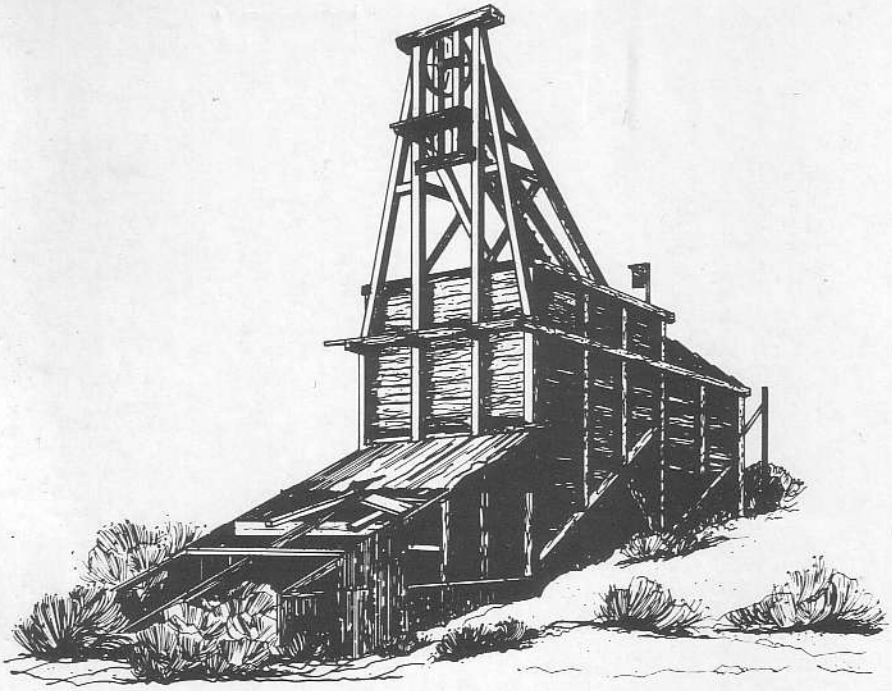
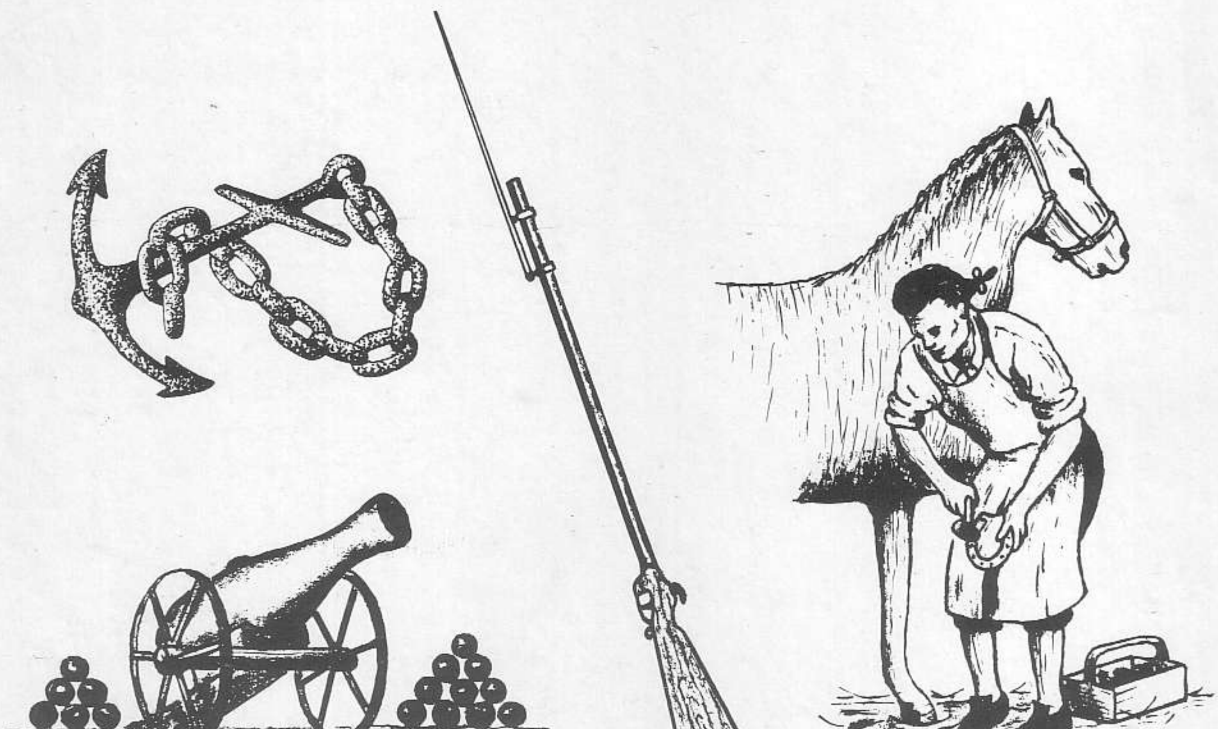


MINERAL INDUSTRY IN EARLY AMERICA



BUREAU OF MINES ★ UNITED STATES DEPARTMENT OF THE INTERIOR

Mineral Industry in Early America

By Hillary W. St. Clair

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.

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MINERAL INDUSTRY IN EARLY AMERICA

by

Hillary W. St. Clair[1]

ABSTRACT

Mining activity began in colonial times with ironmaking operations scattered along the eastern seaboard. Iron furnaces and forges manufactured iron implements from bog iron ores using charcoal from the extensive forests as a fuel. Lead ores were mined in the Mississippi Valley and copper ores in the Lake Superior region. However, the real beginning of the American mining industry did not occur until the 19th century.

The history of American mining is organized around three epochal events. The first was the discovery of gold in California in 1848, which marked the beginning of a period of apprenticeship in mining and metallurgical techniques. The second was the discovery of the fabulous Comstock Lode in western Nevada in 1859, which expanded mining throughout the Far West and led to large-scale underground mining and the development of smelting techniques for lead, silver, and copper ores. The third event was the building of a transcontinental railroad system after the Civil War, which brought about the consolidation of the industry from a large number of independent mines, mills, and smelters into integrated operations run by large corporations. Thus developed the mining industry that today supplies the energy and critical materials for the greatest industrial complex the world has known.

INTRODUCTION

Anniversaries have long been occasions to review and ponder the past. In keeping with the general review of our history that took place during the 200th anniversary of the Republic, the Bureau of Mines sponsored a review of the early history of American mining. In this study, mining is considered in its broadest sense; it includes not only the extraction of ores and minerals from the earth, but also the separation and refining of metals and mineral products to prepare them for use.

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[1]Metallurgical engineer (now retired).

ACKNOWLEDGMENTS

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MINING DURING COLONIAL TIMES

Although one of the declared purposes for establishing the first colony in Virginia was to prospect for precious metals, this hope met with great disappointment. Precious metals such as the Spanish found in Central and South America were not found by the original North American colonists. The only mineral industry that developed widely from colonial times through the 18th century was ironmaking. This industry was based on the plentiful supply of wood for making charcoal rather than extensive or high-grade iron deposits. The iron was made from relatively small, widely scattered deposits of bog iron ore; it was produced in small quantities to supply local needs. There is also evidence of some lead mining, particularly during the War for Independence, but these operations seem to have been desultory and small scale. In fact, most of the lead used for the American Army's bullets was imported or reclaimed from lead objects such as sash weights or lead pipe. Shortly after the Revolution began, Governor Winthrop of Connecticut ordered a leaden equestrian statue of King George III melted down; it produced 42,000 bullets.

The earliest systematic study of the geology and mineral deposits of North America was undertaken by William Maclure, a Scotsman who became an amateur geologist. He immigrated to America in 1779 and successfully entered the mercantile business. Later, he turned his attention to the geology of the New World and crossed the pathless tracts of the Allegheny Mountains alone no less than 50 times. His observations covered the area from the St. Lawrence River to New Mexico. In 1809, he published his observations and a geological map showing a systematic classification of rocks. He has been referred to as the father of American geology.

Ironmaking in the 17th and 18th Centuries

The early iron furnaces were usually variations of the catalan forge, named for Catalonia, Spain, where a large proportion of the world's iron was once produced. This furnace had a shallow hearth with an airblast and resembled a large blacksmith's forge. A large pasty mass of iron weighing 300 to 400 pounds was formed on the hearth after coarsely pulverized ore was heated in burning charcoal for about 3 hours; this mass was called a bloom. Thus, the process that evolved in America became known as the American bloomery process. It was a direct process because the ore was converted directly into malleable iron, which could be hammered and worked to remove the slag and produce a bar of wrought iron.

At the time of the colonization of North America by the English, iron production was declining in the Mother Country because of the diminishing supply of charcoal from British forests. At the same time, the demand for iron was increasing. Consequently, there was great incentive to begin ironmaking in America and thereby take advantage of the plentiful supply of wood in American forests, which had to be cleared in any case. Although iron ore was discovered in 1585 in North Carolina by Sir Walter Raleigh's expedition, no use was made of it at the time. In 1607, the Virginia Co. of London founded the first permanent English colony. In April of the following year, a load of iron ore was shipped to England and smelted to produce 17 tons of iron. In 1610, Sir Thomas Gates reported to the company council in London that the plentiful supplies of iron ore in the colonies would yield iron as good as any in Europe.

In 1619, the London Co. sent a shipload of immigrants to Virginia. About 150 of these persons were skilled in iron manufacture. Smelting works were erected near Falling Creek, a branch of the James River, not far from Jamestown. The brown ores of the region produced tolerably good iron. Unfortunately, this operation aroused the hostility of the Indians and in May 1622, 345 settlers were killed and the ironworks and glass furnace were destroyed. As a result, ironmaking in Virginia was discontinued for more than a century, although there were plentiful supplies of both wood and iron ore.

In 1724, there were four furnaces in Virginia but no forge. The iron was converted to bar iron at the Principio Forge in Maryland. For a report on the status of the iron industry in Virginia, we have no less authority than Thomas Jefferson. In his Notes on Virginia, published in 1781 (37, pp. 27-28),[2] he makes the following observations:

> "The mines of iron worked at present are Callaway's, Ross's, and Ballandrine's on the south side of the James River, Old's on the north side in Albermarle, Miller's in Augusta, and Zane's in Frederick. These last two are in the valley between the Blue Ridge and North Mountain. Callaway's, Ross's, Miller's and Zane's make about 150 tons of bar-iron each in the year. Ross's makes also about 1,600 tons of pig-iron annually; Ballandrine's, 1,000; Callaway's, Miller's and Zane's about 600 each. Besides these, a forge of Mr. Hunter's at Fredericksburg makes about 300 tons a year of bar-iron imported from Maryland; and Taylor's forge, on Neapsco of Potomac, works in the same way, but to what extent I am not informed. The undertakers of Iron in other places are numerous, and dispersed through all the middle country. The toughness of the cast iron of Ross's and Zane's is remarkable. Pots and other utensils cast thinner than usual may be safely loaded into and out of wagons in which they are transported. Salt pans made of the same and no longer wanted for that purpose, cannot be broken up in order to be melted again unless previously drilled in many parts."

Along the eastern seaboard of New England were a large number of bogs containing spongy iron ore. The ore fused easily and produced good metal for castings. Siliceous ores and seashells were available for flux. Most colonial smelting furnaces were small and crude; they produced only 12 to 20 tons

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[2] Underlined numbers in parentheses refer to items in the list of references preceding the appendix.

per week of iron. This iron was used to manufacture pots, kettles, wagon and sleigh tires, chains, anchors, and other immediate needs because the cost of importation was so great.

The first successful ironworks was established in the province of Massachusetts Bay, where iron ore was discovered in the flat meadows on the upper part of the Saugus River, near Lynn, soon after its settlement in 1629. Specimens were taken to London in 1642 with the hope that a company might be formed to finance an iron-manufacturing venture. In 1643, John Winthrop the Younger (son of Governor Winthrop of Connecticut) and 10 partners were granted the exclusive privilege of making iron for 21 years, with the provision that they could make enough iron for the colony's use within 2 years. Additional grants in 1643 provided for other settlers to become proprietors by paying £100 plus an allowance to the original investors for the £1,000 already disbursed. The purpose of the grant was "so the country may be furnished with all sorts of bar iron for their use at £20 per ton" (12, p. 473).

The first works were erected near Lynn on the west banks of the Saugus River. Some of the principal workmen, who came from Hammersmith, England, named the new village Hammersmith. A self-sufficient community, Hammersmith grew its own food and kept its dependence on the outside to a minimum. It was known as an iron plantation and may be considered the first American "company town." Company housing was provided and, in all likelihood, there was a company store.

Hammersmith was a complete ironworks, consisting of a blast furnace, a foundry, a forge for producing bar iron, a large trip hammer, an extensive waterpower system, storage facilities, accommodations for the workmen, and a pier for the boats to ship the products. There also was a rolling and slitting mill, the first in the New World. Fortunately, this plant has been restored by the U.S. Park Service and is available for the public to see how iron was made preceding the American Revolution. Since this plant was typical of ironmaking in colonial times, it will be described in some detail.

Local ores were mined by full- and part-time employees at pay rates ranging from 1 to 3 shillings per ton. The limonite ore, from swamps or low-lying areas that were once ponds or stagnant streams, was hauled to the works in carts at a cost of 6 or 7 shillings per ton. Flux for smelting was mined from a gabbro deposit because of its silica content. Although it was less difficult to mine iron ore than this dense igneous rock, both were mined for the same pay. The wood for making charcoal was cut by indentured servants, neighboring farmers, and craftsmen who went into the woods when their own work was slack. They were paid 2 shillings per cord for cutting and 6 shillings per score for cording.

The work of the collier, who converted the wood into charcoal, was highly skilled and therefore the best paid job at the ironworks. In 1653, colliers were paid 5 shillings per load; sometimes they earned more than the manager. The wood was charred from May to October in pits or carefully stacked mounds 10 to 14 feet high. A mound was constructed with four main tiers or layers radiating from a center chimney; chinks and crevices were plugged with smaller pieces of wood. Finally the mound was covered with turf or leaves and a coating of dust, the residue from previous charring operations. The chimney was then filled with wood chips and the mound was ignited. The trick was to char the wood without completely consuming it. Usually the pit or mound was safe for 12 hours, but thereafter it had to be tended day and night. Flames might break through the covering and destroy the pile or a gas explosion might blow off the cover. When charring did not proceed evenly, the collier had to find the weak areas and correct for them by cutting draft holes. To keep everything in balance and achieve the desired blue smoke and even settling of the pile required experience and constant attention. Charring took 5 to 6 days, and cooling, 2 or 3 more. Cooling required almost as much care as charring lest the coal be rekindled. When the collier's trained eye saw that charring was complete, the charcoal was removed and hauled to the coal house near the furnace or forge.

The blast furnace was a structure about 26 feet square at the base and 21 feet high; the outer walls sloped inward as they rose. Made of granite or other local stone bonded with a clay mortar, the furnace rested on level ground into which a subterranean drainage system had been built to avoid dampness. The furnace interior was an egg-shaped cavity, about 6 feet in diameter at its widest level. At progressively lower levels were the sloping surfaces, or "boshes," that supported the charge and a square crucible lined with refractory sandstone. Two of the outer walls of the furnace had large, deep arches; the noses of a pair of 18-foot bellows passed through the smaller arch as did the conduits, or "tuyeres," through which the blast was delivered to the crucible. The working area of the hearth and the casting floor were under the larger arch (fig. 1).

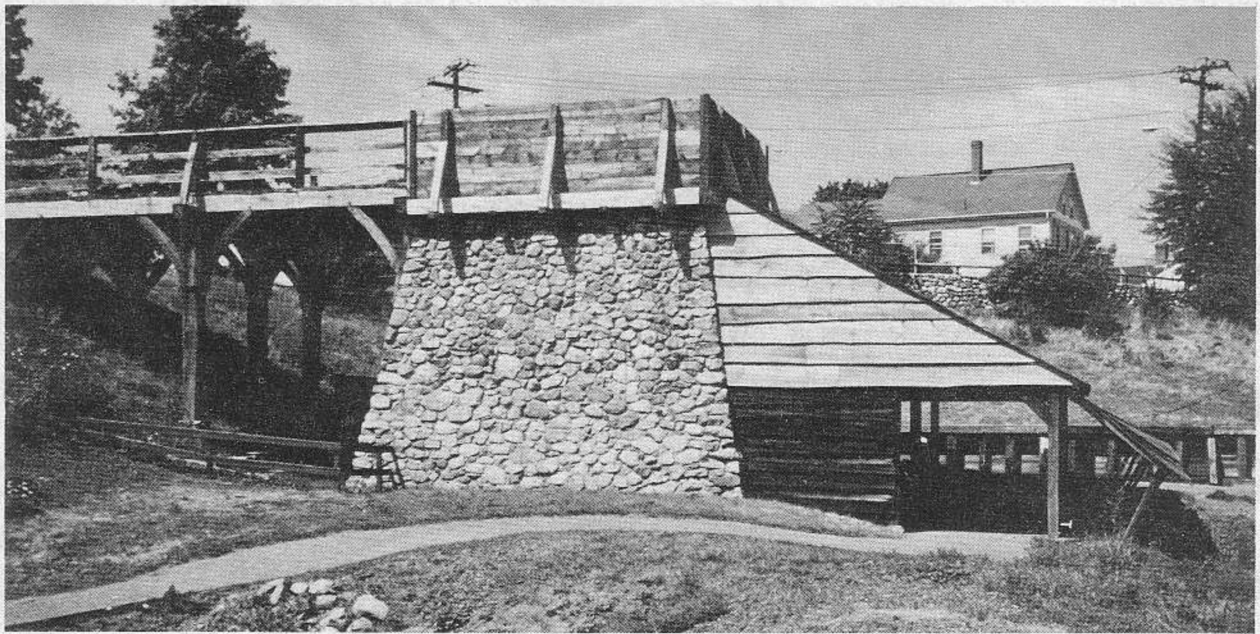

FIGURE 1. - Blast furnace at restored Hammersmith ironworks, Saugus, Mass.

To make sure that all was perfectly dry, the furnace was seasoned by firing the crucible. After 2 or 3 days, the first loads of real charge were dumped into the furnace from the charging floor and the blast was started. Approximately 3 tons of bog ore and about 265 bushels of charcoal were required to make 1 ton of iron. The ratio of ore to flux was about 3 to 2. New increments of ore, flux, and charcoal were added as needed to maintain the top of the charge at the proper level. The furnace was then operated continuously for 30 to 40 weeks. The rate of smelting was determined by the rate of the blast, which in turn was controlled by regulating the flow of water to the water wheel that drove the bellows. If the iron was kept in contact with incandescent carbon for a sufficient length of time, a considerable amount of carbon was absorbed by the metal, thereby producing a molten alloy of iron and carbon that could be readily separated from the slag. However, the resulting metal, called cast iron, was no longer malleable and was suited only for casting.

Once or twice every 24 hours, the slag was tapped; the clay plug was removed from the bottom of the furnace to allow the molten iron to run into a V-shaped ditch that had short branching ditches on either side; the iron in the main ditch was known as the sow and the iron in the branches as pigs. Hence, the term "pig iron." Sometimes the molten iron was run into molds to produce cast iron articles such as holloware or cast utensils.

Pig iron, or cast iron, an alloy of iron, carbon, and small amounts of other elements, such as silicon and manganese, is brittle and lacks toughness, strength, and malleability. To produce a forgeable, strong, tough metal such as steel or wrought iron, the pig iron must be refined to remove carbon, silicon, and other impurities. This is an indirect process. At the Hammersmith forge, the pigs were refined to wrought iron in a two-hearth process. They were first melted down and decarburized in a hearth known as the finery. The bloom produced in this hearth was heated repeatedly and hammered with a waterpowered trip hammer to produce an "ancony," a dumbbell-shaped piece that consisted of a square bar of the desired cross section in the middle and two cubical lumps at the end. At the second hearth, known as the chafery, the ends of the bar were reduced to the same uniform cross section as the middle portion. These iron bars were either marketed in this form or converted into flats, strips, or rods by reheating and rolling.

The Hammersmith forge was equipped with a set of rolls and a slitting mill, both driven by a water wheel. The slitting mill was a corrugated roll that divided flat strips into nail rods. The cut nails were finished in a blacksmith's forge (fig. 2).

Hammersmith flourished for only a few years. Although these works effected the first sustained production of cast and wrought iron in the colonies, they never produced sustained profits and eventually went into bankruptcy. Nevertheless, Hammersmith exerted a profound influence in the Massachusetts Bay Colony and other iron-producing colonies. Indeed, it served as an early prototype of American heavy industry. In addition, Hammersmith was a source of talent for other technologic activities in the colonies. John Winthrop the Younger has often been called America's first scientist; he was

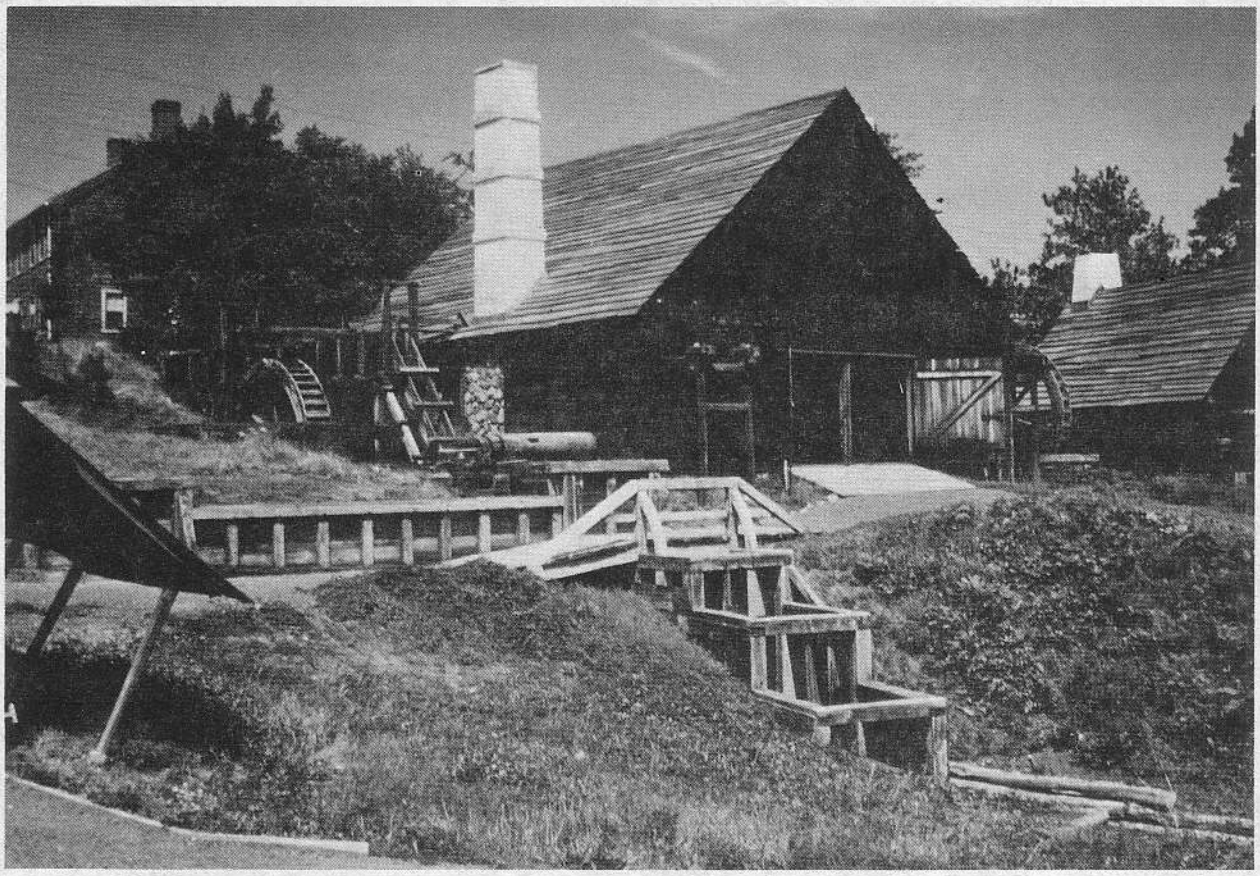

FIGURE 2. - Forge at restored Hammersmith ironworks, Saugus, Mass.

eminent enough to be admitted to the Royal Society of London, to which he contributed scientific papers. His successor as manager of Hammersmith, Richard Leader, has claim to the title of America's first engineer. He built Hammersmith; he also erected large sawmills in Maine. An employee named Joseph Jenks, a skilled blacksmith, was awarded the first machine patent in America for "engines of mills to go by water," and another patent for an improved scythe that was used widely. He is credited also for making the dies for the pine-tree shilling and building the first fire engine in America. Henry and James Leonard, skilled workers at Hammersmith, were the forebears of the Leonard family that played an important part in many iron-manufacturing operations along the east coast.

The same company that operated Hammersmith built a furnace and forge at Braintree, about 10 miles south of Boston, but ceased operation after 7 years because of lack of suitable ore. A bloomery works began operations at Taunton, Mass., in 1656 to make bar iron directly from the ore. Still active in 1865, the Taunton works then consisted of four forge fires, two hammers, and two water wheels. Other ironworks were built at Topsfield near Ipswich in 1677, at Boxford in Stony Brook in 1680, and at other sites near Taunton in 1696. Massachusetts remained the center of colonial iron manufacture for more than

100 years. Most of the works were bloomeries, but others were blast furnaces to produce castings.

The first ironworks in Connecticut were erected at New Haven in 1658. Iron was made at Pawtucket, R.I., in 1675. No evidence exists for ironmaking in Maine, New Hampshire, or Vermont before the 18th century, although numerous forges operated in New England during the latter part of that century.

The earliest New Jersey ironworks were established by Col. Lewis Morris in the town of Shrewsbury in Monmouth County. In 1676, Col. Morris was granted 3,540 acres near the east branch of the Raritan River. Around 1665, ironmaking began in Sussex and Morris Counties. By the close of the 18th century, 10 mines in Morris County supplied ore for 2 furnaces, 3 rolling and slitting mills, and 40 forges with 2 to 4 fires each. A charcoal furnace was built at Oxford in Warren County in 1743.

New Jersey bog iron ores were found in the Little Egg Harbor swamps in Burlington County. The Batsto furnace was built in 1766 near the junction of the Batsto and Egg Harbor Rivers. During the War for Independence, cannon balls and bombshells were cast there for the American Army. In 1765 several ironworks were established in the southern part of Duchess County where a furnace and foundry later produced steel and castings for the Revolutionary Army.

After the Revolution, New York's most important iron deposits were discovered in the valleys of Lake Champlain and the St. Lawrence River in the northern part of the State. Vast beds of magnetic and specular iron ore were found in the counties of Essex, Clinton, Franklin, and St. Lawrence. A foundry was set up in Willsboro, Essex County, to manufacture anchors weighing 300 to 1,500 pounds. Later, it was changed to a bloomery and produced cranks for sawmills, gristmill machinery, and steamboat irons. After construction of the Champlain Canal, a furnace was erected in the Adirondack hills near a deposit of the richest ore. The iron was exceptionally strong and tough and especially adapted to making steel and nails.

In Maryland, bog iron ores were found in Worcester, Caroline, and Dorchester Counties on the eastern shore and in Prince Georges County on the western shore. Iron manufacture began soon after 1681 when the Maryland Legislature passed a law to discourage its import. In 1719, the British Parliament authorized the award of 100 acres of land to anyone who would set up furnaces and forges in the province. As a result, by 1750, according to a report by the Governor, there were eight furnaces and nine forges in Maryland. Maryland and Virginia together exported more than 2,500 tons per year to England. The price of iron in Maryland in 1773 was £20 ($53.20) per ton for bar iron and £8 ($21.30) per ton for pig iron (<u>44</u>). The Principio Forge in Cecil County at the head of Chesapeake Bay, several miles east of the Susquehanna River, produced excellent iron from local ores and ores from Virginia, which at that time had no forge. Iron was produced in Baltimore County from ores along the Patapsco River; a furnace was erected at the mouth of Gwynns Falls and a forge, on James Falls. The abundance of iron ore, limestone, timber, stone, and waterpower stimulated the rapid growth of Baltimore as an iron-producing center after the Revolution. The proximity of these raw materials for ironmaking also led to the construction of furnaces and forges in Washington County during the 18th century. Three forges operated along Antietam Creek. The Catoctin furnace on the Monocacy River in Frederick County was built in 1774. Near Hagerstown, the Mount Etna furnace cast cannon for the Army during the Revolution. The richest iron-producing area in Maryland was Allegheny County in the westernmost part of the State, but the industry did not develop there until after construction of the Chesapeake and Ohio Canal and the Baltimore and Ohio Railroad. One of the great ironworks of the country, the Mount Savage Iron Works, about 9 miles west of Cumberland, consisted of three large steam-driven hot blast furnaces and a rolling mill with twenty-seven furnaces and two trains of steam-driven rolls.

Although iron deposits in Pennsylvania were mentioned in the correspondence of William Penn as early as 1683, the first ironworks were not built until about 1720. At that time, a bloomery began operations on French Creek in Coventry Township, Chester County. In 1728, there were four furnaces in Pennsylvania. The famous Cornwall blast furnace was built in Lebanon County about 1742. The Cornwall ore was an exceptional grade; it contained about 70 percent iron. The Mount Hope charcoal furnace, erected in 1785 in Lancaster County about 6 miles south of Lebanon, produced 800 to 1,000 tons of pig iron annually; the price was £6, 10 shillings per ton in Pennsylvania money, or $17.33 (44). Several forges appeared along Manatawney and Perkiomen Creeks. At the entrance to Valley Creek and the Schuykill River was an ancient forge known as Valley Forge. It became memorable as the winter quarters of General Washington during the darkest days of the Revolution. Before 1743, a furnace and forges were erected in Bucks County. The ore came from the Durham and Easton hills. In 1750 the "Durham boat" was specially designed to transport iron ore. It was about 40 feet long, 8 feet wide, and drew about 20 inches of water with a load of 15 tons. General Washington used the Durham boats on Christmas night in 1776 to cross the Delaware to attack the Hessian brigade in Trenton.

Of great importance to Pennsylvania's developing iron industry was the discovery in 1791 of extensive anthracite deposits in Carbon and adjacent counties. It was originally called "stone coal" and used to some extent by blacksmiths. First attempts to use anthracite as fuel for forges failed. On one occasion, after an unsuccessful attempt to raise a heat, a worker happened to return to the forge and found the furnace in a white heat. The crew was summoned and four batches of iron were heated and rolled without renewing the fire. Thus began the use of anthracite in forging. Ironmaking with anthracite began in 1839 in this country at Pottsville, shortly after it was first used successfully in South Wales.

The first western Pennsylvania ironworks was the Bedford furnace in Huntingdon County near where the town of Orbisonia is today. Another furnace was built in Huntingdon in 1795. This region had four furnaces and six forges by 1810. By 1837 there were 16 furnaces, 24 forges, and a rolling mill, which produced 13,750 tons of pig iron and 9,300 tons of blooms per year. The first furnace west of the Alleghenies was constructed in 1790 in Jacobs Creek, between Fayette and Westmoreland Counties, 15 miles above where it empties into the Youghiogheny River. The Fairchance blast furnace, 7 miles south of Uniontown, was built in 1794 and the Union furnace on Dunbar Creek, 14 miles east of Brownsville, in 1792-93.

Pittsburgh, which became the center of iron and steel production, owes its industrial importance to two physical characteristics of the area: The great bituminous coal seam, and the strategic location of the town at the confluence of three great rivers. The privilege to mine coal in the hills opposite the town was granted by the Penns in 1784. Following completion of the first furnace on the Youghiogheny River in 1790, Pittsburgh grew rapidly with increased numbers of furnaces, foundries, rolling mills, wire mills, nail works, and related manufactories.

The first steel furnace in the Pennsylvania province was built in Philadelphia in 1747. The city's forges, furnaces, and steel furnace provided iron, steel, and nails for the Philadelphia shipbuilding industry. In 1766, Philadelphia exported 882 tons of bar iron and 810 tons of pig iron at £7, 10 shillings per ton. Shortly thereafter, in 1771, 1772, and 1773, iron exports had increased to 2,358, 2,205, and 1,564 tons per year, respectively.

Notwithstanding the abundance of good iron ore in the Carolinas, very little iron was produced south of Virginia. Several ironworks were operating in North Carolina before the Revolution, however, principally around Salisbury in Rowan County. Other operations were in Guilford, Stokes, and Burke Counties. In the later part of the 18th century, ironmaking began in Washington, Carter, Greene, Johnson, and Jefferson Counties. The first ironworks in South Carolina were erected in 1773, but they were destroyed by the Tories during the Revolution.

A rolling and slitting mill operated near Wilmington in Delaware. Bog ores from Newcastle County provided the iron.

In summary, the ironmaking industry of early colonial times centered around Massachusetts. In time, principal production dispersed to New Jersey, New York, Maryland, and Pennsylvania. At the time of the War for Independence, iron was produced to some degree in each of the Thirteen Colonies.

Lead Mining in the Mississippi Valley

It is believed that the lead deposits in the Mississippi Valley were known to the French-Canadian voyagers who traded with the Indians in the 17th century. Probably during the latter part of that century, small amounts of metal were extracted by crude methods to make ammunition. Louis Hennepin's map of 1687 shows a lead mine near the present site of Galena, Ill. Father Hennepin was a companion of Robert de LaSalle, who traveled down the Illinois and Mississippi Rivers in the spring of 1682.

One of the first miners in this area was Philippe Renault, who became Director General of the Mines of the Royal India Co. in Illinois. He left France for New Orleans in 1719, taking with him 200 miners and craftsmen. On the way, he bought 500 Negro slaves in Santo Domingo. He later dispatched several exploring parties from New Orleans. Some of these explorations were led by Antoine de la Mothe Cadillac, after whom was named the Mine la Motte in the Ozark Hills of Missouri. Between 1723 and 1804, the estimated output of this mine was 8,000 tons of lead.

In 1916, some old tools were found in the abandoned workings of Mine la Motte. One tool was a three-pronged grappling iron used to displace and extract oxidized and partly oxidized ore from the cavities. Also found were small wooden car wheels, worn in a way that indicated they had run along a track of wooden rails. Another relic consisted of a bar of lead cast in the shape of a horse collar. Apparently, it was carried on a mule's shoulder during overland transport.

In 1774, Julian Dubuque, a French-Canadian, discovered lead ore near the future site of the city in Iowa that now bears his name. At a council of the Sauk and Fox Indians in 1788, he was granted formal permission to mine lead in an area 3 leagues wide and 7 leagues long beside the Mississippi River. (A league is about 3 miles.) This grant was later confirmed by the Governor of Louisiana. When Dubuque died in 1810, his Indian friends buried him in a lead coffin and refused to allow any other European to operate the mines. As a result, the Upper Mississippi lead deposits were neglected until 1821.

The Indians with whom Dubuque lived had learned from earlier Europeans how to mine and smelt the ore. Mining was done chiefly by squaws and a few old men. Usually they gathered only the ore that was near the surface. When they dug below the surface, the ore was loaded into deerskin bags and dragged up inclines by long thongs of hide. When they encountered a hard rock, they built a fire to heat the face and then caused it to crack by dashing it with cold water. This method was known to all primitive miners; it was used in Europe even after explosives were available. The Indians used staghorns for picks just as primitive European miners did. The ore was smelted in a trench furnace that consisted of a hole about 2 feet wide and 2 feet deep dug into the face of a hillside; it was tapered like a hopper and lined with flat stones. Across the lower end, narrow stones were placed to form a crude grate. A channel was dug from this crude furnace to a depression in the ground that served as a mold. The channel was filled with ore, dry wood, and brush and then ignited; the fire was maintained until the ore was reduced to lead metal. The flat ingots produced in this way weighed about 70 pounds each.

By the Treaty of Fontainbleau in 1762, France ceded the territory of Louisiana to Spain, but in 1800 at Napoleon's behest the secret Treaty of San Ildefonso returned the province to France. The retrocession was confirmed by the Treaty of Madrid in 1801. President Thomas Jefferson learned of this arrangement soon afterward and started proceedings to purchase Louisiana for the United States. By the treaty of cession signed in May 1803, the United States acquired 828,000 square miles between the Mississippi River and the Rocky Mountains for 60 million francs (about $15 million).

In 1810, the Indians of the galena district of Illinois were producing lead on a considerable scale. Likewise, the lead in Missouri was being actively mined. By this time, the smelting technique had improved somewhat over that used by Dubuque's Indian associates. The furnace, known as a log furnace, consisted of a steeply inclined hearth built on a hillside. The hearth was enclosed on two sides and at the lower end, where the wall was about 7 feet high, it had an arched opening for the admission of air. Three large supporting logs were placed transversely in the hearth to occupy the full width of the furnace. Split logs, galena ore, and then more logs were placed on the supporting logs to completely surround the ore. Although they lacked any clear notion of the scientific reasons for doing it, the workmen started the smelting with a gentle heat and raised the temperature gradually, thereby oxidizing some of the lead to the oxide and sulfate. As the temperature rose, the oxidized products reacted with galena to produce metallic lead and sulfur dioxide. Later this same reaction was carried out more effectively in the Scottish hearth that became widely used to smelt galena throughout the Mississippi Valley. From 24 to 36 hours were required for smelting; about one-half the lead content was recovered as molten lead. The residue, called lead ashes, was washed and smelted in an inclined reverberatory furnace to recover another 15 percent (fig. 3).

The first Scottish hearth was erected by Peter Lorimier in 1834 on Catfish Creek near Dubuque, Iowa, an important event for lead manufacture in the Mississippi Valley. This type of furnace was intermediate between a reverberatory and a blast furnace.

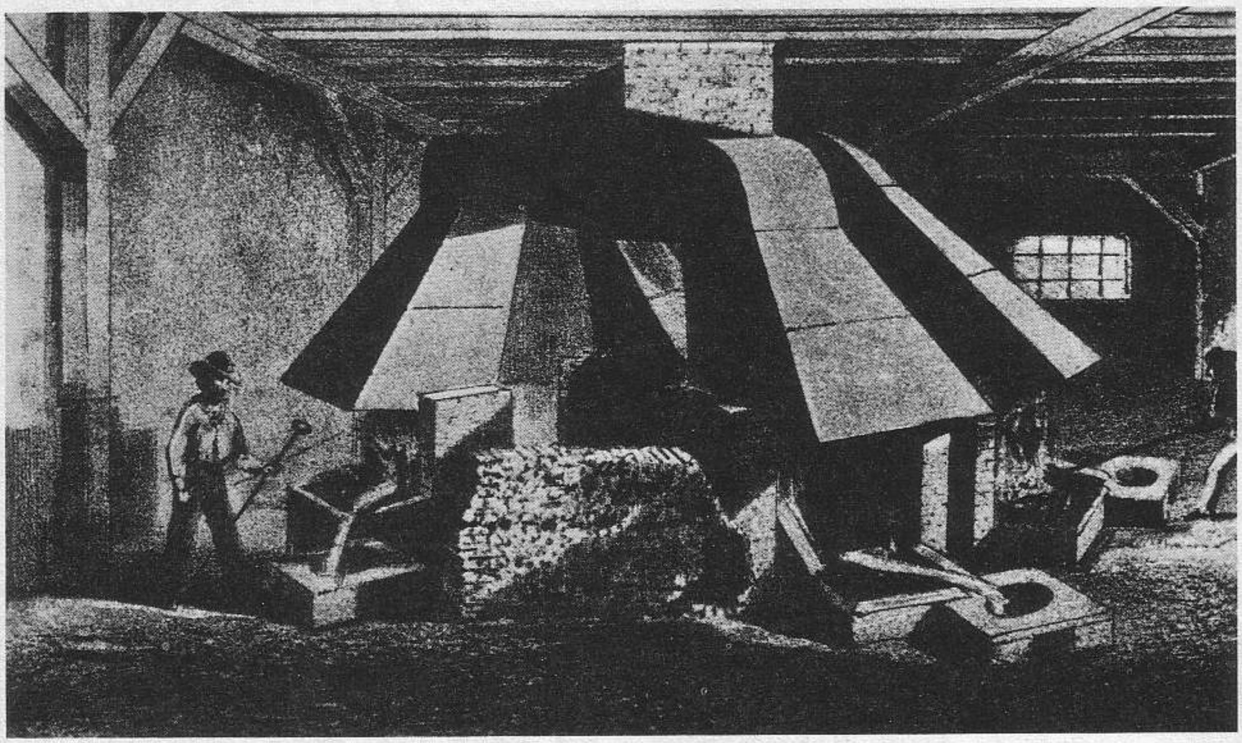

FIGURE 3. - Scottish hearth for smelting lead.

In March 1807, the U.S. Congress passed a law that reserved all Government lands containing lead ores and authorized leasing at a royalty of 10 percent. The rents and royalties specified by the act were paid regularly for a while, but as time went on, the miners paid more slowly. Although the royalty was decreased from 10 to 6 percent, even that was collected for only a short time. Eventually, the Government found itself powerless to enforce collection and in 1847 decided to sell the mineral lands.

In 1822, a Kentuckian, Col. James Johnson, obtained a lease in the Fever River Mining District, located in the vicinity of Galena, Ill. He imported some experienced miners and Negro slaves and proceeded to mine on a scale and in a style hitherto unknown in the area. Johnson's success attracted others and by 1826 more than 450 persons were working in the region. Prospectors were soon digging holes all over the Illinois-Wisconsin lead district. They did not restrict themselves to searching and mining on Government lands and frequently trespassed on the Indian hunting grounds, even where treaties specifically reserved the grounds for the Indians. In 1827, for example, Henry Dodge and 50 armed men occupied the land of the Winnebago Indians in the Wisconsin Valley and started to produce lead metal. Ignoring official warnings from the Federal agent for Indian Affairs and the Commandant at Fort Crawford, he began shipping lead down the Mississippi to New Orleans for transshipment to Europe.

At first, the Mississippi River provided the only way to transport lead to the outside world, but as early as 1822 some ore was shipped to the Atlantic Coast by way of the Fox and Wisconsin Rivers and Lake Michigan. In 1836, a company operated a combined wagon and boat service between Galena and Chicago and on to eastern markets by the Erie Canal. By 1845, the output of the Galena District was 54.5 million pounds; the average price was less than 3 cents per pound.

In 1864, the St. Joseph Lead Co. was organized to acquire and exploit a tract of 946 acres at Bonne Terre, Mo. During its first years, however, the company suffered a series of financial difficulties and misfortunes, including a raid by Confederate troops. Eventually, after a group of Cornish miners were imported and a wood-fired reverberatory furnace was erected, the operations became more fruitful. Abundant galena ore in horizontal sheets 6 to 8 inches thick was found at a depth of 4 to 8 feet. The ore was blasted, broken with heavy hammers, crushed by a Blake crusher and Cornish rolls, and concentrated by jigging. The jig was a long pole that rested on a heavy log like a seesaw. At one end, a sieve filled with crushed ore was suspended and at the other, a man sat astride the pole and see-sawed the sieve up and down in a pool of water. The heavy galena particles concentrated in the bottom of the sieve. The lighter particles of gangue at the top were discarded and the bottom concentrate was carried to reducing furnaces. These furnaces were stone ovens with sloping hearths reminiscent of the log hearths. At one side of each furnace was a firebox for wood fuel; at the lower end, molten lead ran through an opening into an iron pot from which the metal was ladled into molds. Each furnace was operated by six men and could produce 32 pigs in 24 hours, each weighing 72 pounds. Annual production was about 6,000 pigs or

216 tons. Unfortunately, the mine workings were shallow and could be operated only in dry weather, about 6 months each year.

In 1867, Charles B. Parsons, a lead-ore dresser at Northampton, Mass., was brought to Bonne Terre to become superintendent of the mill. Eventually, he advanced to resident director and guided the fortunes of the company for 43 years.

A diamond drill, imported from France to Bonne Terre in 1869, enabled important information to be obtained concerning the occurrence of ore at depths not yet reached by mining. The ore-bearing formation was a dolomite limestone, about 500 feet thick, in which lead ore was found in layers and masses of irregular shape and at various depths. Since the lead ore was quite free of other metals such as silver and copper, the smelted lead could be marketed without further refining.

In the early years, supplies and machinery coming in and lead bullion going out had to be hauled over a rough wagon road to Summit, a station 14 miles from Bonne Terre. In 1880, a narrow-gage railroad was built and owned jointly by St. Joseph Lead and a neighbor, the Desolge Lead Co. The railroad shipped metal and supplies and also removed tailings, or "chats," from the mill. A railroad that extended to the Mississippi River was completed in 1890.

In 1883, fire destroyed the mill and it was replaced by a new concentrating plant of better design with a capacity of 500 tons per day. It was equipped with newly designed jigs and side-bump Rittinger tables. The new mill recovered about 73 percent of the lead as a concentrate containing 15 percent lead. The milling cost was about 36 cents per ton. In 1890, a smelter was built at Herculaneum, about 32 miles from Bonne Terre.

In a 50-year period, the St. Joseph Co. produced about 2.7 million tons of lead. It was one of the most productive lead enterprises in the world.

Lake Superior Copper Mining

After the British conquered Canada, fur traders in the Lake Superior region began prospecting for copper. In 1766, Alexander Henry went up the Ontonagon River to investigate a copper deposit of which the Indians had told him. He found a large mass of pure copper metal imbedded in rock on the riverbank. Subsequently, Henry organized a company which began to mine the area in 1771. After one season of unrewarding labor, the project was abandoned. Many years later, in 1843, this boulder, which weighed about 6,500 pounds, was transported to the Smithsonian Institution in Washington, D.C.

Douglas Houghton, a farsighted scientist, became interested in the copper deposits near the shore of Lake Superior. After much difficulty, he persuaded the Michigan Legislature to grant a small appropriation to survey upper Michigan. Appointed State Geologist in 1837, he began unraveling the geologic structure of the copper country. His first report, printed in 1841, convinced the world of the vast copper resources in this region. The first mining permits were issued in 1844. Unfortunately, Dr. Houghton's career came to a tragic end the following year when he drowned crossing the lake in a sailboat.

The Lake Superior region was first seriously mined by the Pittsburgh and Boston Co., which was organized in 1844 to operate the Cliff mine in the Eagle River District near Keweenaw Point. The fissure veins in this area, which had been described by Dr. Houghton, contained native silver as well as copper. An adit was started at the base of a cliff where evidence of copper was found; at 70 feet, it ran into a lump of metallic copper, the first discovered by underground mining. This discovery was important because it proved that the metal boulders located erratically on the surface had their origin in lodes. Between 1846 and 1853, the copper recovered was valued at $1.3 million; the company paid dividends of $462,000. In 1870, mining stopped as the grade of ore diminished at lower levels. The mine was reopened under new management in 1872. The output rose to 1,163,000 pounds in 1875 and then declined until 1887, when operations ceased.

The Minesota mine (spelled this way because of an error by the original locater), discovered in 1847, made its first shipment in 1848. This mine is famous for producing the largest mass of native copper known. Discovered in 1857 at a depth of 150 feet, the mass weighed 420 tons. The maximum length was 46 feet; the maximum width, 12-1/2 feet; and the maximum thickness, 8-1/2 feet. The mean thickness was 4 feet. Twenty men worked for 15 months to release the copper from the surrounding rock! Then it was cut into small lumps with hammers and chisels. In all, it took 18 months to remove all the copper from the mine.

Following the initial mining of copper veins in the Eagle River District, lodes of "mass" copper were mined in the Ontonagon District at the south end of the Lake Superior region. Edwin J. Hulbert, a surveyor and a student of mining geology, discovered the Calumet lode. In 1858, while surveying for a State road from Copper Harbor to Ontonagon, he was alerted by a strong deflection of the magnetic compass needle. On the northern part of his survey, he found fragments of a brecciated conglomerate containing native copper. In 1860, while making a final survey, he observed an ancient pit, similar to others on the Keweenaw Peninsula. As a result of these observations, Hulbert bought 1,920 acres of this Government-owned land. He organized the Calumet Mining Co. in 1861 and began production in 1864. In 1866, he opened the Hecla mine. Although successful as a prospector, Hulbert was not a competent manager. To save the company from bankruptcy, he was replaced as manager by Alexander Agassiz, son of naturalist Louis Agassiz. The Calumet and Hecla mines were combined to form the Calumet and Hecla Corp. in 1871.

During the 1870's, more powerful blasting explosives became available and in the 1880's, compressed air drills replaced hand drills. Larger and more efficient steam engines provided power for hoisting and crushing. New diamond drills that extracted rock cores for analytical evaluation were used for prospecting ahead of mining.

In 1880, the output of refined copper from the upper peninsula was nearly 50 million pounds; the net earnings exceeded those of the precious metal mines in California, Colorado, or any other State. Up to 1887, Michigan produced the most copper in the Nation. After that, Montana, then Arizona, and other Western States took the lead.

Because production costs increased as the mines went deeper, the directors of Calumet and Hecla acquired additional mines in order to realize the economies of centralized control. In 1905, they bought into the Osceola, Isle Royale, Tamarock, Ahmeek, and other mines. In 1918, Calumet and Hecla produced 60 percent of Michigan copper. Two other large companies, the Copper Range and the Quincy, produced another 32 percent.

DEVELOPMENT OF MINING IN THE FAR WEST

Although there were sporadic deposits of nonferrous metals in the Appalachian Mountains, nonferrous mining was not important during colonial times or even during the early history of the original 13 States. Gold was mined in the southern Appalachians of Georgia early in the 19th century, but the amount produced was very small compared with later production in the Far West.

Except for lead mining in the Mississippi Valley and copper mining in the Lake Superior region, the nonferrous mining industry in the United States really began with the discovery of gold in California. This event brought an influx of 50,000 would-be miners to California. Many of the disappointed "forty-niners" found it impossible to return to the prosaic life they had once led and so they set out to find gold or silver in other parts of the West. Prospecting became a special branch of mining activity. The lonely, unkempt, professional prospector, supported in his quest by a "grubstake" from some local merchant, was a central figure of Western folklore. His chief resources were a self-taught knowledge of promising indications of ore and the ability to survive anything from desert heat to mountain blizzards.

The prospectors' discoveries led to the founding of mining camps throughout the Cordilleran region of North America. Geologists give this name to the highlands from the Rocky Mountains on the east to the Sierra Nevada on the west, including the central plateau regions and the Great Basin. Some of these mining camps were born, lived through a short boom, and died within a decade. Others became permanent towns and scattered centers for the rapid settlement of the intermountain region. Mining activities in the West hastened the development of a transcontinental railroad system and the coast-to-coast development of the United States.

Three principal eras may be distinguished in the history of Western mining. The first, beginning with the discovery of gold in California in 1848, was a period of apprenticeship and learning. Old mining and metallurgical techniques from Europe, Mexico, and South America developed by trial and error into practical methods of mining placers and quartz on the western slope of the Sierras.

The second era dates from the discovery of the Comstock Lode in 1859. During this period, mining expanded throughout the Far West, originating in

Nevada and spreading through the Great Basin, Colorado, Idaho, Montana, and the Southwest. Underground mining developed on a large scale, as did techniques for smelting lead, silver, and copper ores.

The completion of the first transcontinental railroad in 1869 marks the third era, which extends to the present day. In this period, the nonferrous mining industry matured. Small independent mines and processing plants consolidated into large, integrated operations run by mammoth corporations.

The California Gold Rush

The discovery of gold in California was an epochal event in American history. It occurred on property owned by John A. Sutter, a Swiss merchant who was involved in various economic activities of a pioneer settlement around his fort in the lower Sacramento Valley. Sutter sent his employee, James W. Marshall, to supervise construction of a sawmill in the Coloma Valley on the American River, about 40 miles east of Sutter's Fort. In January 1848, while excavating the millrace for the water wheel, Marshall detected gold particles at the bottom of the stream. This was just 2 weeks before the negotiation in Mexico City of the Treaty of Guadalupe Hidalgo, which officially transferred California to the United States. Sutter, when informed of the discovery, attempted to keep the news a secret until his mill was completed, but that proved impossible. Information in letters from the workers to families and friends attracted prospectors. More gold was found along the American River about 25 miles away at the Mormon Diggings, named after members of the disbanded Mormon Battalion who were mining there. The news arrived in San Francisco with Sam Brannan, a prominent Mormon who owned a store near Sutter's Fort as well as property in San Francisco.

The first public notice of the discovery appeared in the March 15 edition of a newspaper, The Californian, under the headline Gold Mine Found:

> "In the newly made raceway of the saw-mill recently erected by Captain Sutter, in the American fork, gold has been found in considerable quantities. One person brought thirty dollars worth to New Helvetia, gathered there in a short time. California, no doubt, is rich in mineral wealth; great chances here for scientific capitalists. Gold has been found in every part of the country."

On the 29th of May, The Californian announced suspension of publication and also reported:

> "The whole country, from San Francisco to Los Angeles, and from the seashore to the base of the Sierra Nevada, resounds to the sordid cry of gold! gold! gold! While the field is left half-planted, the house half-built, and everything neglected but the manufacture of picks and shovels, and the means of transportation to the spot where one man obtained $128 worth of the real stuff in one day's washing; and the average for all concerned is $20 per diem."

As more and more gold seekers moved into the foothills of the Sierras, they made new discoveries until nearly 10,000 men were grubbing away in an area extending 150 miles from the Feather River in the north to the Tuolumne River in the south. This region along the western slope of the Sierra Nevada became known as the "Mother Lode," a name that originated from a prevailing belief that all the gold in this part of California came from a single source. The population increased to 40,000 by the end of 1849, and exceeded 100,000 by the end of 1852, the year of peak production.

Fortunately for the prospectors, the geologic evolution of California had caused physical conditions favorable for the simplest kind of placer mining. In early geologic time, a subterranean intrusion of molten material produced a system of countless small veins of gold-bearing quartz that made up the so-called Mother Lode. Eventually, the overlying rock eroded, exposing the veins to westward-flowing streams that washed away the surrounding quartz and concentrated the gold in sand bars and along the bottom of streambeds, resulting in one of the richest gold-placer regions ever known (fig. 4).

For several decades preceding 1848, primitive placer mines had been worked in Georgia, North Carolina, and other States along the Appalachian Mountains. Also, many generations of Mexicans and South Americans had experience in gold, silver, and mercury mining. A few veterans from these areas came to California, but most of the forty-niners had little or no knowledge of mining. Working with the simplest tools, such as a shovel and a gold pan, the new miners washed the gravel with a circular shaking movement

FIGURE 4. - Placer mining in California.

of the pan until only a glittering streak of gold particles remained. The typical prospector's gold pan was 15 to 16 inches in diameter, 10 to 11 inches across at the bottom, and 3 to 4 inches deep.

Later a simple rocker, or "gold cradle," was devised to separate the gold more expeditiously. A gently sloping wooden box about 3 feet long was mounted on rockers. Above the upper end, a smaller box with a wire screen or perforated sheet-iron bottom was attached to prevent passage of coarse gravel or stones into the lower box. The coarse material was removed by lifting off the upper box periodically and dumping it by hand. A handle was fixed to the side of the rocker so that the operator could rock it to and fro as he poured water over the gravel with a short dipper. The fines that passed through the perforated box were washed away, leaving the gold and heavy sands behind in the bottom (fig. 5).

Although the rocker was a big improvement over the gold pan, it did not recover the finer gold particles. A further improvement, known as the "long

FIGURE 5. - Gold cradle or rocker.

tom," was a trough 8 to 10 feet long with transverse cleats or riffles to entrap the gold particles more effectively. The long tom evolved into a series of sectional launders or sluice boxes through which a stream of water passed. In the bottom of each sluice box, the riffles were supplemented by blankets whose fibers entrapped very fine gold particles better than the riffles alone. Finally, mercury was placed in the riffles to amalgamate the gold and hold it even more effectively. The amalgam was recovered periodically and squeezed through a buckskin bag. The gold residue was then heated in a retort to volatilize the mercury and leave the gold (fig. 6).

FIGURE 6. - Miner panning gold near a sluice box in California.

As more capital became available, three more advanced mining techniques developed: river mining, hydraulicking, and quartz mining. In river mining, a stream was dammed and diverted so that gold could be dug from the dry bed. This was a speculative enterprise that required careful planning and the combined effort of many men. Work began in late June or early July. After a summer of toil, the stream was usually diverted by September, allowing several weeks to remove the gold before the annual fall rains washed out the temporary dam. This method was very profitable in the mid-1850's, but by the end of the decade the richer river bottoms had been worked out. Operations on marginal streams were continued by Chinese immigrants who were willing to work for smaller returns (fig. 7).

The deep gravels were first mined by digging shafts and tunnels, but later hydraulic mining proved more effective. In hydraulic mining, the gold-bearing gravel bank was washed with a jet of water that passed through a high-velocity nozzle. To build up the necessary pressure, the water from upstream flowed horizontally in wooden flumes along one wall of a valley and then down through iron pipes to the bottom of the valley. This violent jet of water produced a slurry that passed through long lines of sluice boxes to separate and recover the gold (fig. 8).

Hydraulic mining could be applied only in areas with extensive deposits of deep gravels; it required large amounts of capital to purchase expensive equipment and supplies and develop the water supply. It was better suited to hired labor working under a supervisor than to informal cooperative

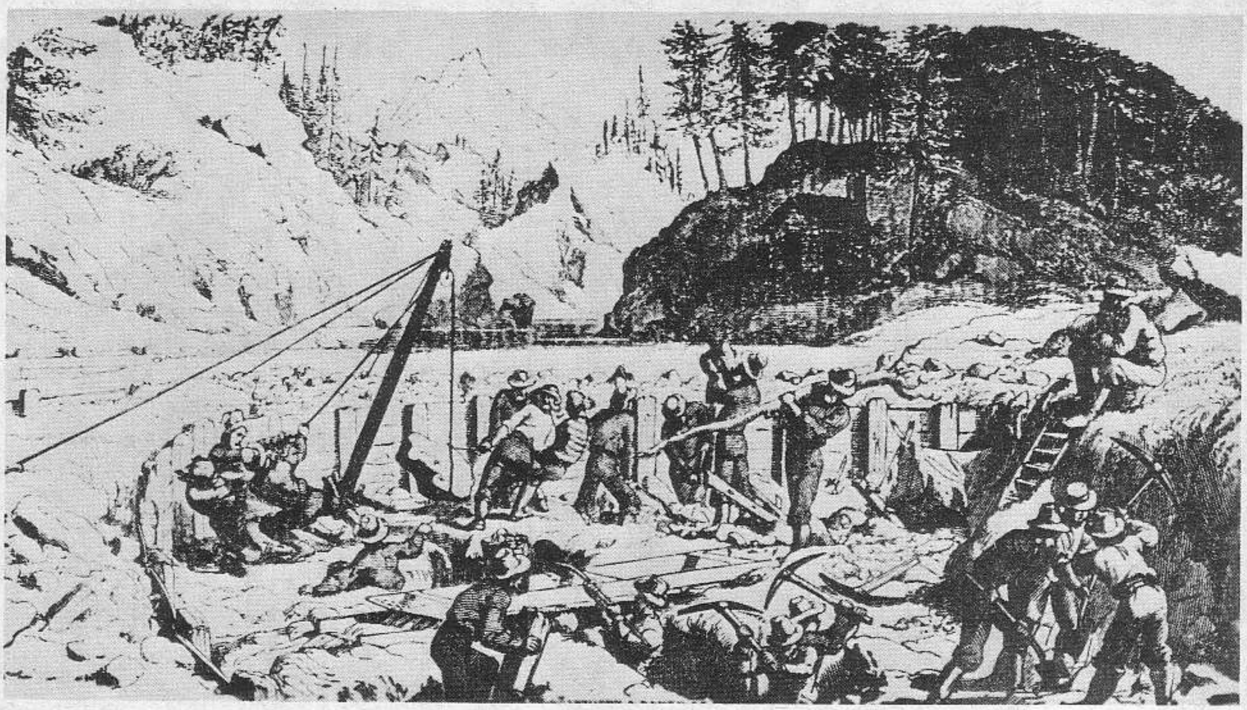

FIGURE 7. - River mining in California.

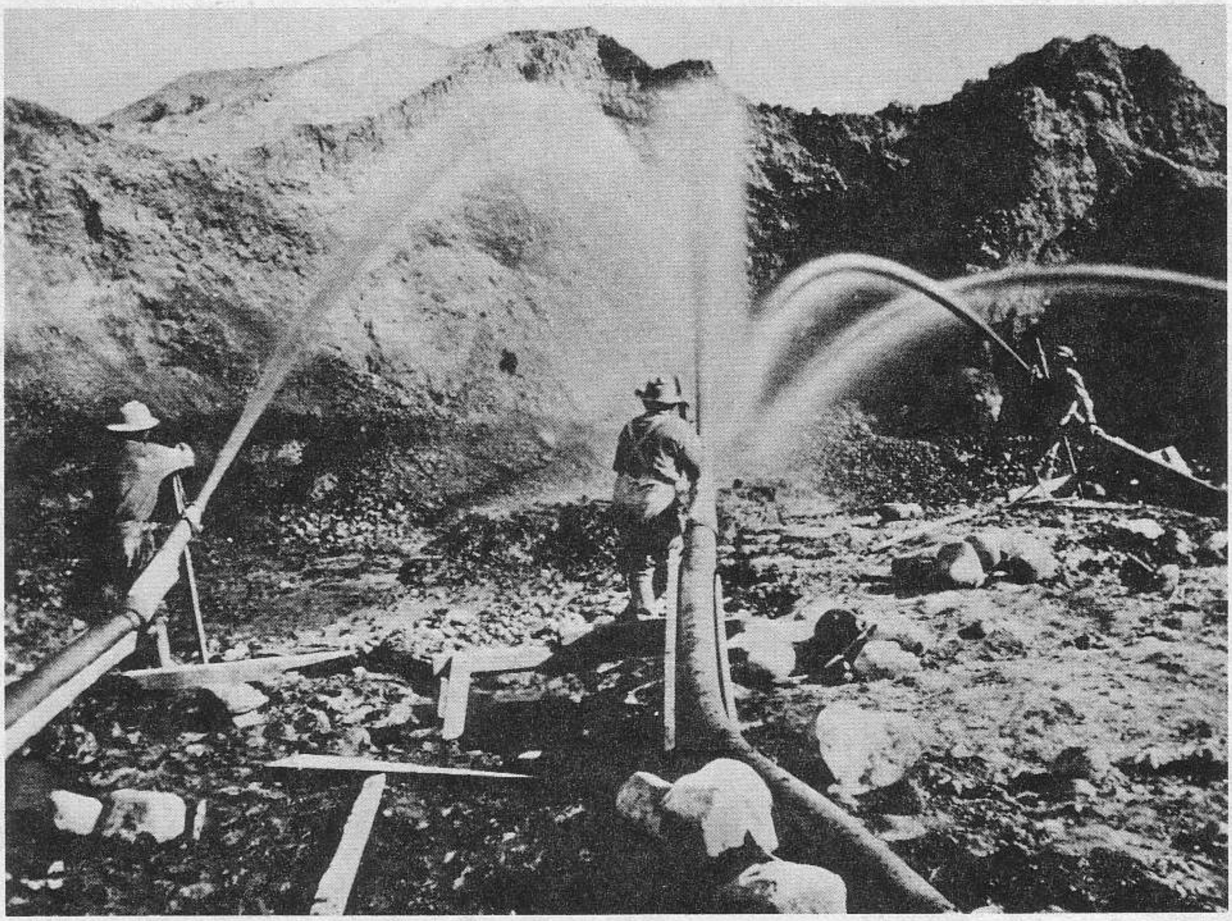

FIGURE 8. - Hydraulic mining in California.

arrangements. On a large scale, hydraulic mining became a very inexpensive mining method, especially after the technique had been refined; it was eventually possible to recover the gold at a cost of a few cents per cubic yard of gravel. Unfortunately, the more effective this method became, the more destructive it was to the landscape. Whole hills were washed away, leaving huge open cuts in the previously forested mountainsides. At the end of the sluices, the dirt, gravel, and rocks spread out along the canyon or valley until the heavy winter rains swept the whole mass down into the lower valleys at the foot of the Sierras. As this rich farmland was brought into cultivation during the 1860's and 1870's, the frustrated farmers sought injunctions to restrain hydraulic mining and finally succeeded in a series of suits from 1881 to 1884.

Quartz mining, or underground mining of gold-bearing quartz veins, accounted for about 10 percent of California's gold production in the 1860's and about 30 percent in the 1870's. The chief quartz mining towns were Grass Valley and Nevada City. It was long-term mining that required technical skill of a high order, backed by a growing capital investment. Mining techniques were learned from veterans of older mining regions--Cornishmen, Georgians, Spanish Americans, and Germans. Since early shafts were quite shallow and the underground workings were small, operators were spared the more difficult problems of hoisting, timbering, and ventilation. Even so, hewing out gold-bearing rock was a difficult business. It took several years of painful trial and error to learn how to sink a shaft, break the ore loose, hoist the ore to the surface, and extract the gold (fig. 9).

Since the gold in the vein was not free, as in placer deposits, the quartz had to be finely crushed to release the gold particles. A cheap and simple means for crushing was the arrastra, a device used by the Mexicans and South Americans. The ore was crushed by the abrasive action of heavy stones hitched to a horizontal arm pivoted to a post in the center of a hard-surfaced circular bed with retaining walls. The arm was rotated originally by mule power and later by waterpower. Sometimes the Chili mill, a modified arrastra, was used, in which a massive stone wheel was substituted for the heavy stones (fig. 10).

Generally, the arrastra and Chili mill functioned too slowly and were subsequently replaced by a stamp mill, in which the crushing was done by a heavy stamp striking a mortar. The stamps were heavy iron heads mounted on vertical stems that rose and fell by the action of cams on a rotating shaft. The rock was introduced at the back of the mortar and the fine material was discharged as either a dry or wet pulp through screens on the front. The gold was then separated from the gangue in much the same way as in placer mining. As a result of the many practical improvements made by California

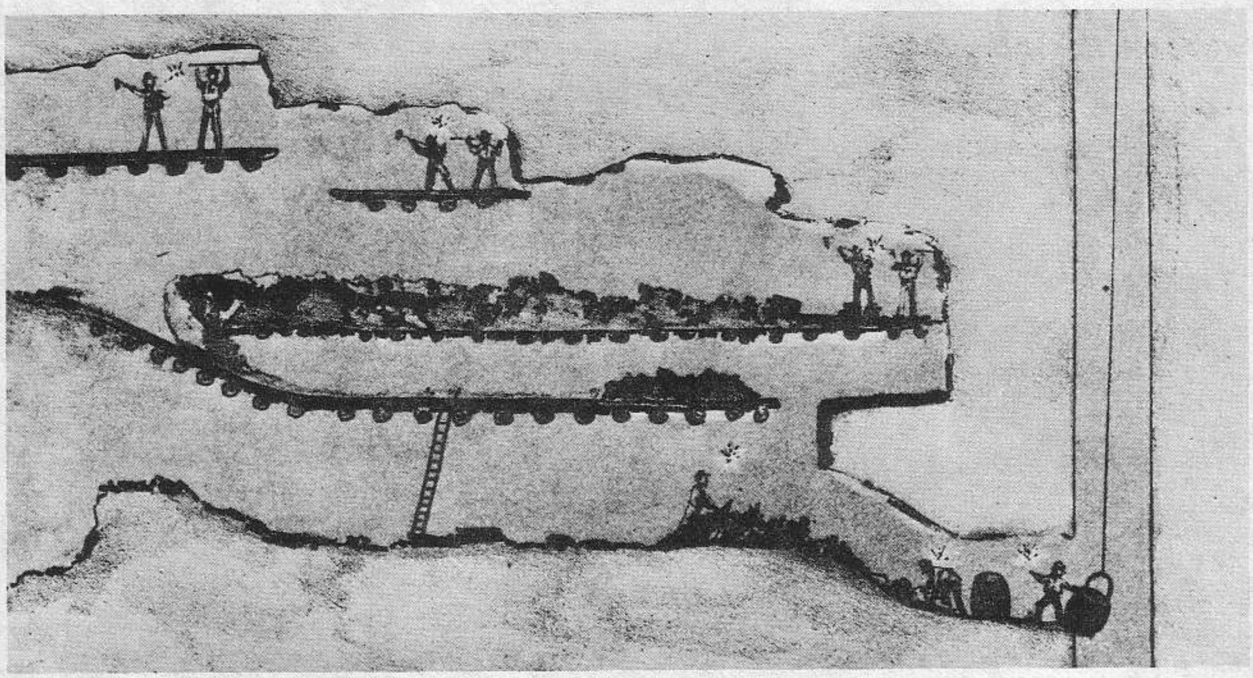

FIGURE 9. - Quartz mining in California.

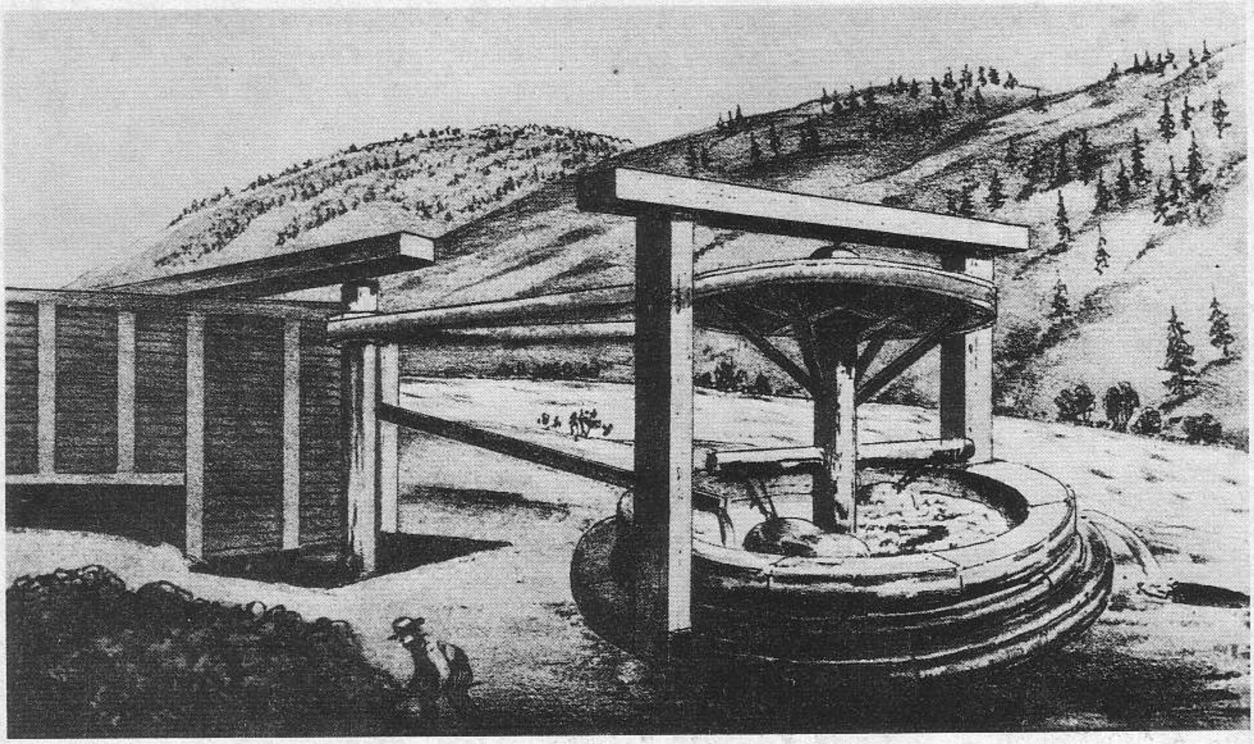

FIGURE 10. - The arrastra.

operators, this machine was called the California stamp mill. It was one of California's contributions to mineral technology (fig. 11).

Since no government existed in the new frontiers, the new settlers had to devise their own rules and procedures for protecting property rights, especially the ownership of mining claims. Lead miners from Wisconsin had some limited experience with this problem; Spanish Americans were familiar with the mining ordinances of Mexico, which in turn were based on old European codes; and the Cornishmen and Germans were also versed in well-developed and tested codes. In California, each locality formed a mining district by voting itself that status at a self-initiated meeting. The residents elected a presiding officer, drafted and adopted a code of laws that was enforced by the combined action of the group, and chose a recorder to keep a descriptive list of mining claims. A claim belonged to the man who discovered it or bought it from a previous claimant, provided he did a specified amount of development work. Maximum permissible dimensions for a claim were stipulated. To give everyone equal opportunity, the early laws stated that no man could hold more than one claim within a district. Usually controversies over ownership were arbitrated by an elected judge or presiding officer, or argued before a committee or town meeting sitting as a jury. In 1851, Stephen J. Field, a young assemblyman who later became a justice of the U.S. Supreme Court, induced the State of California to pass a statute that declared the following:

"In actions respecting mining claims, proof shall be admitted of the customs, usages, or regulations established and in force at the bar, or diggings, embracing such claim; and such customs, usages, or regulations, when not in conflict with the Constitution and Laws of this State, shall govern the decision of the action."

The precedent-setting California codes and procedures migrated to other parts of the West along with the veterans of the Mother Lode and placers. When the Public Lands Commission examined the situation in 1880, it concluded that California common law had become the American mining law for the whole area west of the Missouri River.

The Comstock Lode

In the wake of the California gold rush, the fabulous Comstock Lode was discovered in 1859 in the Washoe Mountains, a range of sagebrush-covered hills that jut eastward from the Sierras into the Great Basin. About 2,000 feet below the summit of Mount Davidson, the most easterly hill, was a vein of decomposed quartz that yielded silver and gold worth $300 million during the next two decades.

Initially, miners were attracted to the Washoe Mountains by gold washed from smaller veins. Members of the disbanded Mormon Battalion panned the first gold there in the summer of 1848. The news of this discovery prompted drifters from California to try their luck. Because the returns were scant, most of the miners moved on. Two young brothers from Pennsylvania, Ethan A.

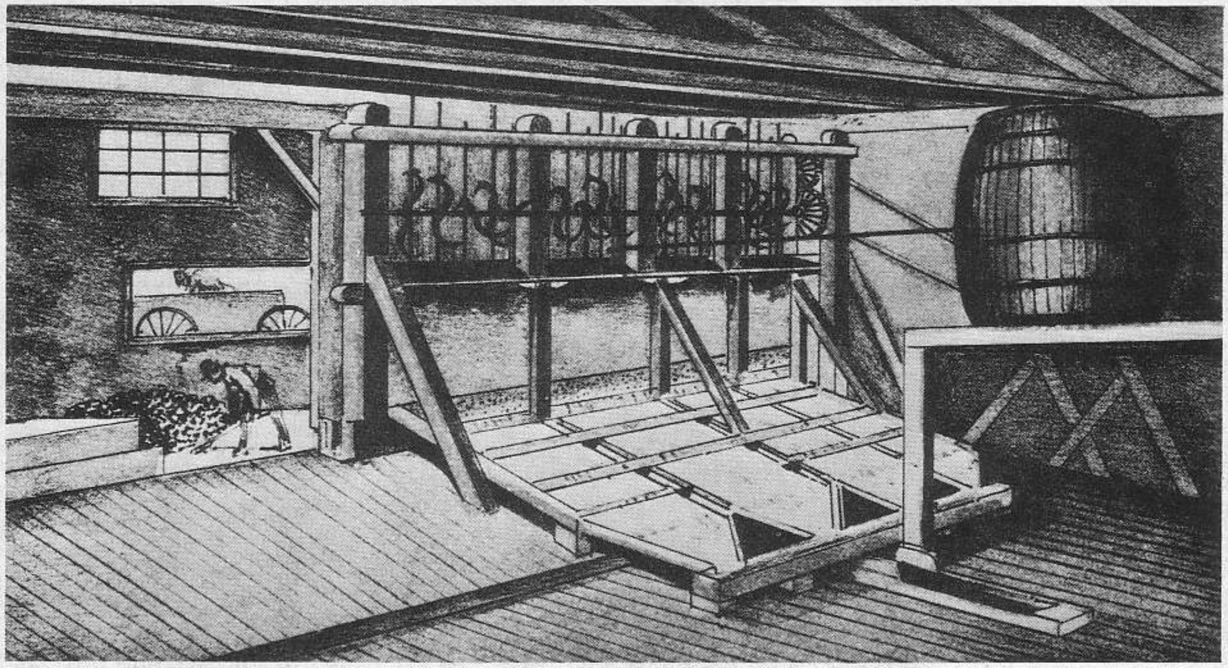

FIGURE 11. - The California stamp mill.

and Hosea B. Grosh, came to Washoe in 1851 and stayed in the belief that their superior education would enable them to find the source of the placer gold. They spent their days mapping the quartz veins that honeycombed the mountain. In a letter to their father, written in November 1856, they said, "We found two veins of silver at the forks of Gold Canyon. One of these is a perfect monster." A year later, they were ready to seek capital to develop their claims, but Hosea died from an injury. Before Ethan could pay off the debts contracted during Hosea's illness, snows blocked the Sierra passes. While trying to reach California in December 1857, Ethan suffered a fatal case of frostbite. Probably the vein discovered by the Grosh brothers was not the Comstock Lode, but a subsidiary vein that later proved unprofitable.

The main lode was discovered by James Fennimore (alias Finney), also known as "Old Virginny," a bibulous prospector reputed to be the best judge of placer ground in the Washoe country. In January 1859, he and three friends found encouraging traces of gold in their washing pans at a spot they named Gold Hill. In the spring, they found richer dirt as they progressed down the hill and in April, they chanced upon a branch of the Comstock Lode at a depth of 10 feet. Unfortunately, their find went unappreciated. The vein was rediscovered later by two prospectors, Peter O'Reilly and Patrick McLaughlin, while they were accumulating a grubstake to move on to more promising country. As they dug a reservoir to catch spring water, they found a heavy dark soil similar to that of Gold Hill, a yellowish sand mixed with bits of quartz and a friable black rock. They washed it in their rocker and were overjoyed to find the bottom of the cradle covered with gold dust.

Henry T. P. Comstock was a tall, gaunt Canadian who had staked a claim at Gold Hill. A lazy opportunist, he took over the cabin vacated by the Grosh brothers and kept title to his claim through the labors of two Indians. Passing by soon after McLaughlin and O'Reilly had been working their cradle, he noticed the rich contents of the rocker. Cooly he informed them that they were trespassing on land that belonged to him, Emanuel Penrod, and Old Virginny, pretending that he had staked out 160 acres encompassing the two men's spring and trench. Hence, Comstock and Penrod became partners of McLaughlin and O'Reilly and Comstock agreed to buy out Old Virginny. Later, Joseph D. Winters became a fifth partner. Since Henry Comstock was the most officious and garrulous of the five, the mine became known as Comstock's Lode. Within a few days, it was producing $300 in dust and scales for every cradle of dirt. On June 11, the decomposed black rock ran into a heavy bluish quartz that clogged their cradles. Penrod, suggesting it might be valuable, proposed that each partner locate an additional 600 foot claim. When samples were assayed in Nevada City, Calif., on June 27, the troublesome "blue stuff" was identified as silver ore worth $3,876 per ton. Although the mine, named the Ophir mine by the partners, became one of the richest in mining history, all the original owners sold out for pitifully small amounts. McLaughlin got $3,500; Comstock, $10,000; and O'Reilly, who held out the longest, $40,000. All died in poverty.

The Ophir strike triggered another rush to the Washoe country, one quite different from the Sacramento Valley rush. All the Washoe mines were already appropriated; the area offered no great prospects for the individual miner without capital. His only opportunity lay in employment as a miner working for wages and even this possibility was delayed until capital could be raised to develop the mine. Those who stayed threw up a group of shanties that evolved into the famed camp of Virginia City. Supposedly, the name was bestowed by Old Virginny, who stumbled home from the saloon one night, fell, and broke his bottle of whiskey. Staggering to his feet, he sprinkled the few remaining drops on the ground and proclaimed, "I baptize this ground Virginia town" (fig. 12).

Most of the rush migrants were refugees from the decaying placer camps in California, unsuccessful prospectors, or inexperienced hands from the Missouri frontier, along with the usual complement of speculators, saloon-keepers, merchants, and drifters. Since much capital and skill were required to develop silver veins, many who stayed turned to speculating in mining claims and town lots. As a result, the land was soon covered with nearly 17,000 ill-justified claim notices, most of them worthless for mining purposes. One-half the total production and four-fifths of the dividends came from only two pairs of adjacent mines--the Crown Point and Belchar, and the Consolidated Virginia and California.

Ore from the Comstock Lode was extracted by a few experienced, but not prosperous, veterans from California lode mines. An illustrious example was intelligent, hardworking George Hearst, who had experience in the Missouri lead mines before he came to California in the autumn of 1850. Unsuccessful as a placer miner and storekeeper, he decided to concentrate on quartz mining in Nevada City and Grass Valley. Upon hearing of the fantastic assays of the "blue stuff," he hurried over the mountains, arranged to buy one-sixth interest in the Ophir mine, and then backtracked to Nevada City to raise money. He sold his share in a California mine and borrowed $1,000, returned to Washoe, got out 38 tons of selected ore, and packed it over the mountains on muleback through the winter snow. It was smelted in San Francisco and returned $91,000 to Hearst and his associates. Thus began the famed Hearst fortune.

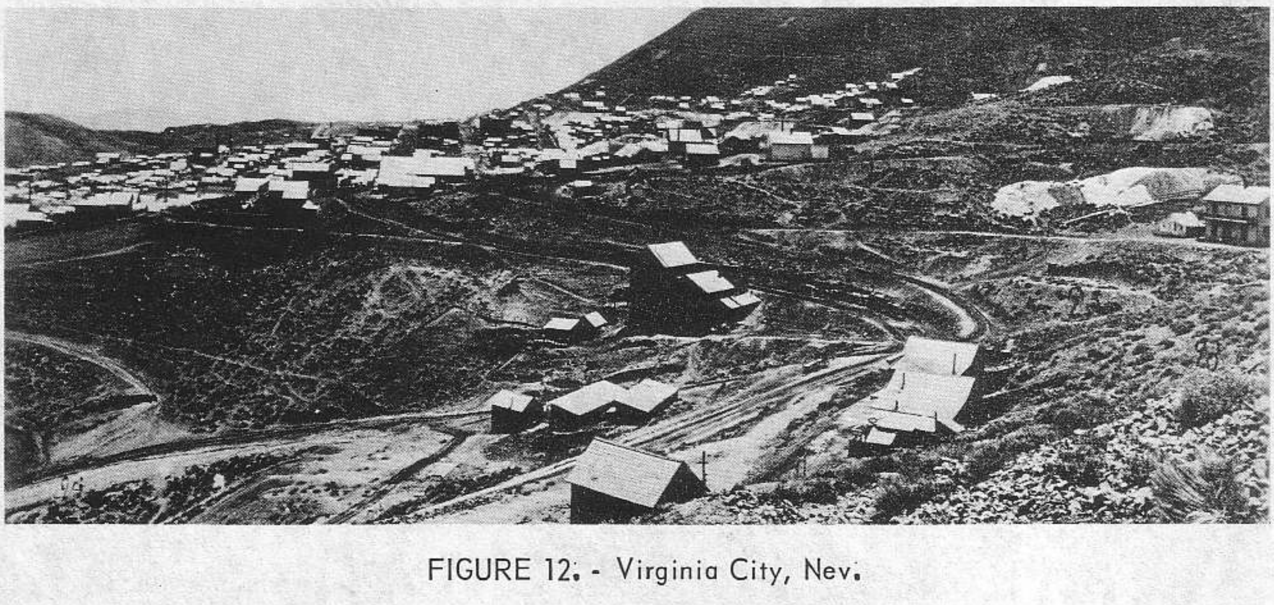

FIGURE 12. - Virginia City, Nev.

At a depth of 50 feet, the Ophir mine became flooded with underground water, and pumping and hoisting equipment had to be installed. At a depth of 175 feet, a totally new problem arose. The vein expanded to 45 to 65 feet in width and the ore was soft and crumbling. Timbers used as pillars broke under the load. It looked as though further mining would be too dangerous. To solve this problem, an able young German mining engineer, Philip Deidesheimer, was hired to improve the method of timbering to support the ground. Within a few weeks, he designed a system of timbering based on his experiments in California gravel and quartz mines that adapted well to the purpose. Timbers were framed together in rectangular sets, each set composed of a horizontal square base made of four timbers (sills and crosspieces) from 4 to 6 feet long, surmounted at the corners by four posts from 6 to 7 feet high, and capped by a framework identical to the base. The cap pieces at the top of any set also served as the base, or sills, of the set immediately above. These sets could be extended to any required height and over any area, forming a series of floors like the stories of a house. The spaces between the timbers were filled with rock waste to form a solid structure for maximum firmness. The square-set method was an outstanding contribution to mining technology (fig. 13).

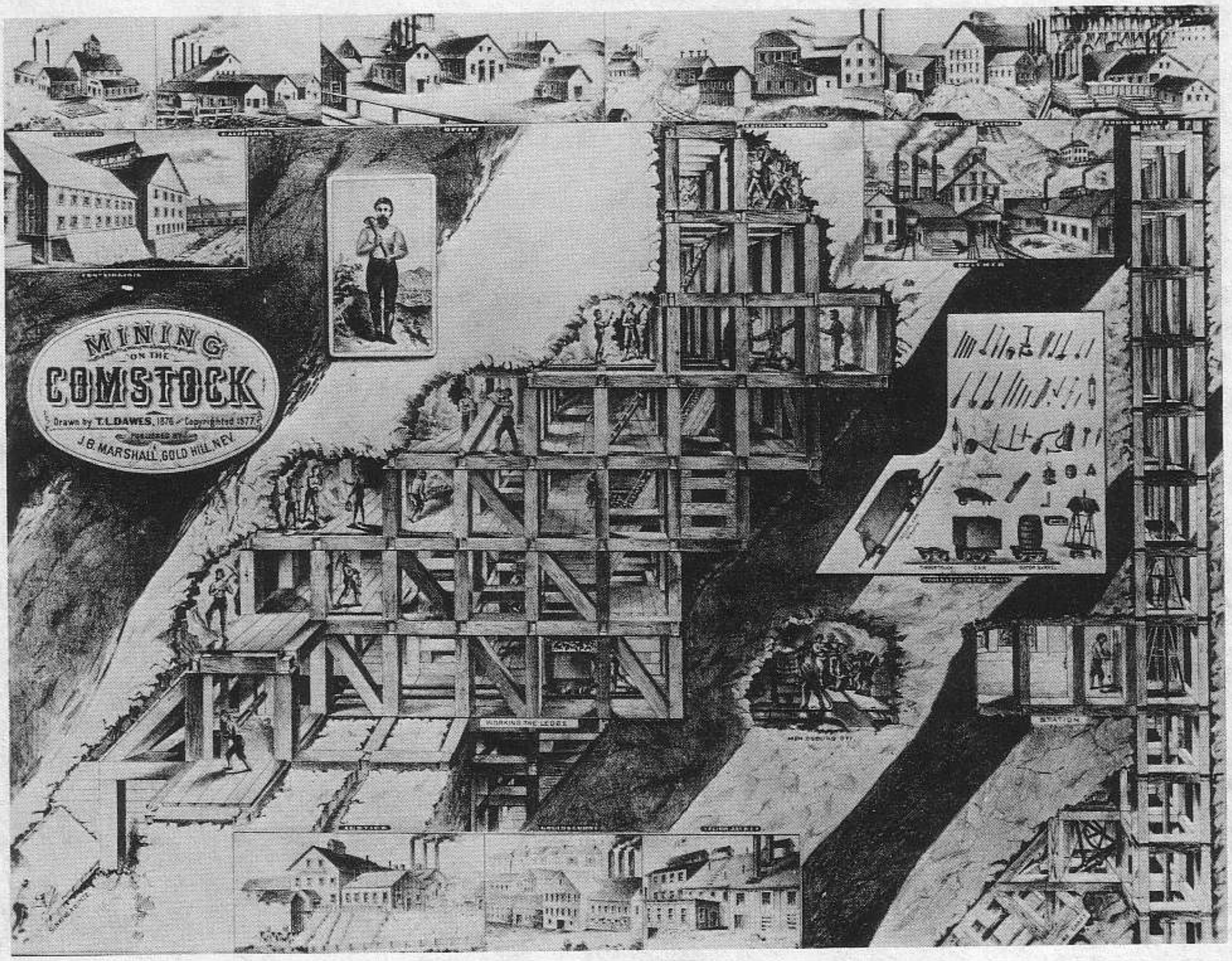

FIGURE 13. - Mining on the Comstock Lode using the square-set mining method.

Another problem was a satisfactory process for recovering the silver from the ore. Temporarily, some operators were shipping the richest ore to England for smelting. (Most of the world's silver is associated with base metals such as lead, zinc, and copper and can be recovered from its ores only by smelting. Fortunately, the Washoe ores, associated primarily with gold, could be treated as gold ores.) The principal pioneer in silver recovery technology was Almarin B. Paul, a veteran forty-niner and a friend of Hearst. His experience was acquired in the mines of Lake Superior. Once in California, he became well-informed on California gold-milling practice and also studied the available texts on silver metallurgy. His experiments with Washoe ore during the winter of 1859-60 culminated in the decision to build a 24-stamp mill at a spot where water was plentiful. A risky venture to begin with, it became even riskier when he was forced to sign contracts with mine owners that specified the onset of crushing operations within 60 days. Fortunately, San Francsico foundrymen responded quickly. Timber was transported expeditiously to the millsite from a forest 20 miles away. Paul was able to complete the mill precisely on the last day of the contract (fig. 14). It was a modified California stamp mill equipped with improved iron pans.

FIGURE 14. - Gold and silver mill at Virginia City, Nev.

Paul also borrowed some techniques from the Mexicans, who had been working with silver ores for generations. One was the "cayo" process in which ore pulverized in an arrastra was mixed with mercury, then boiled in a copper-bottomed vat (cayo) with salt and more mercury. In the "patio" process, which could be operated on a larger scale, the pulverized ore was spread out on a paved yard (patio), coated with salt and copper sulfate, and then trampled by mules or horses. In the Mexican process, the only source of heat was the sun, but in Mexico that was sufficient. Paul and others wanted to mechanize the Mexican processes and incorporate them into California gold-milling techniques. Paul added mercury, sodium chloride, and copper sulfate to his pans, steam-heated the pans, and adapted heavy iron mullers to aid in the grinding. Iron particles worn from the mullers proved an essential ingredient for good extraction. By 1862, Paul's "Washoe pan amalgamation process" had been combined with settling devices and traps to separate the amalgam from the gangue (fig. 15).

The Comstock mining companies eagerly adopted new mining techniques from all over the world. For example, they employed the compressed-air drill and diamond-studded rotary drill, which were invented in France and improved by eastern firms. Similarly, dynamite, developed by Alfred Nobel of Sweden in 1866, was introduced to the Comstock Lode in 1868. A. S. Hallidie of San Francisco, the designer of the city's cable cars, devised a flat, woven-wire

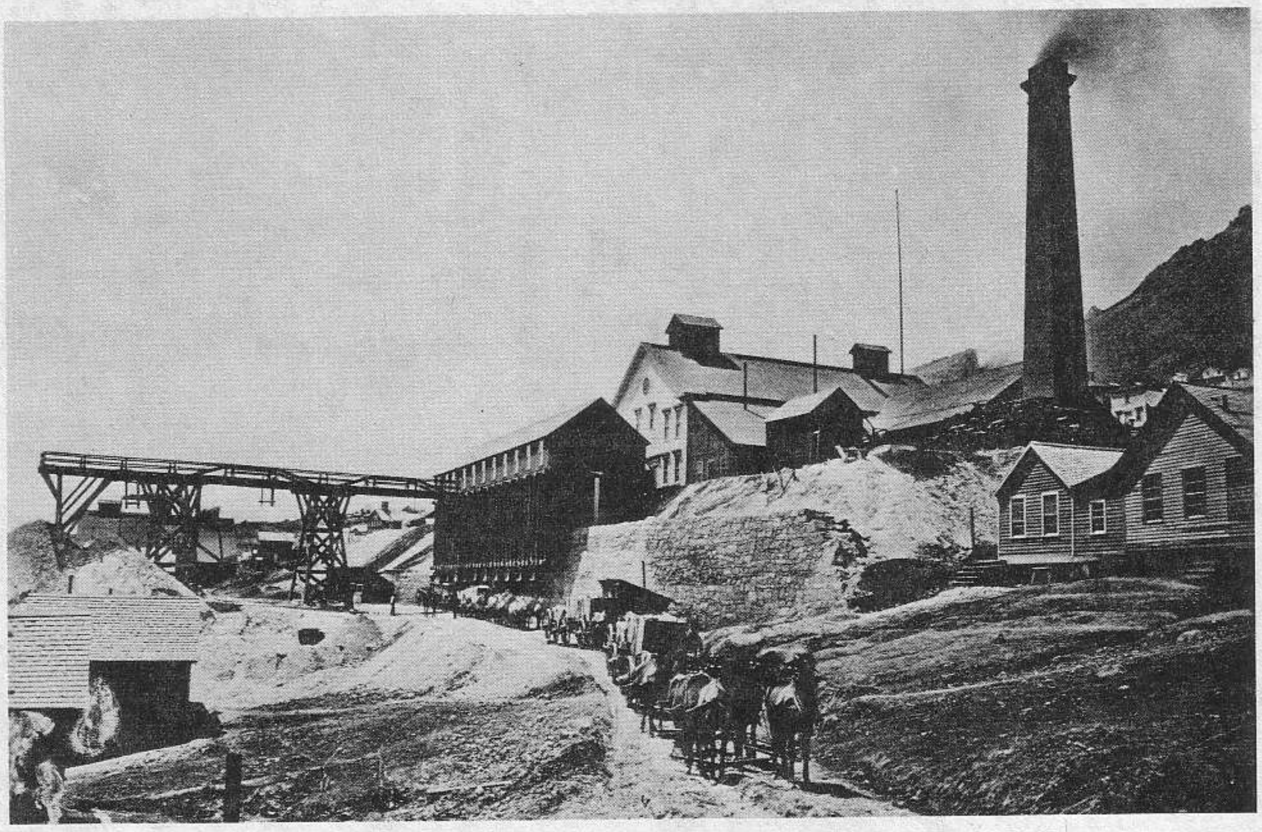

FIGURE 15. - Ore haulage at Virginia City, Nev.