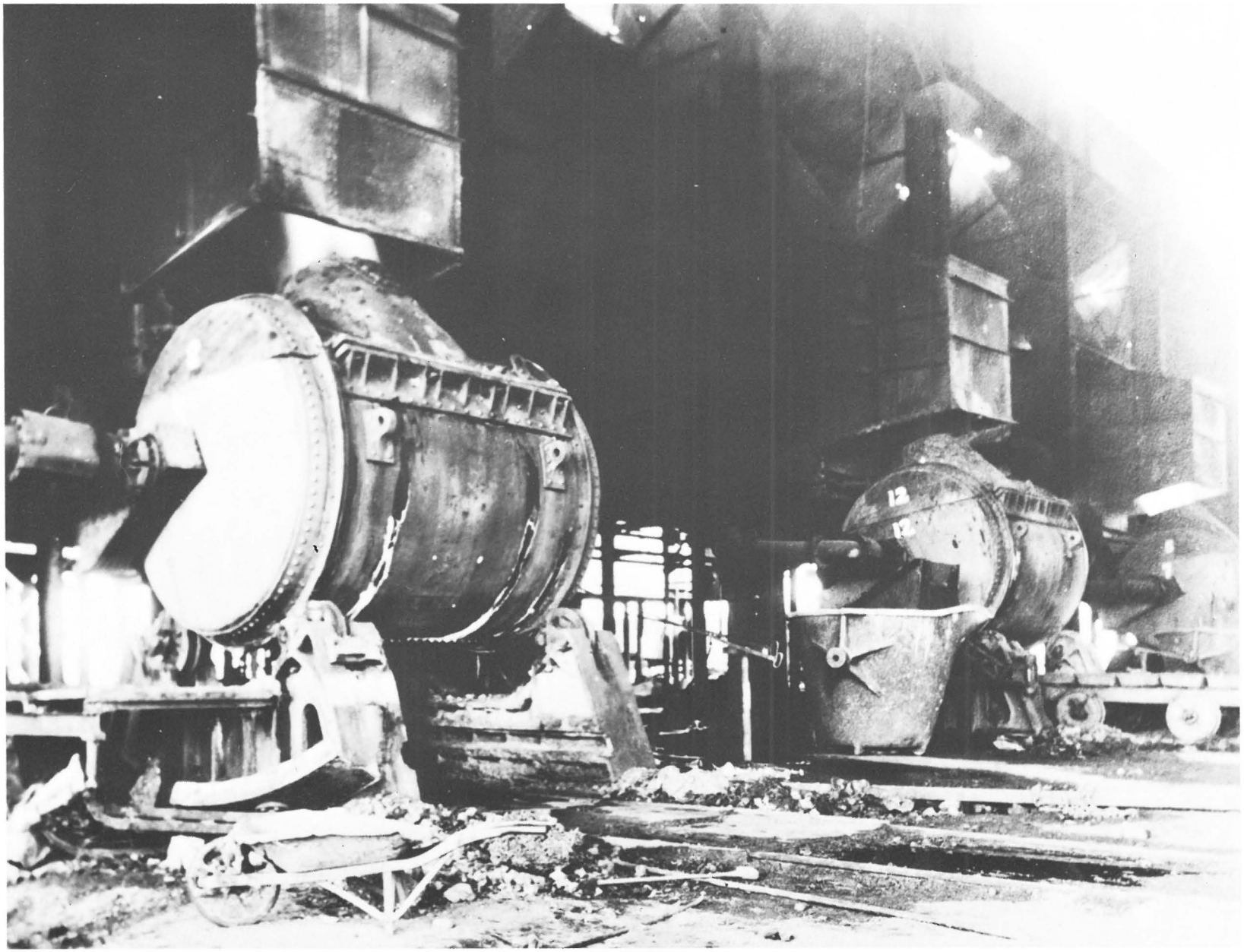
Arizona Smelting Company smelter at Humboldt. Construction began in 1905. Rated at 1000 tons per day. *Courtesy of Phelps Dodge Corp.*



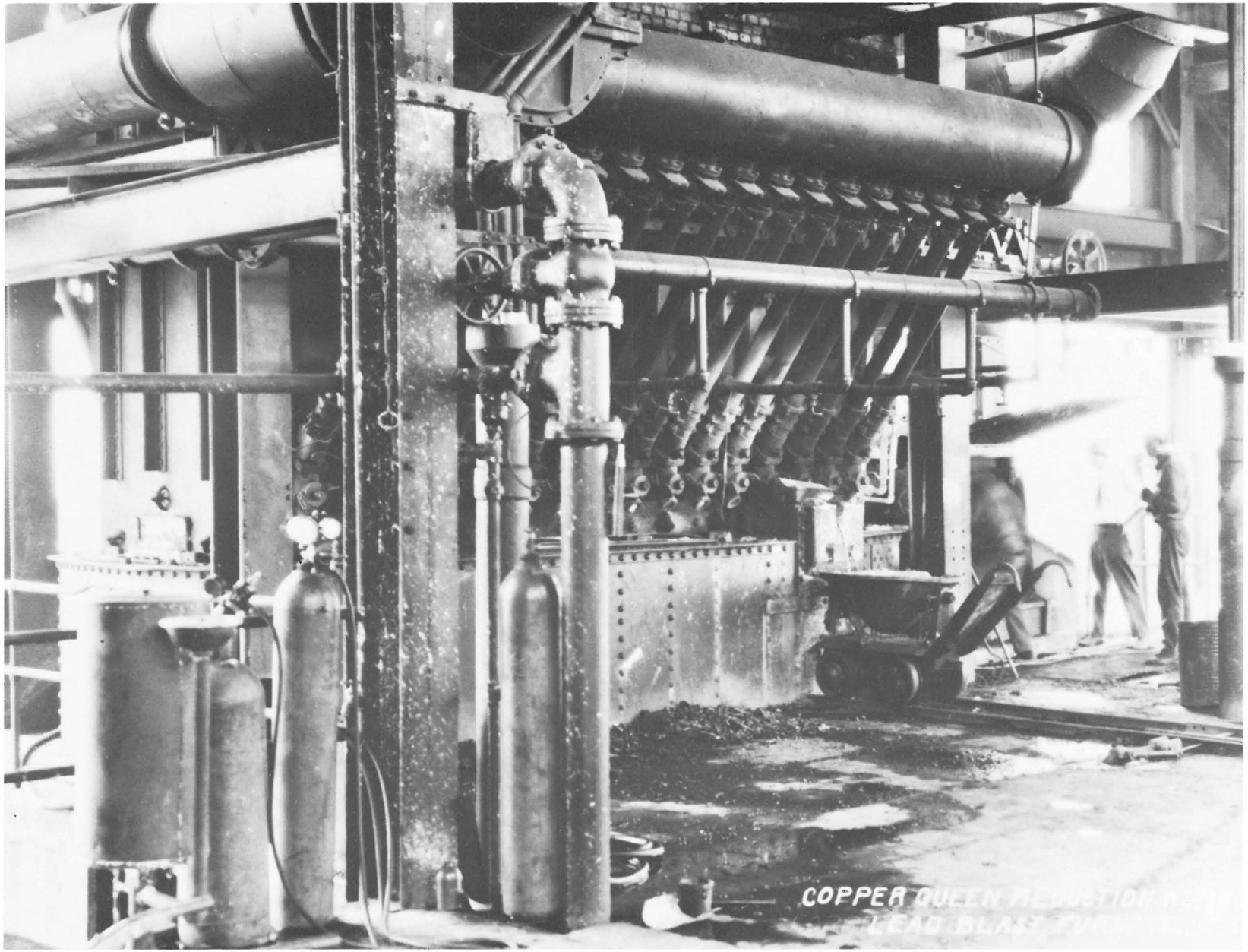
Copper Queen Consolidated Mining Co. (Phelps Dodge & Co.) Probably the Third Bisbee Smelter, c. 1898. A dinky trolley engine is pouring slag into larger railroad slag pot car. *Courtesy Lewis Douglas Collection—Bisbee Mining and Historical Museum.*



Calumet and Arizona Mining Co. (?) Douglas Smelter (?), 1904. Converter repair area. *Courtesy of Arizona Historical Society.*

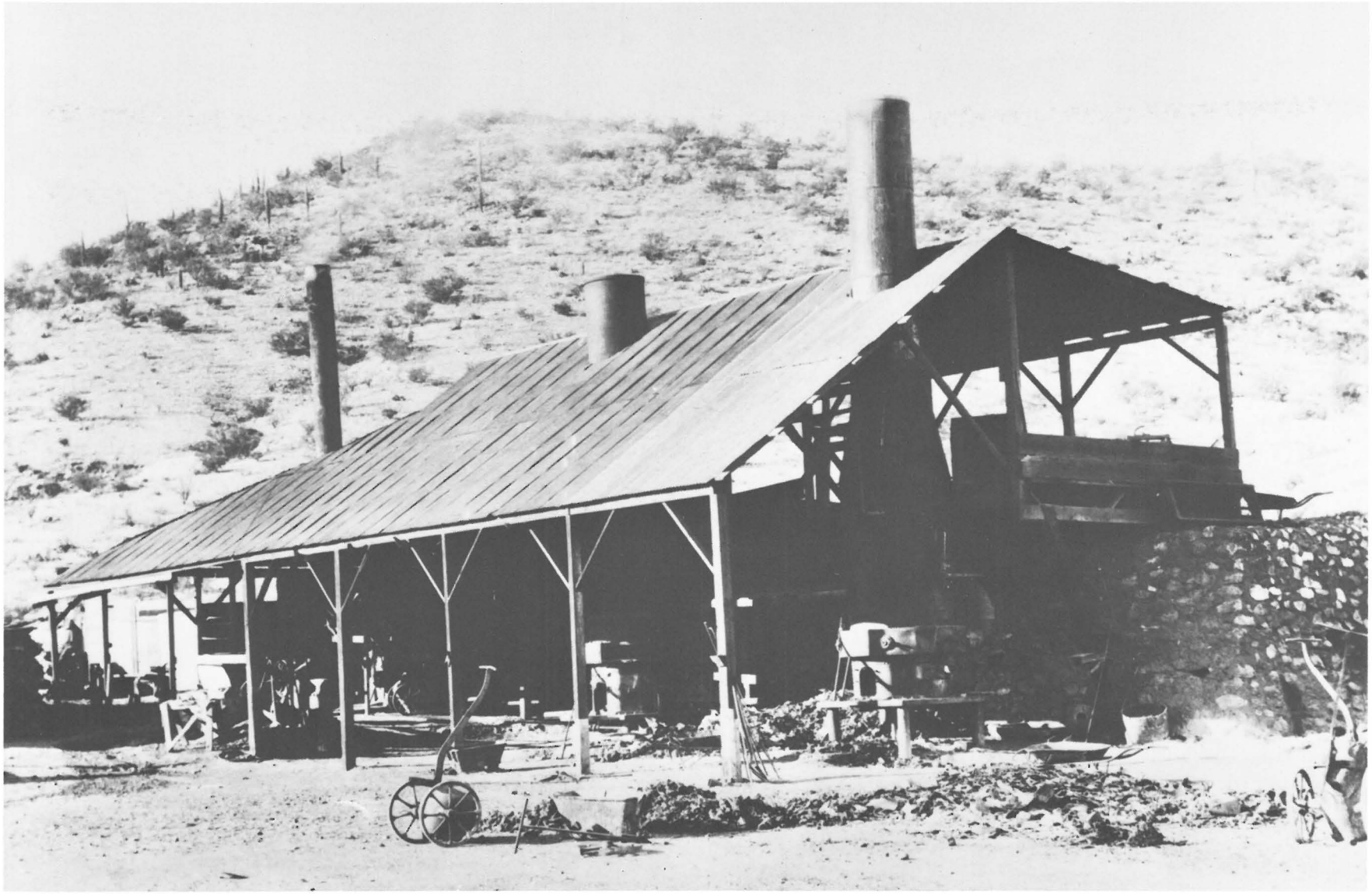


Copper Queen Consolidated Mining Co. (Phelps Dodge & Co.) Douglas Smelter, 1904. Converter aisle. *Courtesy of Phelps Dodge Corp.*

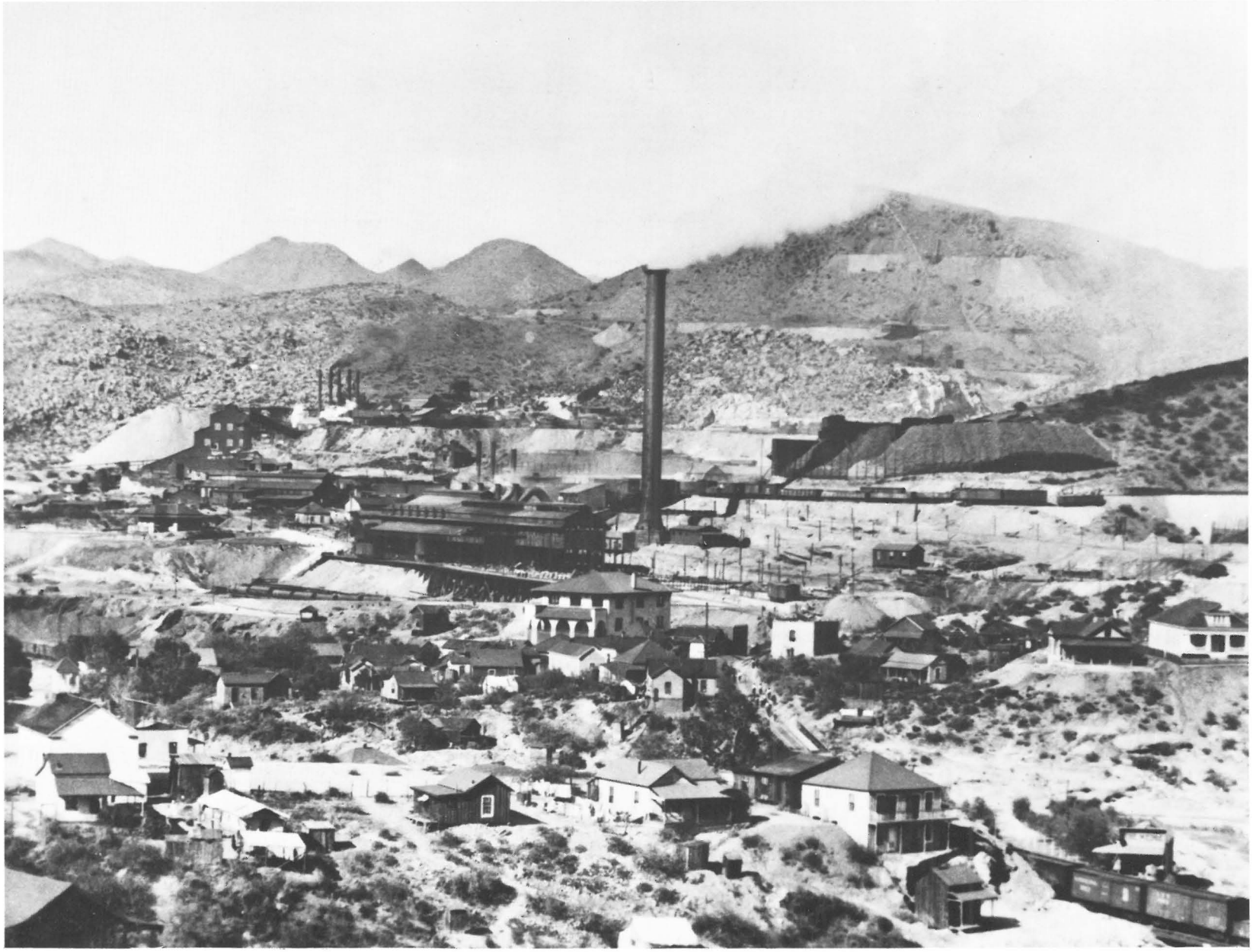


Phelps Dodge Corp. Douglas Smelter, 1927. A lead blast furnace of 200 tons daily capacity. *Courtesy of Phelps Dodge Corp.*

At top: Calumet and Arizona Mining Co. Douglas Smelter operations. At bottom: Phelps Dodge Smelter, c. 1931. *Courtesy of Phelps Dodge Corp.*

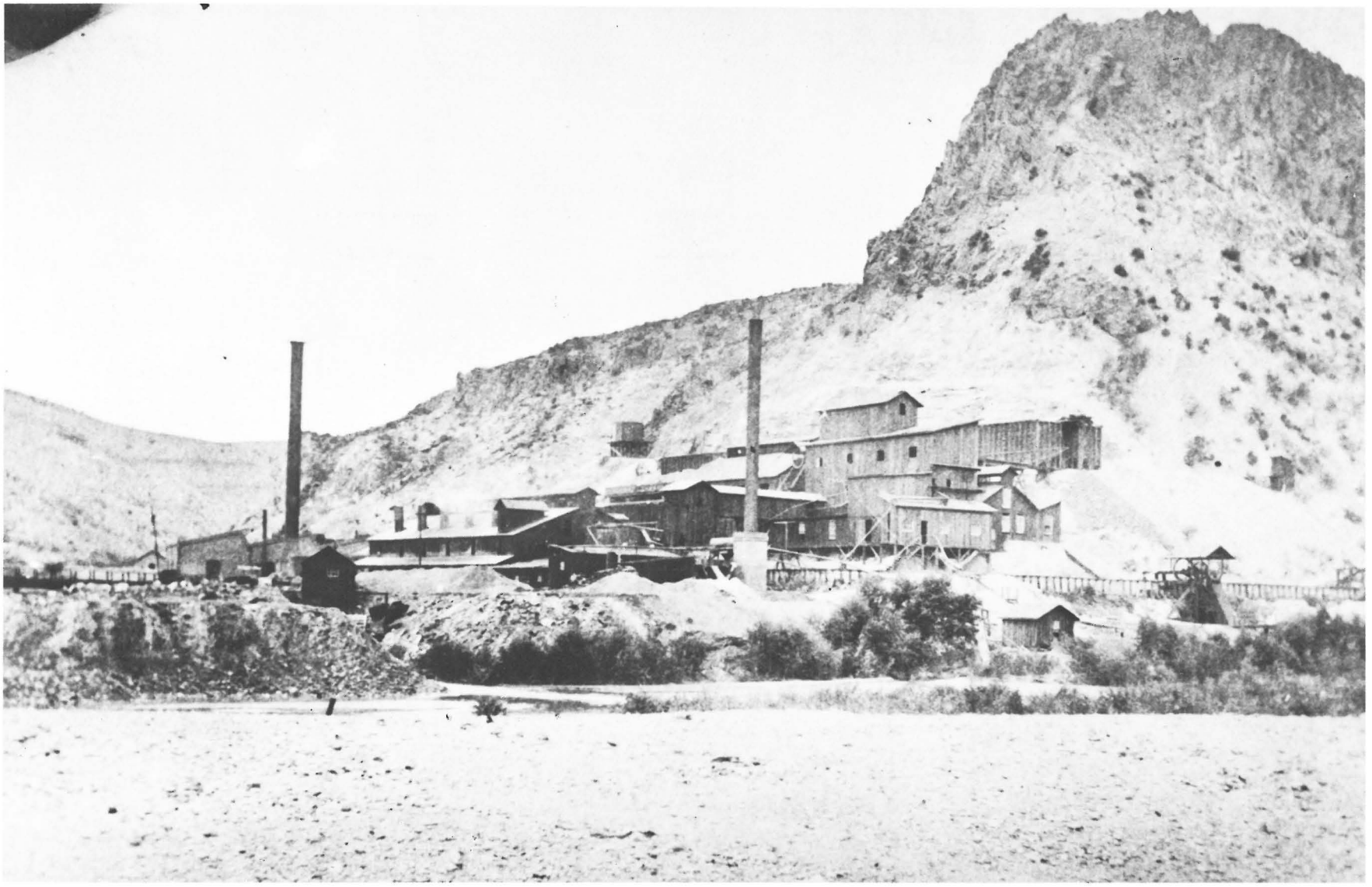


Buffalo Mining and Smelting Co.—Smelter at Buffalo Mine—Globe, c. 1882. *Courtesy of the Arizona Historical Society.*



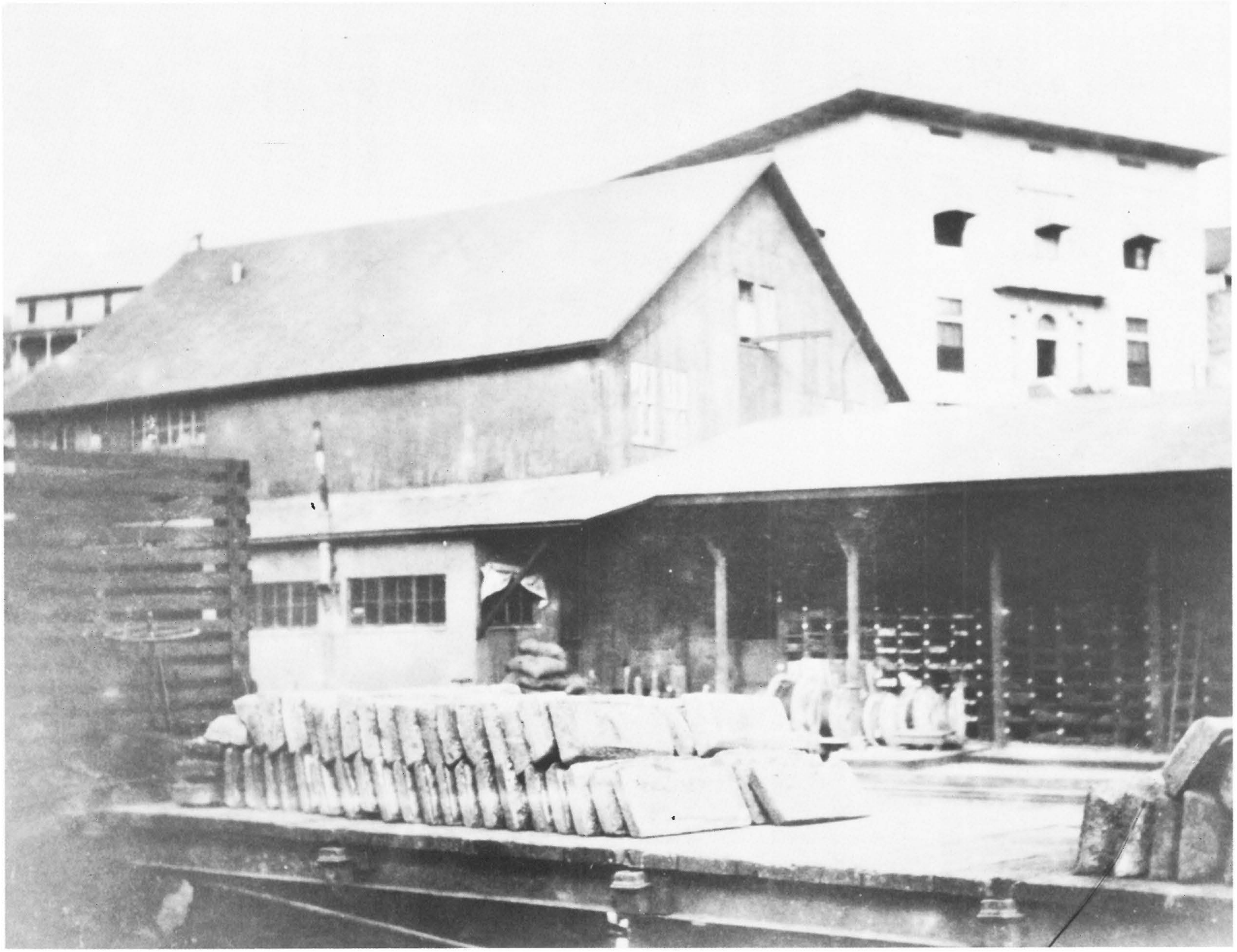
Old Dominion Co., new smelter at Old Dominion Mine, Globe, c. 1908. *Courtesy of Arizona Historical Society—Woody Collection.*

Saddle Mountain Mining Co., Christmas Smelter, 1907. *Courtesy of Arizona Historical Society.*

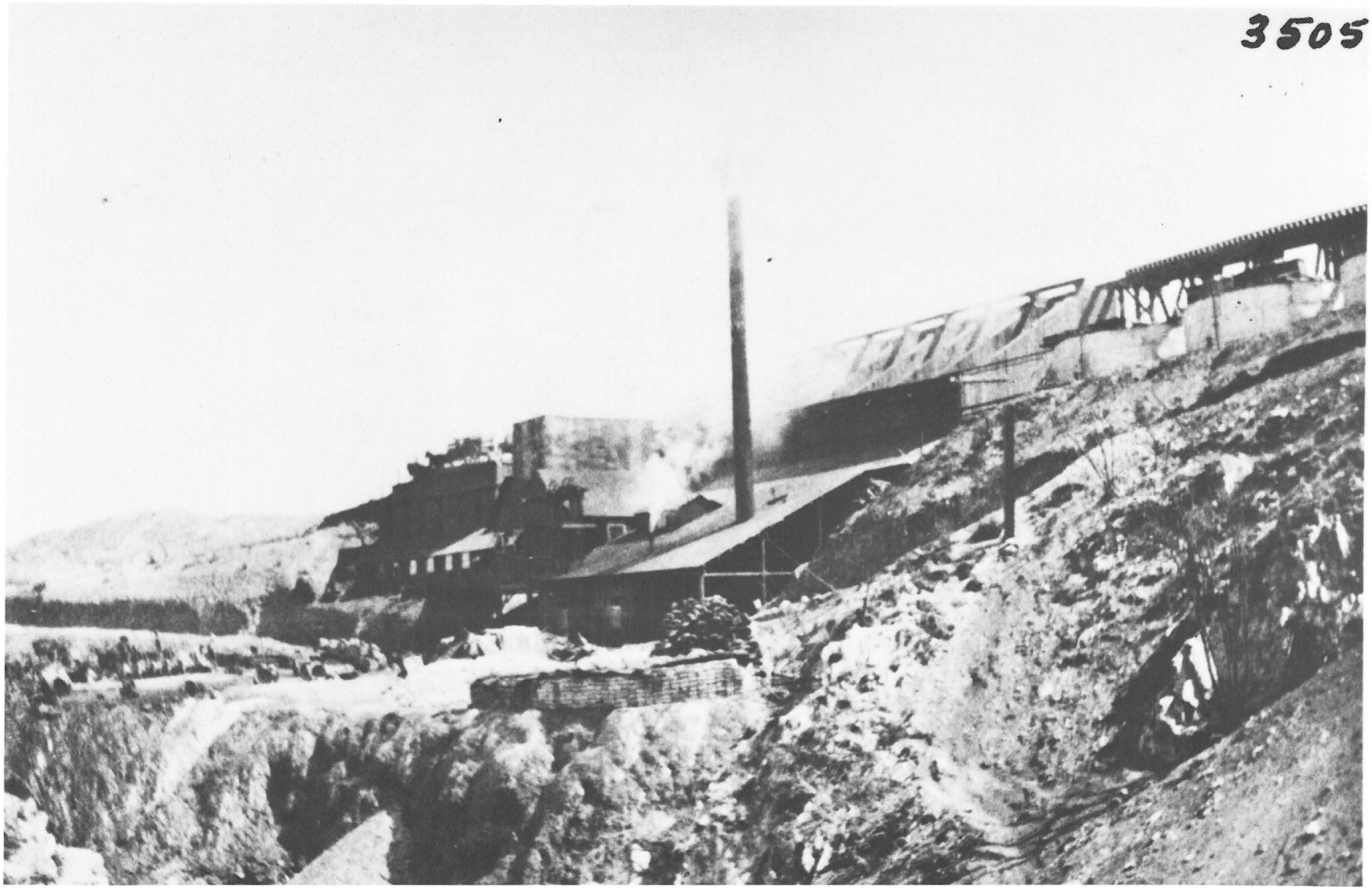


Arizona Copper Co., smelter at Clifton, 1880's. *Courtesy of Arizona Historical Society.*

Detroit Copper Mining Co., smelter near Copper Mountain-Morenci, 1896. *Courtesy Phelps Dodge Corp.*

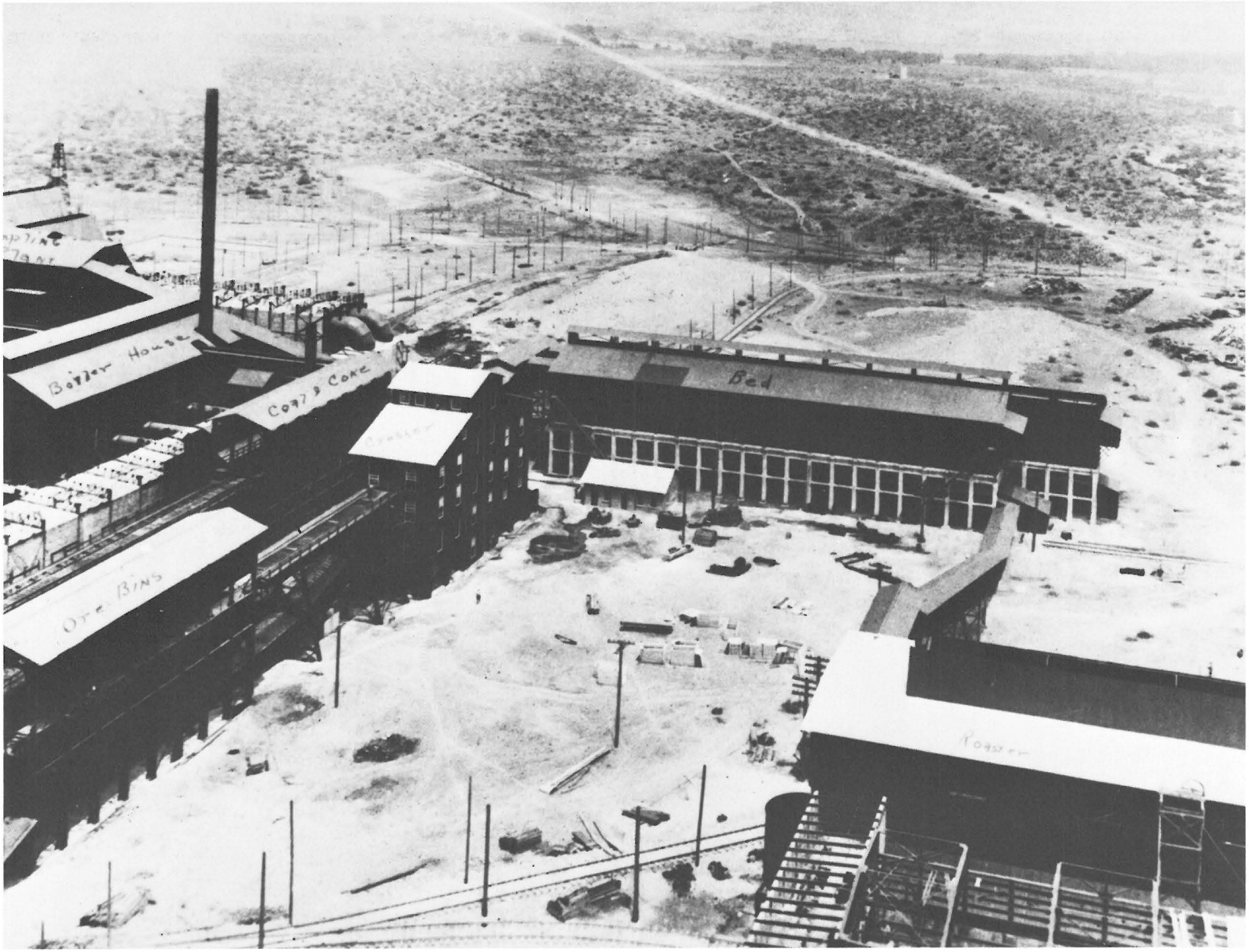


Detroit Copper Mining Co. Copper bars on a railroad car, 1901. *Courtesy of Arizona Historical Society.*

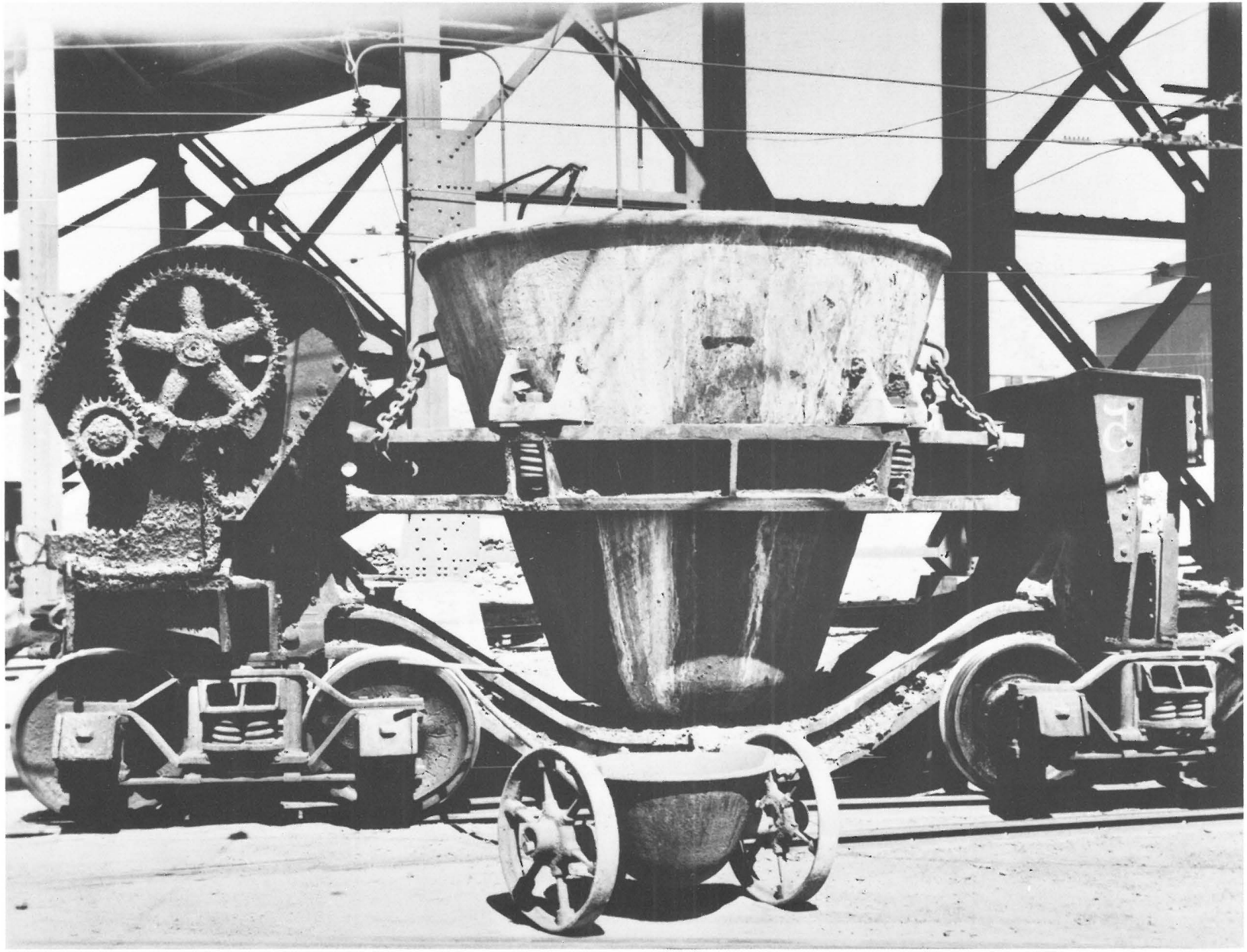


Columbia Copper Mining Co. Smelter at Helvetia, c. 1902. *Courtesy of Arizona Historical Society.*

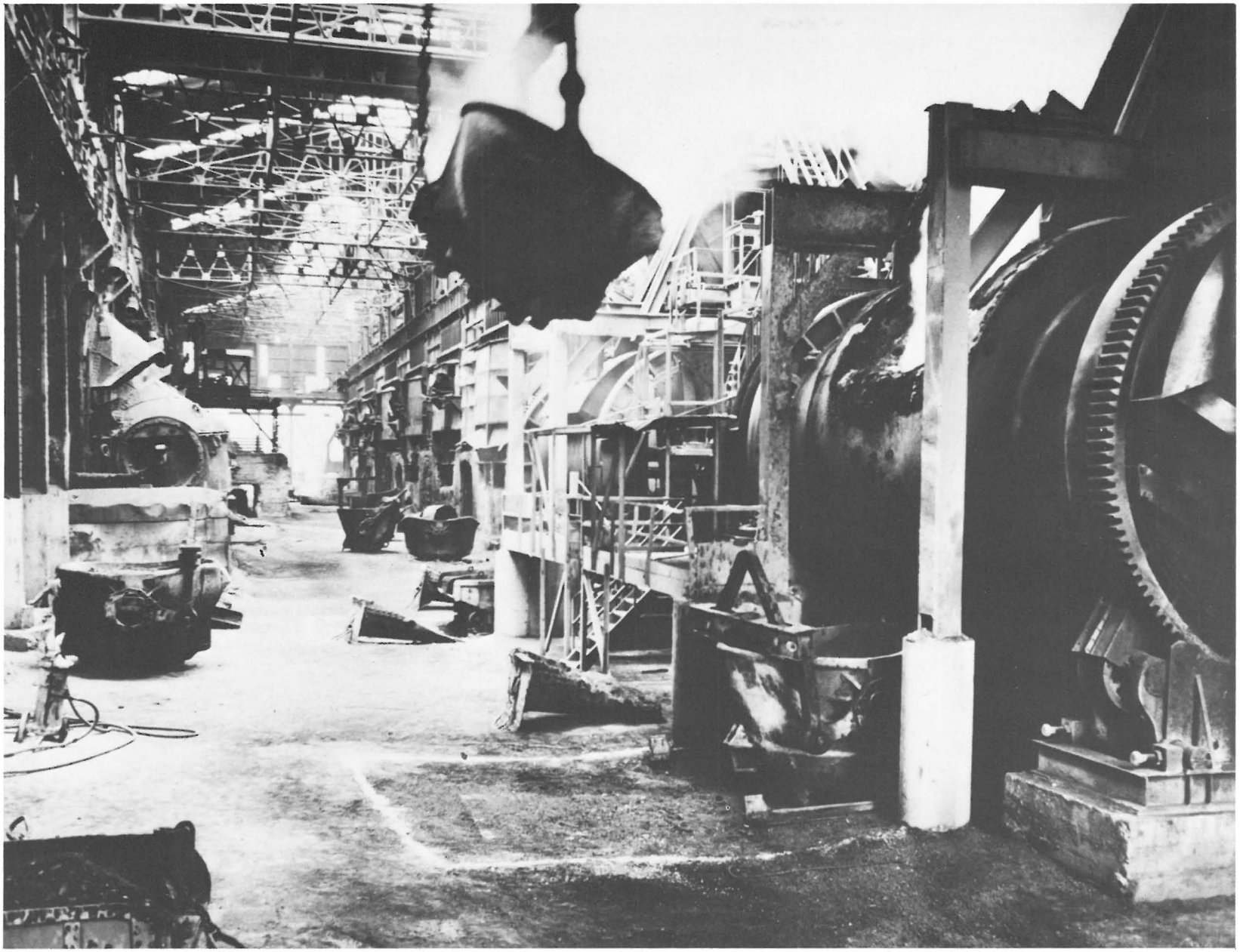
United Verde Copper Co. Ore roasting heaps smoking on the hillsides adjacent to the Jerome Smelter, 1896. *Courtesy of Arizona Historical Society.*



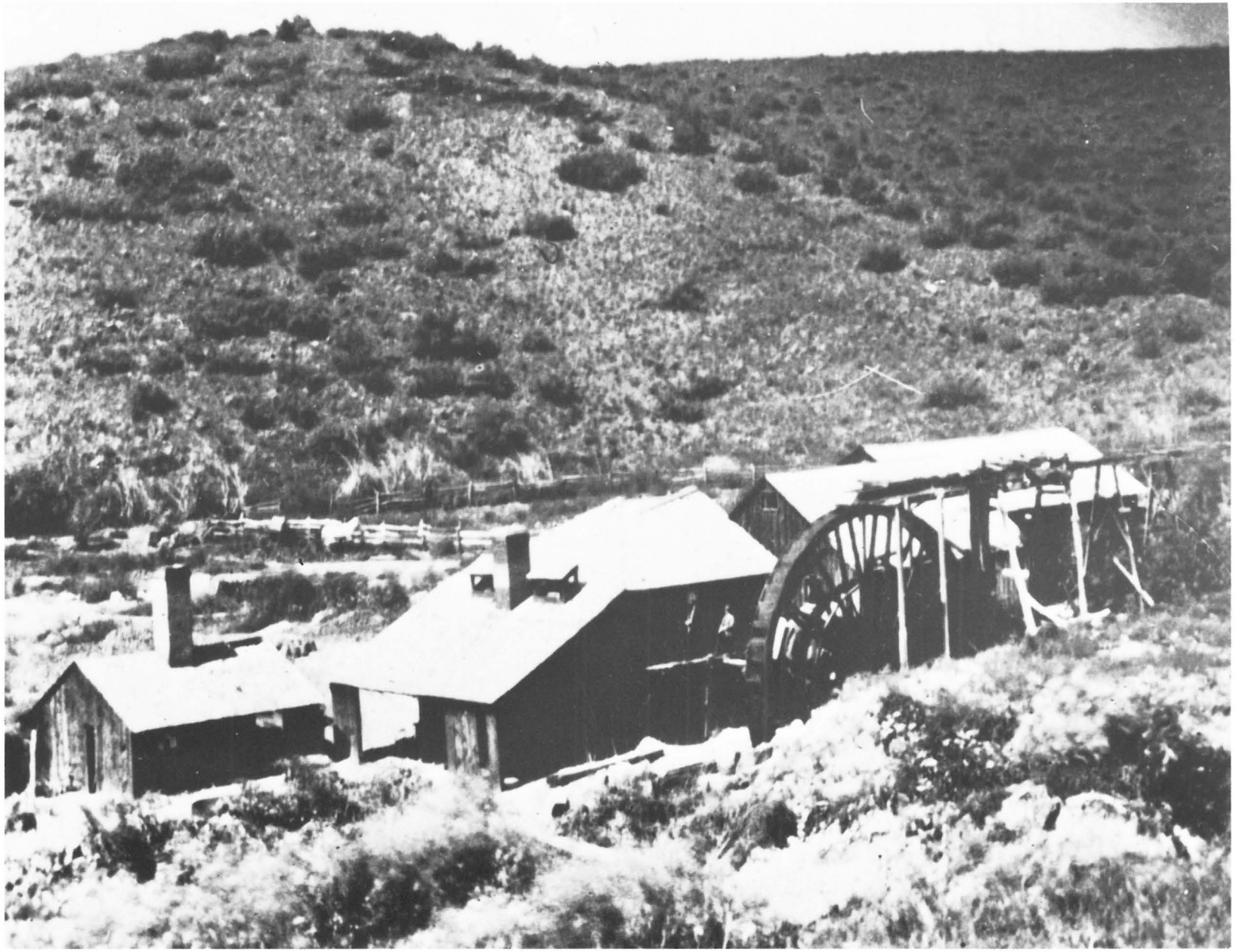
United Verde Extension Mining Co. Clemenceau Smelter, 1918. *Courtesy of Jerome State Historical Park.*



United Verde Copper Co. Clarkdale Smelter (no date). Foreground is a two-wheeled hand slag pot—early days of the Jerome Smelter. The larger pot was used at the Clarkdale smelter. *Courtesy of Phelps Dodge Corp.*



Phelps Dodge Corp.—United Verde Branch. Clarkdale Smelter, c. 1938. *Courtesy of Phelps Dodge Corp.*



Agua Fria Smelter, 1878, near Humboldt. 20-ton capacity, operated 1876-1884. *Courtesy of Sharlot Hall Museum.*

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EDITORS
J. MICHAEL CANTY
MICHAEL N. GREELEY

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