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phelps dodge Corporation

New Cornelia Branch

Phelps Dodge Corporation is the second largest copper producer in the United States. The Company's activities include the mining, concentrating, smelting, refining and sale of copper, and the manufacture and marketing of copper products.

This booklet tells the story of one of Phelps Dodge's western operations, the New Cornelia Branch at Ajo, Arizona.

The New Cornelia Branch mines copper ore and treats it metallurgically by concentrating and smelting. The copper it produces is shipped by rail to Phelps Dodge's refinery in El Paso, Texas, for further refining before it is sold or converted into manufactured products. It produces about 60,000 tons of copper annually.

Ajo, a community of about 7,000 persons, is located in the western part of Pima County in Southern Arizona. Tucson, the county seat, is 130 miles to the east, and Phoenix, the state capitol, is 110 miles northeast. Ajo is 40 miles north of the Mexican border and 105 miles northeast of Rocky Point on the Gulf of California.

Ajo's elevation is approximately 1,800 feet. Average annual rainfall is about 9 inches. Maximum summer temperatures range from 110° to 115° F., and minimum winter temperatures range from 35° to 17° F.

Geology

The New Cornelia Mine is located at the eastern end of the Little Ajo Mountains. These mountains are maturely dissected sierra-type with sharp ridges and peaks, surrounded at the base by well-developed pediments. Other mountains in the Ajo district are youthful mesas composed of gently inclined blocks of massive lavas separated by broad detritus-filled alluvial valleys. The rocks range in age from the Pre-Cambrian basement gneiss in the Little Ajo Mountains to the late Tertiary lavas of Black Mountain and recent alluvial deposits in the valleys.

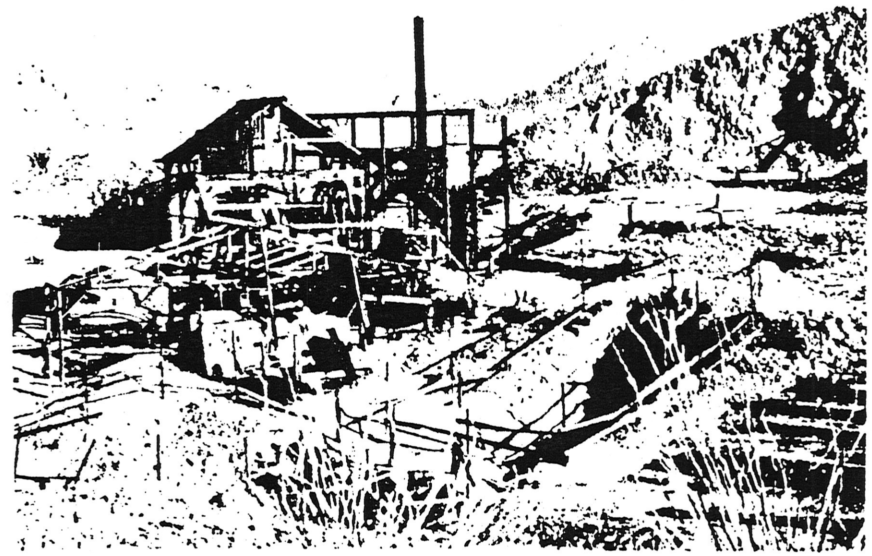
The New Cornelia ore body was formed early in Tertiary time at the beginning of the Cenozoic era, or about 50,000,000 years ago. It was during this period that North America assumed approximately its present outline and relief.

The ore body is in the apex of an offshoot from the Cornelia quartz monzonite stock which forms the north end of the Little Ajo Mountains. The mineralized part of the apex is about three-fourths of a mile wide and one and one-fourth miles long with the long axis trending northwest. The primary copper-bearing minerals, bornite and chalcopyrite, are disseminated through the quartz monzonite and to a lesser extent in the volcanics as veinlets. Overlying the ore body on its south end is an alluvial conglomerate, termed Locomotive fanglomerate, which rests on the erosion surface of the older rocks, and is many hundreds of feet thick.

There were two widely separated periods of oxidation and enrichment at Ajo. Oxidation of the sulfides in the rhyolite to a depth of 600 feet was the first event in the enrichment process. Only a minor amount of secondary copper mineral was formed in the rhyolite during this period as a result of very weak primary mineralization. After faulting displaced the rhyolite capping, the primary copper minerals were again exposed at the end of the apex.

Oxidation following the faulting resulted in the formation of abundant hematite and minor amounts of cuprite, chrysocolla, shattuckite and malachite. The chrysocolla and malachite gave the color to The Three Green Hills of Ajo that attracted the Indians and Spaniards as early as 1750.

History



The first American company to mine in Arizona, the Arizona Mining and Trading Company, arrived in Ajo in October 1854. This company found abandoned workings, rawhide ore buckets and crude tools as mute evidence of earlier attempts to mine the small veins of native copper, cuprite and chalcocite occurring in the three small hills that then stood where the huge open pit mine is today. The Arizona Mining and Trading Company failed in 1859 due to the high cost of hauling the ore to the ports of Yuma and San Diego and then shipping it around Cape Horn to Swansea, Wales.

Intermittent attempts to exploit the ore deposits followed, but the lack of water and the difficulties of transportation prevented success.

The activities at Ajo in the 1890's and early 1900's can best be described as strange and mysterious. A. J. Shotwell, a mine promoter, interested John P. Boddie, a successful drygoods salesman from St. Louis, Missouri, in the mines at Ajo. These two men organized the St. Louis Copper Company. This company failed, and Shotwell organized the Rescue Copper Company "to rescue" the St. Louis Copper Company. The Rescue Company also failed, and Shotwell and Boddie with others formed the Cornelia Company, so named in honor of Boddie's first wife. The Ajo ore was found to be too lean to work with the then conventional methods. Shortly thereafter several self-styled metallurgists undertook to meet this need with some of the weirdest inventions ever to have been tried in the history of American mining.

The first was the Rendall Process. This process, it was claimed, would treat "all classes of copper ores including oxides, carbonates, sulfides, chlorides, silicates and arsenides with equal facility." As it turned out, the plant treated all ores with equal difficulty and was a complete failure.

The second was the vacuum smelter designed and invented by Professor Fred L. McGahan. The mystifying McGahan Smelter was built at Ajo at a cost of $34,000. This invention "would melt the ore, and pure gold, silver, copper, etc. would then be drawn off in separate spigots. After the furnace was once started, the oxygen and hydrogen gases which escaped from the ore would be used to fire the furnace, and the purchase of any additional fuel would be unnecessary." The McGahan Smelter produced nothing but a vacuum in the pockets of the investors.

After this failure Boddie and his stockholders invested $30,000 in a hydrofluoric-acid leaching process almost as fantastic as the vacuum smelter. This leaching plant did produce a few pounds of copper, at a cost of over a dollar a pound.

Success of the Utah Copper Company at Bingham Canyon, Utah, put an entirely new aspect on low-grade copper deposits. From 1908 to 1910 the desert was alive with engineers hunting for the new "porphyries." The big copper companies were actually bidding against each other for a chance to develop "Boddie's folly." The General Development Company, headed by Mr. J. Parke Channing, secured an option on a majority of stock of the reorganized New Cornelia Copper Company. Mr. Seeley W. Mudd and associates optioned the Rendall Ore Reduction Company's claims on the south edge of the Ajo basin. A group of English capitalists took an option on some outlying claims in the Ajo basin. The engineers representing the General Development Company, Mr. Mudd and the group of English capitalists were recognized as among the greatest in the world. All three groups based their planning development on different theories, but they all agreed that the three hills of the New Cornelia property contained a fair amount of copper but the rock was far too hard to allow for the necessary enrichment. None of the groups drilled in the hills, and all three failed to find the ore body.

In 1910 Captain John C. Greenway became the manager of the Calumet and Arizona Mining Company in Bisbee, Arizona, and he directed the company's geologist, Ira B. Joralemon, to find an ore body suitable for mining by the new open pit methods. Joralemon, who had passed through Ajo in 1909, decided it might be worth a try to return to Ajo to see what was under the Three Hills which the big companies had bypassed in their drilling. A few days of study and sampling convinced Joralemon that there might be a great mine at Ajo.

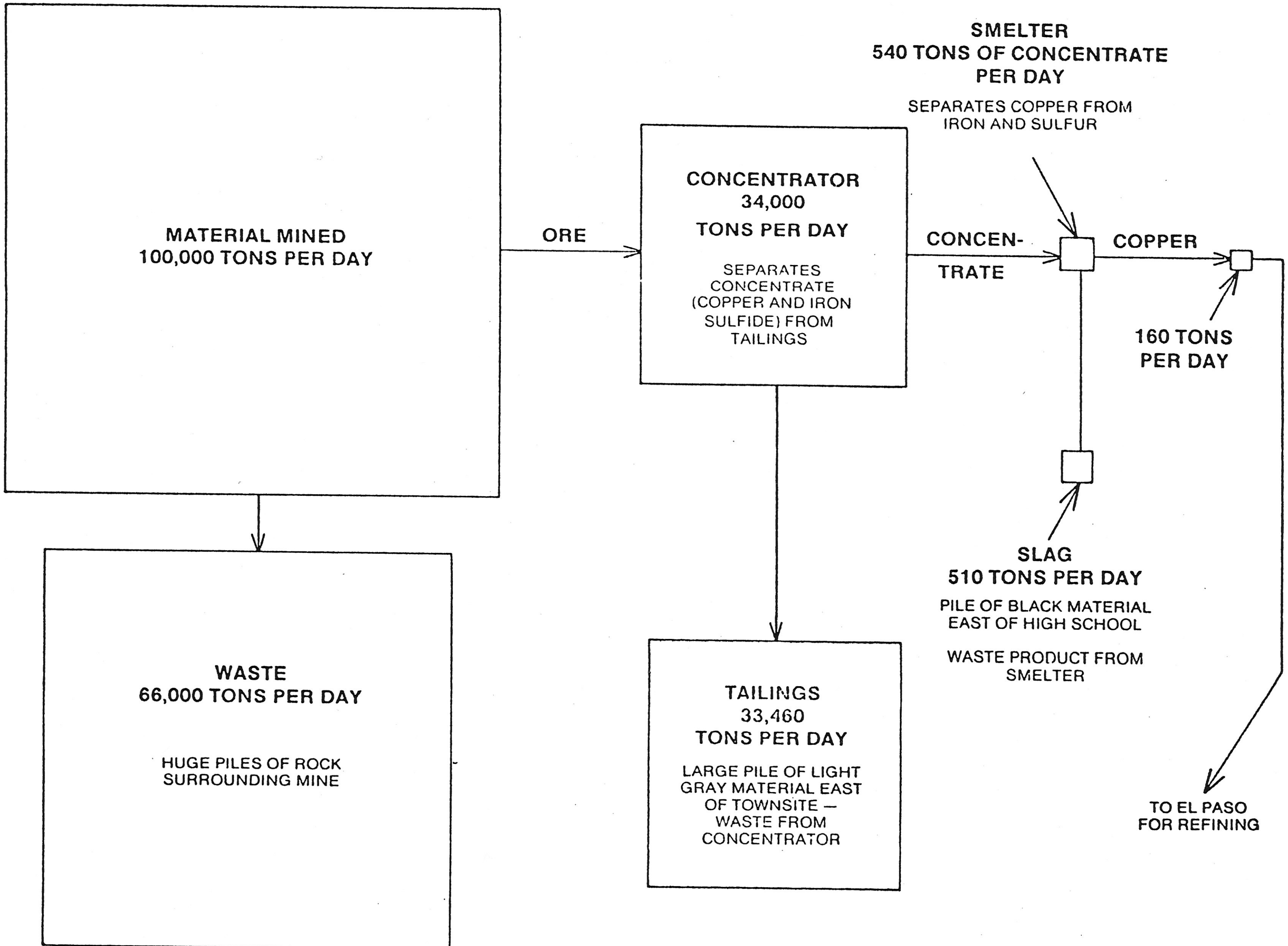
Calumet and Arizona, on the advice of Greenway, then optioned 70 percent of the New Cornelia Copper Company's stock from John P. Boddie. Within two years 25,000 feet of drilling proved that the Ajo hills were underlain by millions of tons of 1.5 percent ore with carbonate ores on top and sulfide ores below.

There was as yet no known method for treating the carbonate ores. Greenway employed Dr. Louis D. Ricketts to help solve the problem. After three years of experimentation, Greenway, Ricketts and dozens of chemists and metallurgists developed a successful miniature one-ton leaching plant at Douglas, Arizona. Subsequently a 40-ton pilot leaching plant was built at Ajo and operated successfully.

By drilling a well six miles north of Ajo, sufficient water was found to conduct a large-scale operation. A railroad from Ajo to Gila Bend was completed in 1916.

In April 1917 the big 5,000-ton-per-day leaching plant to process the carbonate ore was ready to operate. The first electrolytic copper was shipped on May 1, 1917.

Construction of a 5,000-ton flotation concentrator to treat the sulfide ore was begun in 1922, and ore dressing operations started on January 8, 1924. Ore production was increased to 8,000 tons per day in 1929. The New Cornelia Copper Company was consolidated with the Calumet and Arizona Mining Company in 1929. The leaching plant ceased operations in 1930 after all the carbonate ores had been mined, and a total of 16 million tons of carbonate ore had been treated. The Calumet and Arizona Mining Company merged with the Phelps Dodge Corporation in 1931. Further alterations in the concentrator over the years have increased production to 34,000 tons per day. A smelter was built and placed in operation in 1950.



MATERIALS FLOW DIAGRAM TO SCALE

Mining

The New Cornelia ore body is a low-grade, disseminated copper deposit occurring in a formation classified as quartz monzonite porphyry. Its principal ore minerals are chalcopyrite and bornite The ore body has been developed by open pit methods, which require the additional removal of large tonnages of associated rock having no economic value. The mine covers an area of approximately 600 acres. Its bottom level is more than 900 feet below the average rim elevation. Mining operations are conducted on levels or benches which are normally established at vertical intervals of 40 feet. Present production is at a rate of 34,000 tons of ore and 34,000 tons of waste per day by train haulage. Additional tonnage is hauled by trucks.

As all material within the scope of the pit operations must be broken by blasting, the mining cycle begins with drilling a series of blast holes. These holes are located near the edge of the bank and are drilled somewhat deeper than the height of the bank to be blasted. The New Cornelia ore body of quartz monzonite is overlain in the south portion by a tough fanglomerate, which constitutes a drilling problem separate from that of the ore body. In this area 7-inch diameter holes, inclined 20 degrees from the vertical, are drilled by heavy percussion "down-the-hole" drills in which the hammer-type drill follows the bit into the hole. Heavy rotary drill machines are used for drilling 12¼-inch diameter holes in areas other than the fanglomerate. These primary blast holes are each loaded with 300 to 1,500 pounds of explosives. All holes in a series are connected with a detonating fuse and are blasted as a unit. A typical rotary drill hole blast will break about 60,000 tons of rock. After primary blasting, some portions of the broken rock may still be too large to handle in subsequent operations. The further reduction of such material is accomplished by different methods, depending upon its nature and accessibility.

The material broken by blasting is loaded into haulage trains by electric-powered shovels equipped with dippers of 6 to 9 cubic yards capacity. Power, at 4,000 volts, is brought from nearby power lines to the shovels via insulated power cables.

Rail haulage units are made up of 125-ton or 140-ton diesel electric locomotives pulling seven- and eight-car trains, respectively. Each car carries 60 to 80 tons, depending on the size of the car.

The engineer operates his locomotive by means of a portable radio transmitter pack strapped to his back. A receiver on the locomotive activates various controls which operate the train.

Tracks in the loading areas are built in sections which can be moved with a crane, and are moved each time a shovel has made a cut through the material broken by blasting. Mainline tracks connecting the various levels of the pit with the crushers and waste dumps are laid on maximum grade of 3 percent. Approximately 50 miles of standard gauge track is in use. The haul from the bottom level of the pit is 8½ miles to the waste dumps and 7 miles to the ore crushers. A system of signals and power switches for controlling rail traffic in the mine makes it possible for one man at a control board to control train movements through remote operation of track switches and signal lights. The dispatcher keeps informed of train locations by watching indicator lights on the control panel and by direct observation from the lookout building located on the rim of the pit. An electrical interlocking system prevents setting up conflicting train movements. The dispatcher also serves as a communications center for all operations through radio, telephone, and whistle signals.

Milling

In extracting the copper from the ore the copper-bearing minerals are first concentrated into a product which is small enough in bulk and high enough in copper content to treat economically in the smelting operation. In the first steps of the process, the ore is crushed and finely-ground to a size that will free most of the mineral particles.

The coarse crushers receive the ore as it comes from the mine and reduce it to about a 6-inch maximum size. In two additional stages of crushing, the ore is further reduced to a final crusher product of 5/8-inch maximum size.

Belt conveyors carry the ore from the crushing plant to the concentrator storage bins, from which it is later withdrawn and fed, along with water, into ball mills. The ball mills are long steel cylinders each containing about 30 tons of steel balls. Grinding action takes place as the mills revolve, and the balls within tumble, roll and grind the ore between the balls themselves and between the balls and sides of the mill. Extra amounts of water are added as the ore-water mixture (called "pulp") flows from the mills to the classifiers, which are sizing devices. The fineness of the ground product depends upon the dilution in the classifiers. Rotating spirals in the classifier tanks return the coarse material to the ball mills for further grinding. Ore which has been ground to the desired size overflows from the classifiers in a more dilute pulp and goes to the flotation machines.

Flotation is a process to separate the copper-bearing minerals from the barren material in the ore. Frothing agents and other reagents are added to the pulp before it flows to the flotation cells. The frothing agents are used to produce a stable bubble, and the main function of the chemicals is to form a water-repellant, air-adhesive surface on the copper mineral particles. The surface of the waste particles does not become water-repellent. In the flotation machine the copper-bearing minerals adhere to the air bubbles formed by aeration, and they rise to the surface of the pulp. A mineral-laden froth forms and overflows at the sides of the flotation cell. This froth contains primary, or rougher, concentrate, of about 15 percent copper. The pulp, containing the barren material with only a small amount of copper, emerges from the tail end of the cells. This waste, or tailing, is directed to the settling tanks, and the thickened product is pumped to the tailing dam for disposal. The thickening procedure is important from the standpoint of conserving water.

Since the chief copper mineral at Ajo, chalcopyrite, contains approximately 35 percent copper, appreciable waste material is still included in the rougher concentrate. To remove more of this waste material, the rougher concentrate is ground to a smaller particle size in ball mills until it will pass through a 200-mesh screen, and then is refloated. The final concentrate, now about 30 percent copper, is dried by suction filters and a gas-fired rotary dryer. This dried product is delivered to the smelter by a conveyor belt.

The efficiency of the process is such that about 85 percent of the copper and only about one-third of 1 percent of the unwanted rock is contained in the final concentrate.

Smelting

The concentrate, which contains copper together with sulfur, iron, and some insoluble material (primarily silica and alumina), is received from the concentrator and is loaded into containers, which are carried by overhead cranes to the charging stations at the reverberatory furnace.

Concentrate is charged into the reverberatory furnace through the sidewalls, with machines called slingers. The furnace is about 100 feet long, 30 feet wide and 11 feet high. Its main purpose is to melt the concentrate. This is done by firing the furnace with a large amount of natural gas. In the furnace the melting concentrate makes a pool or bath about 4 feet deep. The lighter components of the bath rise to the top making a slag which is periodically skimmed off as a waste product. The heavier (copper-bearing) part of the bath sinks to the bottom and is withdrawn into ladles for further treatment. This product is composed almost entirely of copper, iron and sulfur, and is called "matte." As slag and matte are withdrawn from the furnace, more concentrate is added, and the melting process proceeds. Gases from the reverberatory furnace pass through a set of boilers, making steam for generating electricity, then through a precipitator to the gas treatment plant.

The ladles of matte taken from the reverberatory furnace are transported by overhead cranes to converting vessels. Air is blown through the liquid matte in the converters. Oxygen in the air unites with the sulfur, making sulfur dioxide gas which goes through a flue system to the gas treatment plant. The iron in the matte is also oxidized, and when silica material is introduced into the converter, the iron oxide and silica combine to form a component in the matte which is lighter than the copper. This material rises to the surface to make slag, which is skimmed off and returned to the reverberatory furnace. This process is repeated until a charge (about 50 tons) of blister copper is left in the converter.

The blister copper, which contains a small amount of sulfur, is then poured into an oxidizing furnace. All the remaining sulfur is removed by blowing more air through the liquid copper, leaving a slight excess of oxygen. Now the copper is practically free of impurities.

The copper is then transferred to the anode furnace, where it is accumulated for a 24-hour period and then refined by blowing a reducing gas (reformed mixture of natural gas and air) through the molten charge. The carbon monoxide and hydrogen in the reducing gas unite with the oxygen in the copper, forming carbon dioxide and water which leave the furnace as gases. When nearly all of the oxygen has been eliminated, the copper is cast into 750-pound slabs called anodes.

The anodes are loaded on railroad flat cars and shipped to the Phelps Dodge refinery at El Paso, Texas. There they are put through the electrolytic process for further refining of the copper and recovery of the small amount of by-product gold and silver which has remained in the copper through the smelter.

Gas Treatment Plant

The Gas Treatment Plant consists of a sulfuric acid plant and a sulfur dioxide absorption plant. The former is designed to produce 600 tons of acid per day, and the latter can produce approximately 50 tons of liquid sulfur dioxide per day. The sulfur dioxide from the converters can be routed to either plant to make sulfuric acid or liquid sulfur dioxide, but the gas from the reverberatory furnace, which is too dilute to be treated in the sulfuric acid plant, flows only to the absorption plant. The purpose of both plants is to eliminate sulfur dioxide from the off-gases generated by the smelting operation.

The hot sulfur dioxide gas from the converters, containing dust particles, passes through gas coolers where its temperature is lowered to approximately 600° F, and some of the dust particles are removed. The heat removed from the gas generates steam for subsequent uses. The gas then passes through an electrostatic precipitator, where the majority of the dust is recovered, and then on to the gas scrubbing section of the sulfuric acid plant. The scrubbing section consists of a humidifying tower, a cooling tower, and a mist precipitator. The first two towers cool the gases further and remove the remaining dust particles. The mist precipitator is designed to remove sulfuric acid mists from the gas stream to avoid corrosion of equipment down stream. From the mist precipitator the gas passes through a drying tower, where moisture is removed. The sulfur dioxide gas then passes through two blowers into the shell side of a series of heat exchangers, where it is heated by hot sulfur trioxide gas, and then passes on to a catalyst chamber. Sulfur dioxide gas is converted to sulfur trioxide in the catalyst chamber at an elevated temperature. The sulfur trioxide gas passes through the tube side of the heat exchangers and loses much of its heat before entering the absorbing tower. The circulating acid in the absorbing tower absorbs the incoming sulfur trioxide. Sulfuric acid is produced during the process of absorption. Additional water is required at times to maintain a desired acid strength. The acid is pumped to storage, whence it is shipped by railroad cars or tank trucks to purchasers.

The sulfuric dioxide absorption plant is built to supplement the acid plant with additional sulfur dioxide gas. Reverberatory gas entering the absorption plant is first cleaned by an electrostatic precipitator and gas scrubbers, then absorbed by dimethylaniline solution. The gas is then dried by sulfuric acid, is compressed and is condensed to a liquid form. Liquid sulfur dioxide is stored under pressure and is vaporized to supplement the acid plant operation whenever necessary.

Both plants are equipped with the most modern instruments and automatic controls.

In addition a Supplementary Control System has been installed which consists of a network of eight sulfur dioxide monitoring stations and two meteorological data gathering stations all tied into a central computer. Information from these ten sensing stations is integrated with operating information fed into the computer by the Smelter through a teletype and with added meteorologic information fed in by staff meteorologists. The computer uses this information to make predictions of ambient air sulfur dioxide concentrations. If appreciable concentrations are predicted, the computer alerts the Smelter that remedial action may be requested in future updates. If conditions deteriorate and an exceedance of standards is predicted, the computer tells the Smelter what remedial actions must be taken and when to take them in order to avoid the predicted exceedance.

Service Operations

The operation of a large mining, concentrating and smelting complex requires numerous service operations. They include a power plant, where all required electrical power is generated, and a well field for the production of domestic and process water. Many shops — electrical, machine, boiler, sheet metal, carpenter, paint, etc. — are required for the maintenance and construction of equipment and facilities. Departments for accounting, engineering, medical, house rental, employment, safety, supply and security are also necessary for efficient operation.

The power plant produces electric power for the Branch operations and for purchase by the Ajo Improvement Company, a Phelps Dodge subsidiary, for distribution in the town of Ajo. The Ajo Improvement Company also distributes water and natural gas to the community. Another subsidiary, the New Cornelia Co-Operative Mercantile Company, operates a mercantile store in Ajo. Still another subsidiary, the Tucson, Cornelia and Gila Bend Railroad Company, provides rail transportation between Ajo and Gila Bend.

The Community

The New Cornelia Branch operations and the associated companies dominate the economy of the community. These activities provide employment for about 1,400 people at a wide variety of skills and professions. Employees enjoy high wages, excellent working conditions and generous fringe benefits.

Many small independent enterprises such as barber and beauty shops, garages and service stations, lodging places, stores, food services, a laundry and dry cleaners, and various repair shops serve the needs of the population.

Ajo has an excellent public school system. Approximately 1,200 students attend the elementary school and 550 are in the high school.

The Company provides modern houses at low rent, mainly for Company employees. Some private housing is available, but the selection is limited, with the larger, more desirable units always in short supply. A hotel and several motels are also available.

A 33-bed hospital offers the usual hospital facilities and offices for the doctors who provide medical services to Company employees and their dependents under the Company's Hospital-Medical-Surgical Plan. This facility also serves others on a private patient basis.

Churches of many denominations fulfill the religious needs, and a large number of fraternal and service organizations provide "activity" interests for the community.

Ajo has a library, movie theaters, bowling alleys, a swimming pool, tennis courts and a golf course. The high school has an active athletic program which includes football, basketball, baseball, and track as spectator sports.

One hundred miles away is the Gulf of California, which has been called the biggest fish trap in the world. The abundance and almost unlimited variety of fish attract anglers from Ajo and all parts of the country. The surfcaster tries for sea trout, pompano and sierra, while the deep-water fisherman is likely to hook anything from the deep-water pinto, grouper, and white sea bass to the fabulous marlin or sailfish.

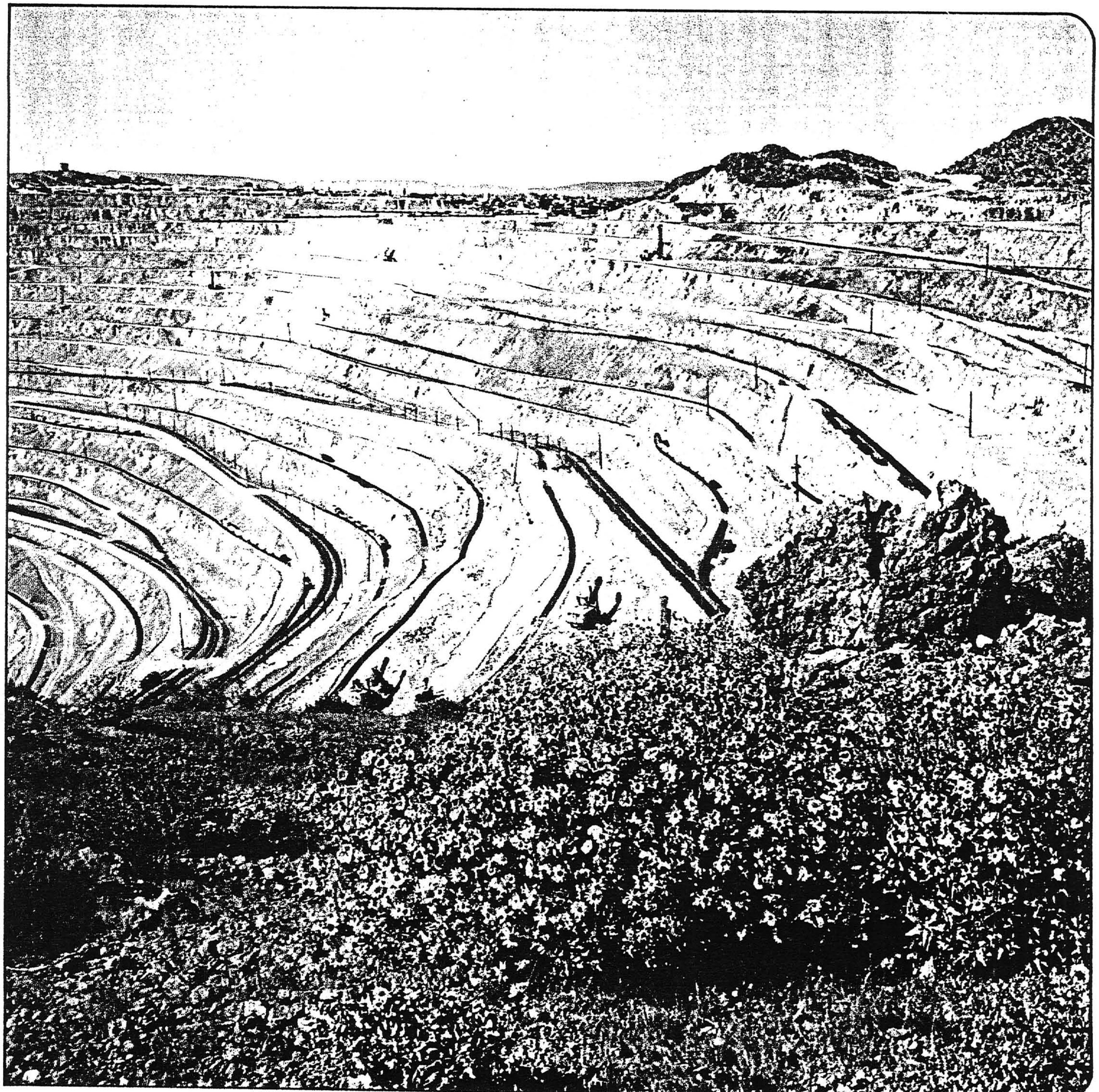
Ajo fishermen also frequent the canals in the Gila Bend, Mohawk-Wellton and Yuma districts, as well as the Colorado River and the warm-water lakes of southern Arizona's White Mountain and Mogollon Rim country.

Dove and quail hunting is good near town. In the farming area near Buckeye, Arizona (70 miles distant), the heaviest concentration of white wing and mourning dove in the nation can be found. White-tail and mule deer as well as javelina have been bagged near Ajo.

Because Ajo is situated on the northern extremity of the Sonoran Desert, interest and enjoyment is had in picknicking, camping, hiking, exploring, photography, rock hunting, and other recreations that are associated with this vast, little-known region.

PHELPS DODGE Corporation

New Cornelia Branch



AJO
ARIZONA

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During recent years the Company has also engaged in the manufacture of aluminum products.

This booklet tells the story of one of the Western Operations, the New Cornelia Branch at Ajo, Arizona.

The New Cornelia Branch, which is a primary source of copper, mines the ore, treats it metallurgically, and produces copper in a semi-refined form that requires further refinement before it can be converted into manufactured products.

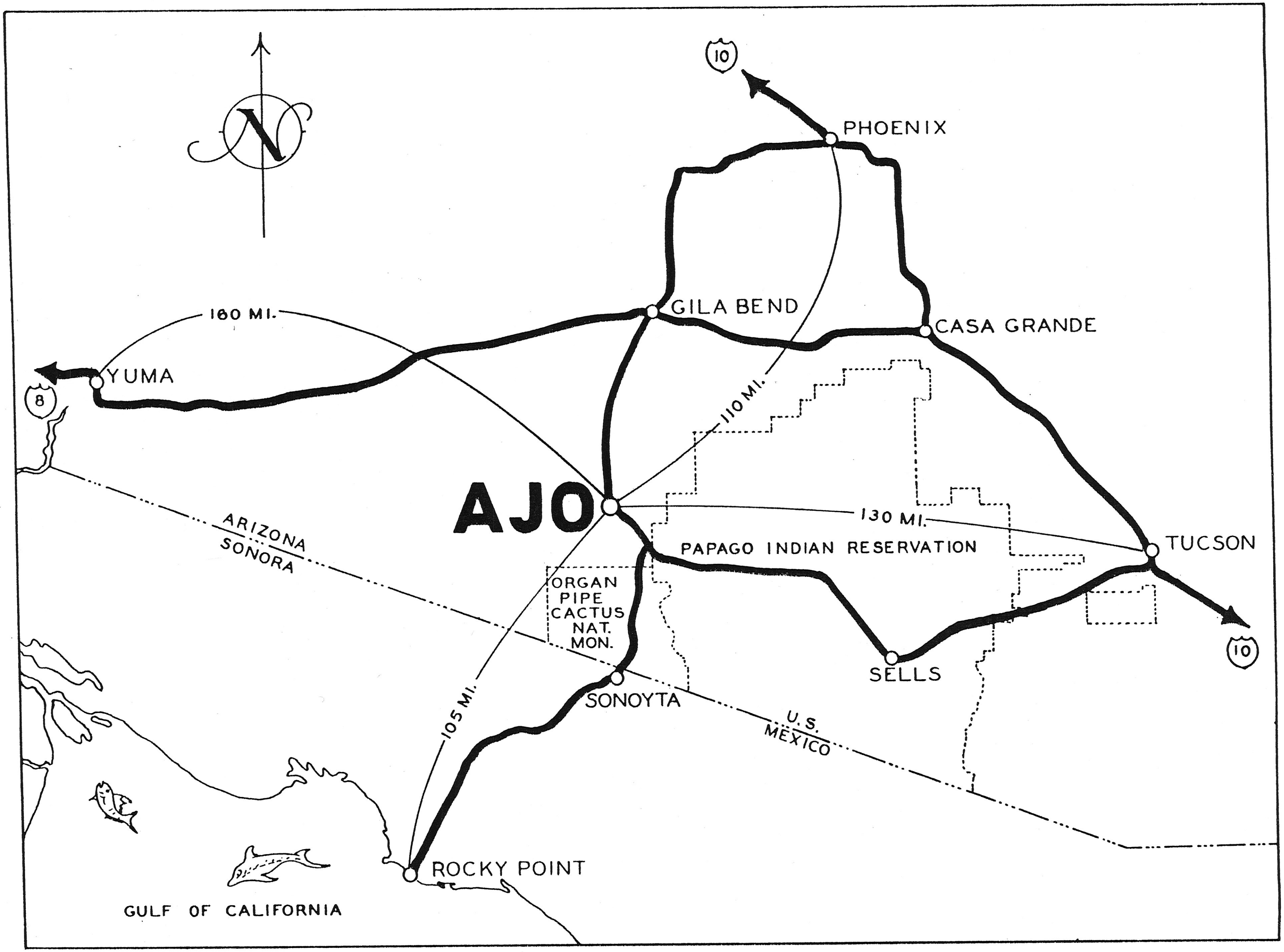
Ajo, a community of about 8,000 persons, is located in the western part of Pima County in southern Arizona. Tucson, the county seat, is 130 miles to the east, and Phoenix, the state capitol, is 110 miles northeast. Ajo is 40 miles north of the Mexican border and 105 miles northeast of Rocky Point on the Gulf of Lower California. Much of the road from Ajo to Tucson runs through the Papago Indian Reservation.

The road from Ajo to Sonoyta, Sonora, Mexico, travels through the Organ Pipe National Monument.

Ajo's elevation is approximately 1,800 feet. Average annual rainfall is about 9.0 inches. Maximum summer temperatures range from 110° to 115° F., and minimum winter temperatures range from 35° to 17° F.

◁ *'A' Mountain*

Front Cover — New Cornelia Mine



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160 MI.
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AJO
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ARIZONA
SONORA
PAPAGO INDIAN RESERVATION
TUCSON
ORGAN PIPE CACTUS NAT. MON.
10
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The New Cornelia ore body was formed early in Tertiary time at the beginning of the Cenozoic era, or about 50,000,000 years ago. It was during this period that North America assumed approximately its present outline and relief, and the minerals were deposited from solutions.

The ore body is in the apex of an offshoot from the Cornelia quartz monzonite stock which forms the relief of the north end of the Little Ajo Mountains. The mineralized part of the apex is about three-fourths of a mile wide and 1¼ miles long with the long axis trending northwest. The primary copper-bearing minerals of bornite and chalcopyrite occur as disseminated blebs scattered throughout the rock and as discrete grains along the veinlets. The ore body of economic mineralization has been defined by prospect drilling with vertical holes usually 200 feet apart. The pit encompasses the entire width of the mineralized monzonite and cuts deeply into the Concentrator volcanics rhyolite to the east, west and south which was the host rock for the intrusive. Overlying the Concentrator volcanics on the south end is an alluvial conglomerate, termed Locomotive fanglomerate, which rests on the erosion surface of the older rocks, and is many hundreds of feet thick.

Bornite and Chalcopyrite

There were two widely separated periods of oxidation and enrichment at Ajo. The first period of oxidation was on the old erosion surface where the rhyolite capping was oxidized to a depth of about 600 feet; however, only a minor amount of copper minerals was formed in the rhyolite where the primary mineralization was weak. After faulting displaced the rhyolite capping, the primary copper minerals were again exposed at the end of the apex. Oxidation of this exposure produced a zone with abundant hematite and minor amounts of cuprite, chrysocolla, shattuckite and malachite. The second period of enrichment was on the present erosion surface. This oxidation period deposited the copper minerals of malachite and chrysocolla to a depth of about 50 feet. These two minerals gave the color to "The Three Green Hills of Ajo" that attracted the attention of the Indians and Spaniards as early as 1750.

History

The first American company to mine in Arizona, the Arizona Mining and Trading Company, arrived in Ajo in October 1854. This company found abandoned workings, rawhide ore buckets and crude tools as mute evidence of earlier attempts to mine the small veins of native copper, cuprite and chalcocite occurring in the three small hills that then stood where the huge open pit mine is today. The Arizona Mining and Trading Company failed in 1859 due to the high cost of hauling the ore to the ports of Yuma and San Diego and then shipping it around Cape Horn to Swansea, Wales.

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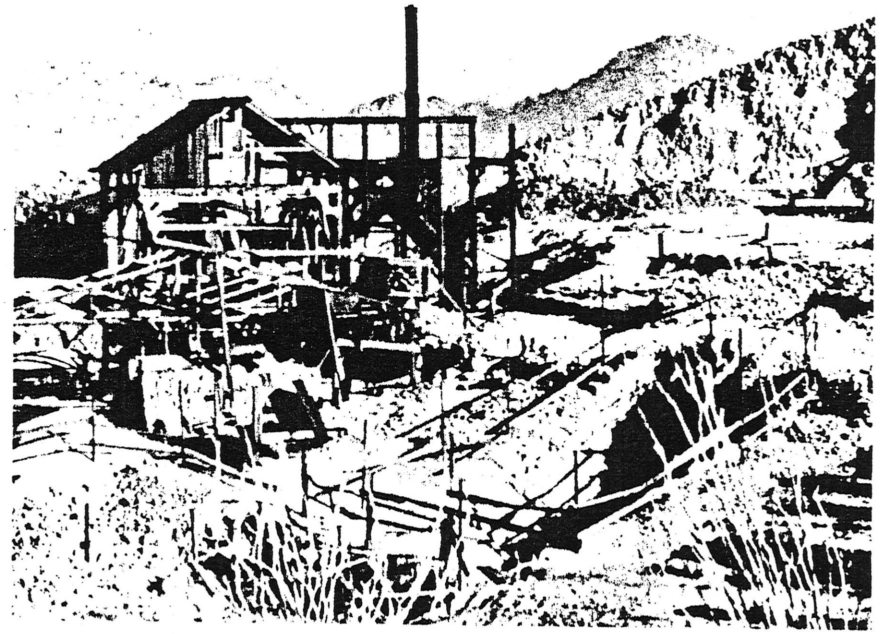

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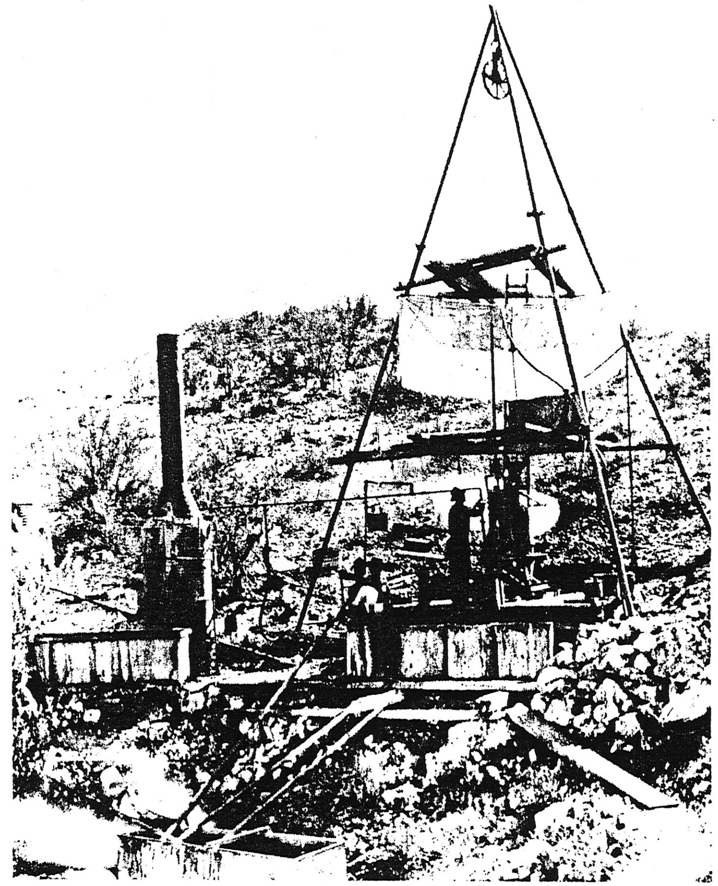
The second was the vacuum smelter designed and invented by Professor Fred L. McGahan. The mystifying McGahan Smelter was built at Ajo at a cost of $34,000. This invention "would melt the ore, and pure gold, silver, copper, etc. would then be drawn off in separate spigots. After the furnace was once started, the oxygen and hydrogen gases which escaped from the ore would be used to fire the furnace, and the purchase of any additional fuel would be unnecessary." The McGahan Smelter produced nothing but a vacuum in the pockets of the investors.

After this failure Boddie and his stockholders invested $30,000 in a hydrofluoric-acid leaching process almost as fantastic as the vacuum smelter. This leaching plant did produce a few pounds of copper at a cost of over a dollar a pound.

Success of the Utah Copper Company at Bingham Canyon, Utah, put an entirely new aspect on low-grade copper deposits. From 1908-1910 the desert was alive with engineers hunting for the new "porphyries." The big copper companies were actually bidding against each other for a chance to develop "Boddie's folly." The General Development Company, headed by Mr. J. Parke Channing, secured an option on a majority of stock of the reorganized New Cornelia Copper Company. Mr. Seeley W. Mudd and associates optioned the Rendall Ore Reduction Company's claims on the south edge of the Ajo basin. A group of English capitalists took an option from Tom Childs on some outlying claims in the Ajo basin. In the course of their prior successes, the engineers of these three companies, among the greatest in the world, had acquired theories that guided the development they planned. Strange to say, all three theories were different, but they all agreed that the three hills on the New Cornelia property contained a fair amount of copper, but the rock was far too hard to allow for the necessary mineral enrichment. None of the companies drilled in the hills, and all three failed to find the ore body.

In 1910 Captain John C. Greenway became the manager of the Calumet and Arizona Mining Company in Bisbee, and he directed the company's geologist, Ira B. Joralemon, to find an open pit copper mine. Joralemon, who had passed through Ajo in 1909, decided it might be worth a try to return to Ajo to see what was under the Three Hills which the big companies had bypassed in their drilling. A few days of study and sampling convinced Joralemon that there might be a great mine at Ajo.

Greenway then optioned 70% of the New Cornelia Copper Company's stock from John P. Boddie. Within two years, 25,000 feet of drilling proved that the Ajo hills were underlain by millions of tons of 1.5 percent ore with carbonate ores on top and sulphide ores below.



Prospect Drilling

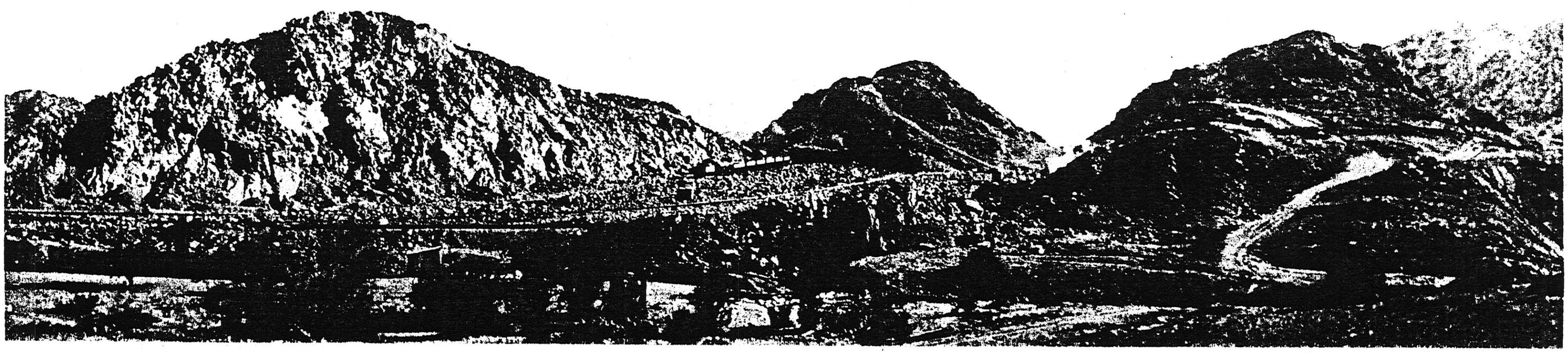
There was still no known method for treating the carbonate ores. Greenway employed Dr. Louis D. Ricketts to help solve the problem. After three years of experimentation, Greenway, Ricketts and dozens of chemists and metallurgists developed a successful miniature one-ton leaching plant at Douglas, Arizona. Subsequently a 40-ton pilot leaching plant was built at Ajo and operated successfully.

By drilling a well six miles north of Ajo, sufficient water was found to conduct a large scale operation. A railroad from Ajo to Gila Bend was completed in 1916.

In April 1917 the big 5,000-ton-per-day leaching plant to process the carbonate ore was ready to operate. The first electrolytic copper was shipped on May 1, 1917.

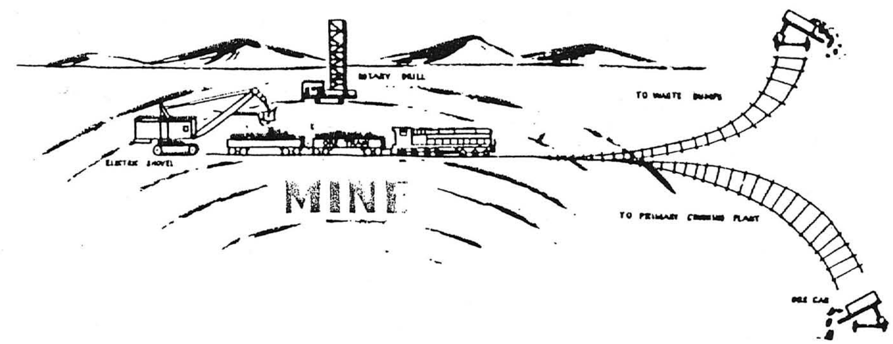
Construction of a 5,000-ton flotation concentrator to treat the sulphide ore was begun in 1922, and ore dressing operations started on January 8, 1924. Production was increased to 8,000 tons in 1929. The New Cornelia Copper Company was consolidated with the Calumet and Arizona Mining Company in 1929. The leaching plant ceased operations in 1930 after all the carbonate ores had been mined, and a total of 16 million tons of carbonate ore had been treated. Calumet and Arizona Mining Company merged with the Phelps Dodge Corporation in 1931. Further alterations in the concentrator over the years have increased production to more than 33,000 tons per day. A smelter was built and placed in operation in 1950.

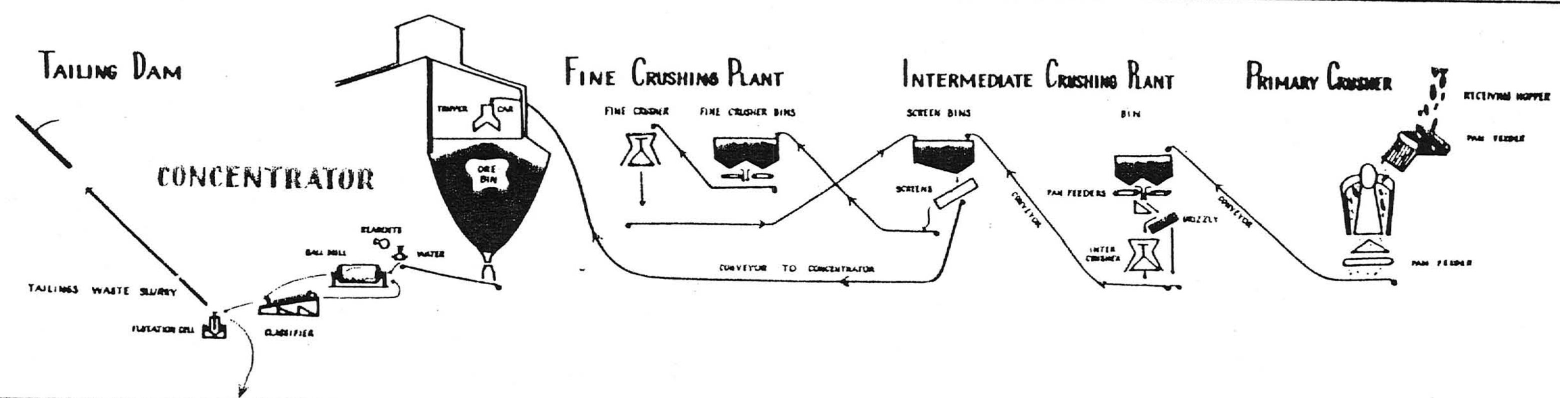
The Three Green Hills of Ajo, 1917

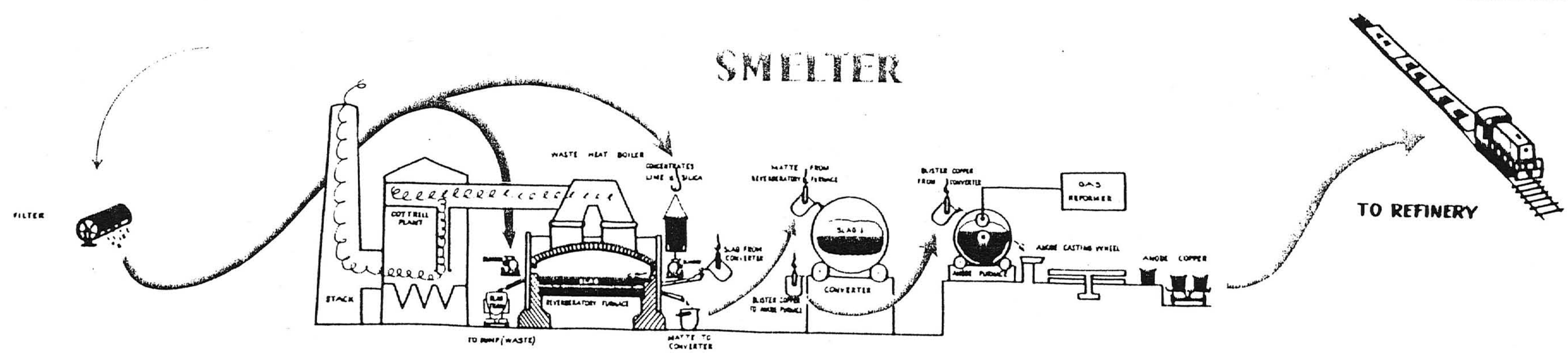


Materials Flow DIAGRAM

FROM MINE AT AJO TO REFINERY



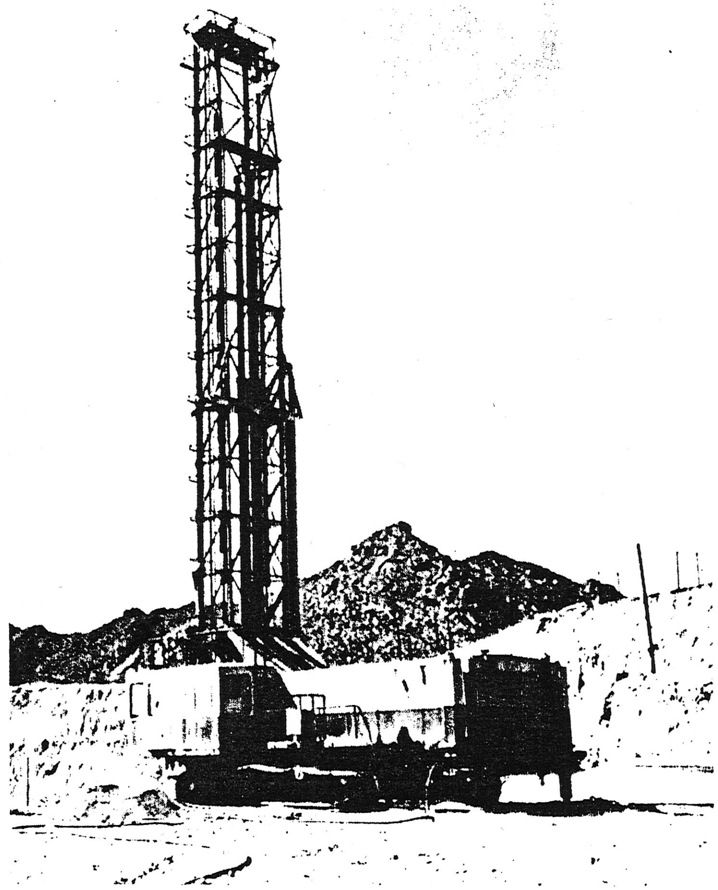




Mining

The New Cornelia ore body is a low grade, disseminated copper deposit occurring in a formation classified as quartz monzonite porphyry. Its principal ore minerals are chalcopyrite and bornite. The ore body has been developed by open pit methods which require the additional removal of large tonnages of associated rock formations having no economic value. The mine covers an area of approximately 500 acres. Its bottom level is more than 800 feet below the average rim elevation. Mining operations are conducted on levels or benches which are normally established at vertical intervals of 40 feet. Present production is at a rate of 33,000 tons of ore and 45,000 tons of waste per day by train haulage. Occasionally additional tonnage is hauled by trucks.

As all material within the scope of the pit operations must be broken by blasting, the mining cycle begins with drilling of a series of blast holes. These holes are located near the edge of the bank and are drilled somewhat deeper than the height of the bank to be blasted. The New Cornelia ore body of quartz monzonite is overlain in the south portion by a tough rocky fanglomerate which constitutes a drilling problem separate from that of the ore body. In this area 7-inch diameter holes, inclined 20 degrees from the vertical are drilled by heavy percussion "down-the-hole" drills in which the hammer-type drill follows the bit into the hole. Heavy rotary drill machines are used for drilling 12¼-inch diameter holes in areas other than the fanglomerate. These primary blast holes are each loaded with 300 to 1,500 pounds of explosives, the exact amount depending on the type of rock and the dimensions of the holes and type of bank. All holes in a series are connected with a detonating fuse and are blasted as a unit. A typical rotary drill hole blast will break about 60,000 tons of rock. After primary blasting, some portions of the broken rock may still be too large to handle in subsequent operations. The further reduction of such materials is accomplished by different methods depending on its nature and accessibility.

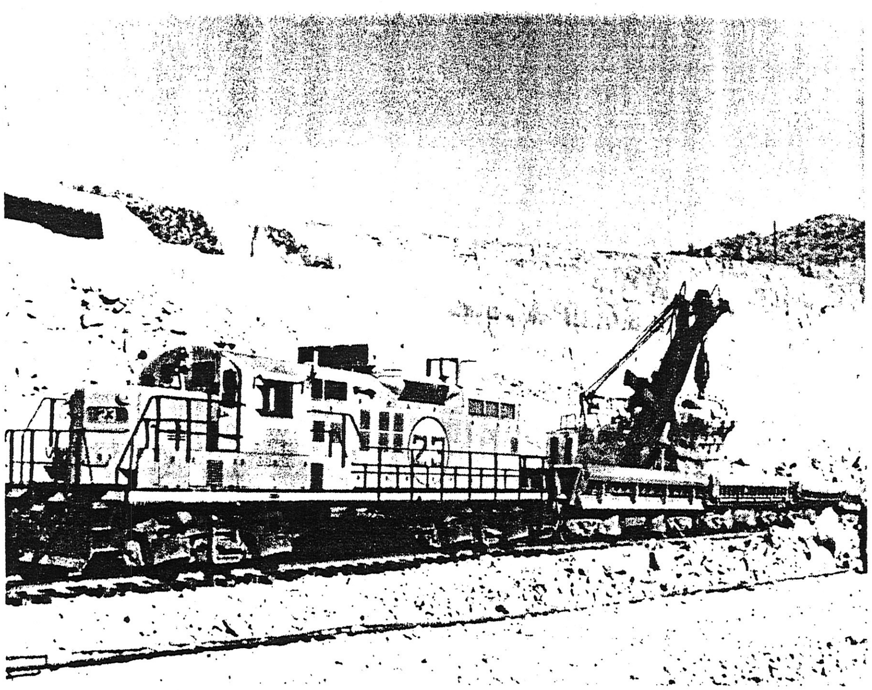


Rotary Drill

The material broken by blasting is loaded into haulage trains by electric powered shovels equipped with dippers ranging from 6 to 9 cubic yards capacity. Power, at 4,000 volts, is brought from nearby power lines to the shovels via heavy insulated power cables.

Rail haulage units consist of 125-ton and 140-ton diesel electric locomotives pulling respectively 7 and 8 thirty- and forty-cubic-yard side dump cars. Each type of car carries a pay load of approximately 65 or 85 tons. The locomotives are operated remotely by radio control. The engineer operates his locomotive by means of a portable transmitter pack strapped to his back. A receiver on the locomotive activates various controls which operate the train.

Shovel Loading and Rail Haulage



Tracks in the loading areas are built in panels or sections which can be moved with a crane. Such tracks are moved each time a shovel has made a cut through the material broken by blasting. Mainline tracks connecting the various levels of the pit with the crushers and waste dumps are laid on a maximum grade of 3 percent. Approximately 60 miles of standard gauge track is in use. The haul from the bottom level of the pit is 7 miles to the waste dumps and 5½ miles to the crushers. A system of signals and power switches for controlling rail traffic in the mine makes it possible for one man at a control board to line up train routes and control train movements through remote operation of track switches and signal lights. The dispatcher keeps informed of train locations by watching indicator lights on the control panel and by direct observation from the lookout building located on the rim of the pit. An electrical interlocking system prevents setting up conflicting train movements. The dispatcher also serves as a communications center for all operations through radio, telephone and whistle signals.

The radio system includes three base stations and approximately 85 mobile units. Two transmitting frequencies are used. Units installed on haulage locomotives operate on one frequency. The other frequency is used principally for units mounted in foremen's pickup trucks and certain supply and maintenance trucks. The radio system results in saving of time for employees and in a reduction of delays in operation and maintenance.

Milling

In the process of extracting the copper from the ore it is necessary to concentrate the copper-bearing minerals into a product which is small in bulk and high in copper content so that it may be treated economically in the smelting operation. To make the separation of the copper minerals from the waste rock, the ore must be crushed and finely ground to a size that will free most of the mineral particles.

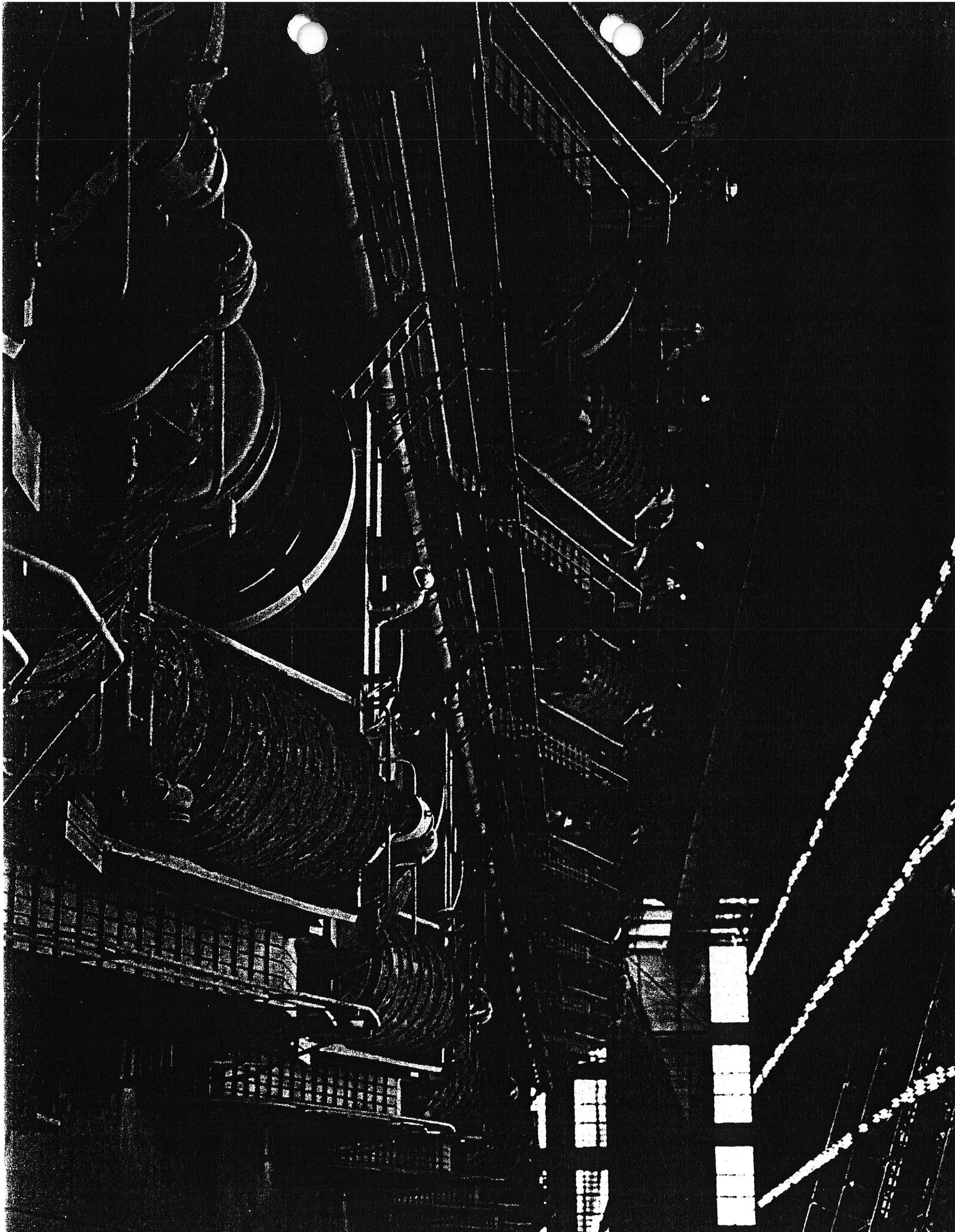
The coarse crushers receive the ore as it comes from the mine and reduce it to about a 6-inch maximum size. In two additional stages of crushing, the ore is further reduced to a final crusher product of ⅝-inch maximum size.

Belt conveyors carry the ore from the crushing plant to the concentrator bins, from which the ore is later withdrawn and fed along with water into ball mills. The ball mills are long steel cylinders each containing about 30 tons of steel balls. Grinding action takes place as the mills revolve, and the balls within tumble, roll and grind the ore between the balls themselves and between the balls and sides of the mill. Extra amounts of water are added as the pulp flows from the mills to the classifiers, which are sizing devices. The fineness of the ground product depends upon the dilution in the classifiers. Rotation spirals in the classifier tanks return the coarse material to the ball mills for further grinding. The ore which has been ground to the desired size overflows from the classifiers in a more dilute pulp and goes to the flotation machines. This product passes through a 35-mesh screen (35 openings to the linear inch).

Flotation is a treatment process to separate the copper-bearing minerals from the barren gangue material in the ore. This is accomplished by adding certain frothing agents and other reagents to the ore-water mixture (pulp) before it flows to the flotation cells. The frothing agents are used to produce a stable bubble, and the main function of the chemicals is the formation of a water repellent, air-adhesive surface on the copper mineral particles. The surface of the waste particles does not become water repellent. In the flotation machine the copper-bearing minerals adhere to the air bubbles formed by the aeration, and they rise to the surface of the pulp. A mineral laden froth forms and overflows at the sides of the flotation cell. This froth is the primary or rougher concentrate and contains about 15% copper. The pulp, containing the barren gangue material with only a small amount of copper, emerges from the tail end of the cells. This waste, or tailing, is directed to the settling tanks, and the thickened product is pumped to the tailing dam for disposal. The thickening procedure is important from the standpoint of conserving water.

Since the chief copper mineral at Ajo, chalcopyrite, contains approximately 35% copper, appreciable waste material is still included in the rougher concentrate. To remove more of this waste material, the rougher concentrate is ground to a smaller particle size in ball mills to the extent that it will pass through a 200-mesh screen, and then is refloated. The final concentrate, now about 30% copper, is dried by suction filters. This filter product is delivered to the smelter by a conveyor belt.

The efficiency of the process is such that about 90% of the copper and only about one-third of 1% of the unwanted rock is contained in the final concentrate.



Smelting

The concentrate, which contains the copper together with sulphur, iron, and some insoluble material (primarily silica and alumina), is received from the concentrator and is loaded into containers which are carried by overhead cranes to the charging stations at the reverberatory furnace.

Concentrate is charged into the reverberatory furnace through the sidewalls with machines called slingers. The furnace is about 100 feet long, 30 feet wide and 11 feet high. The main purpose of the reverberatory furnace is to melt the concentrate. This is done by firing the furnace with a large amount of natural gas. In the furnace the melting concentrate makes a pool or bath about 4 feet deep. The lighter components of the bath rise to the top making a slag which is periodically skimmed off as a waste product. The heavier (copper-bearing) part of the bath sinks to the bottom and is withdrawn into ladles for further treatment. This product called "matte" is composed almost entirely of copper, iron and sulphur. As slag and matte are withdrawn from the furnace, more concentrate is continuously added, and the melting process proceeds. Gases from the reverberatory furnace pass through a set of boilers, making steam for generating electricity. All gases pass through a Cottrell plant, where dust is recovered before the gases pass into a chimney. This chimney is 360 feet high and 15 feet in diameter at the top.

The ladles of matte taken from the reverberatory furnace are transported by overhead cranes to converting vessels. Air is blown through the liquid matte in the converters. Oxygen in the air unites with the sulphur, making sulphur dioxide gas which goes through the flue system to the chimney. The iron in the matte is also oxidized, and when silica material is added to the converter, the iron oxide and silica combine to form a lighter component than the matte or copper. This material rises to the surface to make slag which is skimmed off and returned to the reverberatory furnace. This process is repeated until a charge of blister copper (about 50 tons) is left in the converter.

The blister copper, which contains a small amount of sulphur, is then poured into an oxidizing furnace. All the remaining sulphur is removed by blowing more air through the liquid copper, leaving a slight excess of oxygen. Now the copper is practically free of impurities.

The copper is then transferred to the anode furnace where it is accumulated for a 24-hour period and then refined by blowing a reducing gas (reformed mixture of natural gas and air) through the molten charge. The carbon monoxide and hydrogen in the reducing gas unite with the oxygen in the copper, forming carbon dioxide and water which leave the furnace as gases. When nearly all of the oxygen has been eliminated, the copper is cast into 730-pound slabs called anodes.

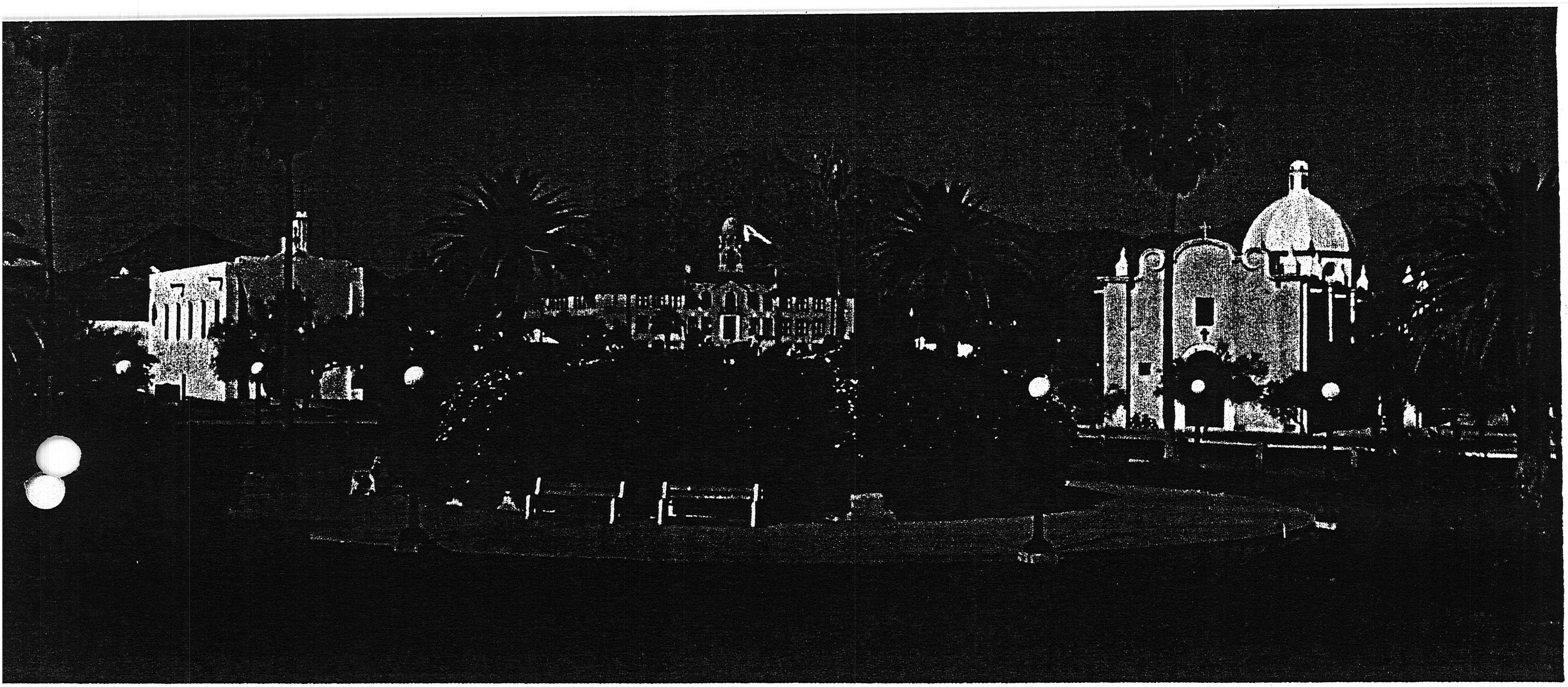
The anodes are loaded on railroad flat cars and shipped to the Phelps Dodge Corporation refinery at El Paso, Texas. There they are put through the electrolytic process for further refining of the copper and recovery of the small amounts of by-product gold and silver which has been carried with the copper through the smelter.

Auxiliary and Subsidiary Operations

Other than the three operating divisions already described there are other important parts of the operations at the New Cornelia Branch. Among these are the power plant, various mechanical and electrical repair and service shops, carpenters, painters and surface maintenance. Other departments include engineering, accounting, medical, rental, employment, safety, supply and security.

The power plant produces electric power for the Branch operations and for purchase by the Ajo Improvement Company, a Phelps Dodge subsidiary, for distribution in the town of Ajo. The Ajo Improvement Company also distributes water and natural gas to the community. Another subsidiary, the New Cornelia Co-Operative Mercantile Company, operates a mercantile store in Ajo. Still another subsidiary, the Tucson, Cornelia and Gila Bend Railroad Company, provides rail freight transportation between Ajo and Gila Bend.

T.C. & G.B. Railroad Co. Station



Ajo Plaza

The Community

The New Cornelia Branch mining operations and the associated companies dominate the economy of the community. These activities provide employment for about 1,400 people at a wide variety of skills and professions. Employees enjoy high wages, excellent working conditions and generous fringe benefits.

Many small independent enterprises such as barber and beauty shops, garages and service stations, lodging places, stores, food services, a laundry and dry cleaners, and various repair shops serve the needs of the population.

The United States Air Force operates a radar installation on a mountain top about 10 miles northwest of Ajo. It is staffed by approximately 150 military and civilian personnel.

Ajo has an excellent public school system. Approximately 1,200 students attend the elementary school and 550 are in the high school.

The Company provides a number of modern houses, at low rent, mainly for Company employees. Some private housing is available, but the selection is limited, with the larger, more desirable units always in short supply. A hotel and three motels are also available.

Interior View of Franciscan Mission

A thirty-four bed hospital offers the usual hospital facilities, and offices for the doctors who provide medical services to Company employees and their dependents under the Company's Hospital-Medical-Surgical Plan. This facility also serves others on a private patient basis.

Churches of many denominations fulfill the religious needs, and a large number of fraternal and service organizations provide "activity" interests for the community.

Ajo has a library, movie theaters, bowling alleys, a swimming pool, tennis courts and a golf course. The high school has an active athletic program which includes football, basketball, baseball, and track as spectator sports.

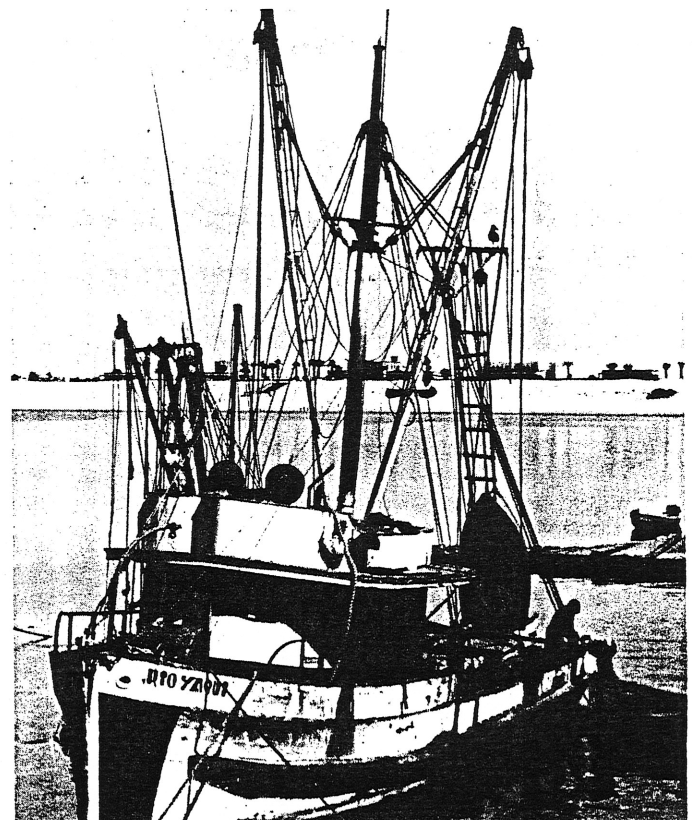
One hundred miles away is the Gulf of Lower California, which has been called the biggest fish trap in the world. The abundance and almost unlimited variety of fish attract anglers from Ajo and all parts of the country. The surfcaster tries for sea trout, pompano and sierra, while the deep-water fisherman is likely to hook anything from the deep-water pinto, grouper, and white sea bass, to the fabulous marlin or sailfish.

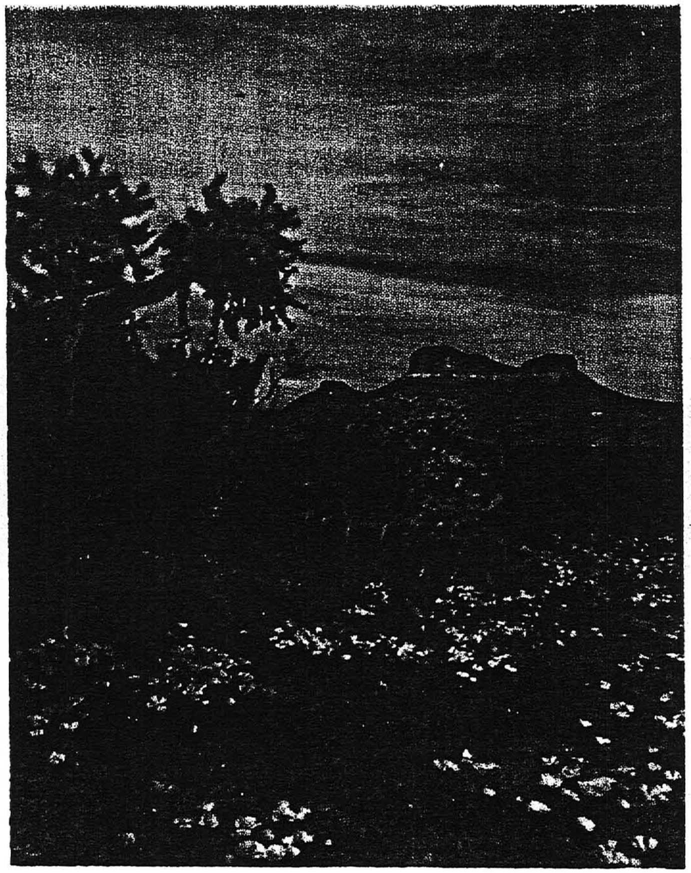
Ajo fishermen also frequent the canals in the Gila Bend, Mohawk-Wellton and Yuma districts, as well as the Colorado River and the warm water lakes of southern Arizona. Trout fishermen visit the lakes and streams of Arizona's White Mountain and Mogollon Rim country.

Dove and quail hunting is good near town. In the farming area near Buckeye, Arizona (70 miles distant), the heaviest concentration of white wing and mourning dove in the nation can be found. White-tail and mule deer as well as javelina have been bagged near Ajo.

Because Ajo is situated on the northern extremity of the Sonoran Desert, interest and enjoyment is had in picnicking, camping, hiking, exploring, photography, rock hunting, and other recreations that are associated with this vast, little-known region, historically one of the oldest in our country.

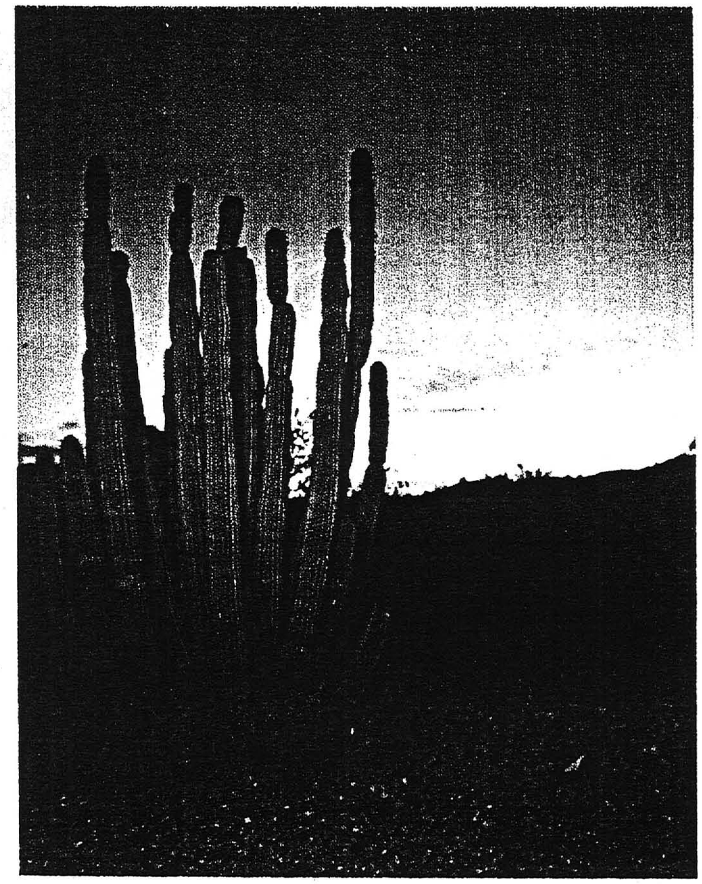
Rocky Point





Coffee Pot Mountain

Organ Pipe Cactus



PHELPS DODGE CORPORATION

P D

MINE TO MARKET

A BRIEF DESCRIPTION OF THE ORE DRESSING OPERATIONS AT THE NEW CORNELIA BRANCH OF THE PHELPS DODGE CORPORATION

MAY 9, 1959

GENERAL

The concentrator at the New Cornelia Branch of Phelps Dodge Corporation is located at Ajo, Arizona. The major supply service is provided by the Tucson, Cornelia and Gila Bend Railway which connects with the Southern Pacific line at Gila Bend, approximately 43 miles to the north.

Paved highways connect Ajo with Gila Bend, Tucson (133 miles) and Lukeville, Arizona on the Mexican Border 40 miles south.

Previously published reports concerned with the development and operation of the property are presented in Appendix I.

Originally designed to process, in 1924, 5,000 tons of ore per day in five sections, the concentrator now treats about 31,000 tons per day in the equivalent of 8½ sections. This increase has been accomplished through changes in the fine crushing equipment, replacing rods with balls in the grinding mills, increasing the length and speed of the mills, converting from two-stage to single-stage grinding and coarsening the grinding product.

ORE CHARACTER

In general, the ore is a disseminated deposit of primary sulphides, mainly chalcopyrite, bornite and pyrite, in three general rock types - quartz monzonite, quartz diorite and rhyolite. There is a thin zone of secondary enrichment where chalcocite, native copper and various copper oxides and silicates are encountered.

The oxide copper content of the ore rarely varies from a reported 0.01%, however, visible tarnishing of the sulphides is common.

Minal analyses indicate the following approximate sulphide contents of the ore milled.

	Cu_2S	$CuFeS_2$	FeS_2
1955	0.27%	1.55%	0.97%
1956	0.32	1.41	0.90
1957	0.40	1.37	0.94
1958	0.33	1.56	1.16

The percentage of Cu_2S tabulated includes not only chalcocite as such, but also the Cu_2S minal which combines two units to one of $CuFeS_2$ to provide the formula Cu_5FeS_4 of bornite.

As compared with most other porphyry ore bodies, the pyrite provides a small percentage of the total sulphide content. For the past four years the ratio of pyrite to copper sulphides has averaged 0.55:1.

Despite the fairly uniform amount of pyrite in the averages, ore from different sections of the pit will vary widely. Concentrates produced from normal ores will range from less than 20% to greater than 45%; material containing chalcocite and native copper will provide concentrate grades of 50%, 60% and even 70% copper.

The ore is considered hard and abrasive. It is relatively fresh in the respect that alteration is limited to about 40%.

PRIMARY CRUSHING

Ore is received from the Mine in 65-ton, standard gauge, side-dump cars.

The No. 1 unit is a single discharge design and is powered by a 300 horse-power motor. The ore is dumped into a 500-ton receiving hopper and then fed into the 54" Superior McCully gyratory crusher by a 96" Amsco feeder. The receiving hopper is a concrete structure, the walls of which also support the railroad bridge and the steel supports for the overhead crane.

The crusher discharge at 4½" - 8" is taken by a 60" Amsco feeder and discharged onto a 48" conveyor. The material eventually discharges into bins above the standard cones.

The No. 2 unit is also a Superior McCully gyratory with a double discharge feature. Here the ore cars are dumped directly into the crusher.

After passing over grizzlies with 2" openings, the coarse material goes to four No. 8K reduction gyratories which discharge a minus 6" product. This material proceeds on two 40" conveyors to an 8,000 live-ton surge bin and finally to the storage over the intermediate crushers.

Daily and hourly treatment rates at the two crushers are compared below:

	Tons/Day	Tons/Hour
No. 1 unit	18,743	1,209
No. 2 unit	12,304	1,547

The greater rate at the No. 2 unit results from the facts that (1) coarser material is usually routed to the No. 1 unit because of the feed control provided by the eight-foot pan feeder and (2) with the attendant 8K gyratories, the discharge opening of the No. 2 can be allowed to enlarge considerably without interfering with secondary crushing operations.

INTERMEDIATE AND FINE CRUSHING

Operations in these departments are illustrated by means of the following average data for 1958:

Hours operated per day	22.55
Tons of ore per day	31,031
Tons of ore per hour	1,376
% +4 mesh in screen undersize	26.9
% - 65 mesh in screen undersize	13.9

There are four 7' Standard Cones equipped with medium bowl liners set at 5/8" on the closed side. The treatment rate credited to these units is 367 tons per operating hour; this includes the fines that pass through the grizzly ahead of the crushers. Iron detectors over the feeder belts give protection to these units.

In 1958, the average life of bowls and mantles for this operation was 112 and 113 days, respectively; these figures include two bowl liners that broke prematurely.

The discharge from these crushers at -1½ inch proceeds to the 750-ton surge bin over the screen plant. 24 Hummer screens operate there. These are 4' x 6' with 3/4" openings ranging between 1/4" and 3/8" in width depending on the character of the ore from a crushing and grinding standpoint.

Screen undersize proceeds to the mill bin, while the oversize goes to a surge bin above the seven-foot short head cones. These seven crushers have fine bowl liners installed and are set at 1/8"; in 1958, their production rate was recorded at 199 tons per hour.

Twenty-five mantles and 20 bowl liners in the fine crushing department failed in 1958; the life obtained in this service averaged 64 and 82 days, respectively.

Data on screen wear are presented below:

	Number	Hours Operated
1/4"	30	779
5/16"	52	675
3/8"	126	594
All screens	208	640

Total crushing and conveying and auxiliary equipment power consumption expressed in kilowatt hours per ton is 2.73.

CONCENTRATING

Screen undersize is delivered to the fine ore bin of suspension bunker type with a nominal capacity of 12,000 live-tons. This bin is fed by a double-discharge tripper car which can traverse the length of the bin in 35 - 45 minutes.

GRINDING

Ore is discharged from the bin onto 42" conveyors which discharge onto 26" conveyors which in turn deliver to a splitter box where the ore is diverted to the various mills in that section. The ore is weighed by a Model E Weightometer on each section.

This department operates with thirty-four 6½' by 15½' ball mills, each in closed circuit with a 78" single spiral classifier. Grinding to about 23% plus 65 mesh, the treatment rate is approximately 920 tons per mill day. Production of minus 65 mesh material averaged 578 tons per day in 1958.

Power consumption for grinding averaged 6.62 and 10.52 kilowatt hours per ton treated and per ton of -65 mesh material produced, respectively.

On the basis of the availability of 34 ball mills, this operation was conducted at 99.30% of capacity last year. Shut-down and start-up procedures accounted for about one-fourth of the outages as do mill liner repairs and other mill repairs.

The grinding floor is serviced by a gantry crane of 80-ton capacity which handles the moving of mills from the grinding floor to the repair bay. Smaller cranes are available for smaller items and ball charging.

Ball consumption for the primary grind was 0.885 pound per ton of ore. Because of the use of ball scrap in the regrind mills, the regrinding operation is debited with some of the balls used as make-up in the primary mills.

Grinding balls (forged and cast steel) are charged in equal amounts of 3" and 2" size at a rate approximating 2,500 pounds every three days. A crane-boat suspended from a Hydroway Scale takes the balls from their storage bins to the mills.

The original grinding mills in this concentrator were 6½' x 12' rod mills; these were, in 1929, lengthened to the present dimensions by providing an 18-inch extension for each end of the mill. Subsequent purchases of new mills, as the concentrator was enlarged, were at the present size. Grinding with balls was adopted in 1932 - 1935. A shutdown from April, 1932 to July, 1934 interrupted this program.

These mills are driven by 300 horse power synchronous motors at a speed of 23.1 r.p.m. which approximates 75% of critical during the life of a three-inch liner.

The low discharge feature is modified to some extent by blanking off the outermost grate openings to provide a little deeper pulp bed for protection of the breast liner.

Liners in use are of several types:

(1) <u>90' Rails</u>: Sawed in 3" lengths and grouted to the mill shell. This type is cheap, but is not used extensively because of the longer time required for repairs. Wear is good.

(2) <u>Cast NiHard</u>: This type in use provides 30 lifters to the mill circumference. Rapid replacement of a failed liner section is a credit to this liner type. Wear varies from good to poor. This is the major type in use.

(3) <u>Combination NiHard and Rail</u>: In this type, rings of NiHard are at each end of the mill; the 3-inch rail is at the center where the wear is less severe.

(4) <u>Mixture of NiHard and Manganese Steel wave liners</u> in which the manganese is at the discharge end of the mill where shattering of NiHard is most frequent.

(5) <u>Manganese steel lifter bars with a rail lining</u>: These last two types are undergoing study.

Ball loads are carried between 45% and 50%, and the mill solids at 70% - 72%.

Operations are usually conducted with seven men per shift; one grinding inspector, four mill operators, one oiler and one cleanup man. In addition, four laborers report on day shift for general cleanup.

FLOTATION

As shown in the flowsheet, the pulp distributors, one on each half of the mill, control the routing of the classifier overflow and the thickened cleaner tailing to the rougher flotation machines.

These cells are the matless pneumatic air-lift type, 62 feet long with a cross sectional area of approximately twelve square feet. The air-lift section, six-inches in width, extends to within 3-3/8" of the bottom of the cell. The air pipes at 4" intervals, terminating approximately 1-1/2" from the bottom are 3/4" and 1" in diameter, the first twenty feet of the cell being provided with the smaller size. Double froth overflow is provided.

Three 8' x 12' center discharge mills in closed circuit with two duplex spiral classifiers regrind the rougher concentrate. The classifier overflow at about 14% solids is treated in two cleaner cells; the cleaner concentrate progresses to a re-cleaner machine which makes the final concentrate and a tailing which flows to a scavenger cell. The scavenger's concentrate is routed to the regrind classifiers, and its tailing combines with the cleaner tailing which is thickened and returned to rougher flotation.

Five centrifugal blowers with a combined capacity of 130,000 cubic feet per minute provide air at two pounds pressure for the flotation cells in the rougher and cleaner departments. Power consumption is about 1.4 kilowatt hours per ton of ore.

With the solids maintained at 29% - 30%, the flotation period approximates six minutes.

A flotation crew consists of five men; two rougher operators, one regrind operator and one helper, all supervised by a flotation inspector.

Automatic samples are obtained of the final concentrate and tailing. Hand sampling of the classifier overflows provides material for the mill head assay. Hand samples are also used as checks on the automatic samples and for intermediate products such as rougher concentrate and cleaner tailing.

The flotation floor is serviced by a five-ton crane for the handling of reagents and repair parts.

Rougher flotation reagents are added as follows: Lime and collectors to ball mills, froths and additional collector to the pulp distributors. Collector can also be added to the flotation machines at a point 15 feet from the head.

In the retreatment section, calcium cyanide is added to the mills and Xanthate to the classifier overflow.

Several samplings of pump and concentrates of the rougher cells have given the following averages:

	Pulp % Copper	Concentrate Produced in Interval % Cu	% Insol	% Fe
Head	0.808			
		28.4	22.2	20.4
11' from head	0.354			
		23.0	35.0	17.2
21' from head	0.186			
		15.2	51.6	12.9
31' from head	0.127			
		10.8	60.0	10.4
41' from head	0.104			
		7.6	66.8	8.5
51' from head	0.098			
		6.7	70.0	7.4
Tailing	0.085			

Pulp alkalinity averaged 7.7 and 1.6 grains per gallon in the rougher and cleaner tailing, respectively.

CONCENTRATE HANDLING

Final concentrate goes to a thickener 60-feet in diameter. The underflow at about 60% solids flows by gravity to the 14' x 14' drum filters. Most of the time two filters are in use, and in 1958 the treatment rate was 364 tons per filter day, and the moisture of the filter cake was 7.75%.

Vacuum will average about 22 inches of mercury and blow-off pressure is about 6 pounds.

In 1958 eight filter blankets were scrapped after averaging 1,645 hours of service.

Filter cake falls to the first of three conveyors which deliver it to either the local smelter or to a loading dock for rail shipment. The latter is practiced infrequently.

In this area, four men are customarily stationed: operators of filters, pumps and tailing thickeners as well as one sampler. On day shift, a repairman and cleanup man report to the filter plant.

TAILINGS DISPOSAL

Rougher flotation tailing is routed to four sand boxes where about fifty per cent of the tailing is removed through numerous one-inch spigots at a solids content of 43% - 45%. The sand house overflow proceeds to four traction thickeners - three 200 feet in diameter, the other 275 feet in diameter. Replaceable rubber bushings clamped into the discharge lines control the underflows which are also maintained at 43 - 45%.

The sand-house and thickener products flow through a steel-trestle-supported wood launder about 1,200 feet to the tailing pump house. There two units with two 12-inch Hydroseal pumps are installed and one three-stage unit with 600 installed horsepower. The two-stage units have 400 and 500 total horsepower so that a choice of equipment for various disposal locations is available.

Two sixteen-inch lines handle the out-put from any two of the pumping units and surround the two main disposal areas; the lines are connected at the most distant point, about 12,000 feet from the pump house. The tailing is spilled onto the dam through 4-inch pipe at 72-feet intervals. Usually twelve to sixteen pipes are required on each line to handle the tailing.

Customarily, dam building progresses as follows: (1) A 12-foot berm is built by borrowing from the outside and the 16" line mounted on it. (2) The dam is filled to the level of that berm and a new 12' berm with borrow from the inside is built. (3) The 16-inch line remains in place, and the 4-inch lines deliver the tailings over the new berm until the dam is filled to that level.

In one area where pushing over two berms was attempted, wet banks were encountered. Therefore, the practice of setting in after every two berms has been established to prevent weakening of the banks; this leaves an overall slope of about 30% on the outside of the dam.

On the South Dam, an area of about 375 acres, spillage has been on four sides from about 17,000 feet of pipe. When this dam was operating, a pond was maintained around a water reclaiming stack which was connected to two 15" tile lines beneath the dam. These lines took the water to a pump house near the base of the dam initially; later, installations of additional piping permitted integration of the tailing and water reclamation pumping in the same building.

The North Dam encompasses approximately 318 acres and is filled from three sides with about 9,700 feet of 16" pipe. In this area the water is impounded against the north side of the South Dam and is reclaimed by scow-mounted units which pump to the main station at the tailing pump house.

Pump house work is handled by one man per shift; on the pipe lines are an operator and a helper per shift. Berm building and piping activities are conducted by a crew of nine men; all of these are under the supervision of a foreman.

WATER RECLAMATION

Water reclaimed from the tailing thickeners and overflow from the 60' thickeners (concentrate and cleaner tailing) flow to a sump near the filter plant. Within the filter plant building are three 5,000 gallon pumps and two 3,000 gallon pumps. Four of these are connected to lines that go through the mill to the reservoir; one of the 5,000 gallon per minute pumps delivers water over the top of the reservoir. About half of the water in the mill tailing is recovered via the tailing thickeners.

Approximately 50% of the water pumped to the tailing dam is returned to the mill reservoirs. Two pumps are available for this service at the tailing pump house. Their capacities are 4,000 and 5,000 gallons per minute, the one operating depending upon the amount of water available at the dam.

REAGENT PREPARATION AND HANDLING

Lime is delivered by bottom-dump cars to a bin of about 500-tons practical capacity. A conveyor running beneath the bin is fed by eight chutes. A ball mill 45" x 9' in closed circuit with a rake classifier produces a slurry of about 15% solids which is pumped against a head of 110 feet to three storage tanks in back of the mill. Two circulating pumps and two lines are available for distributing the lime to all the ball mills. About 1.6 pounds of lime are used per ton of ore.

Water soluble collectors are made up as 2½% and 5% solutions and pumped by monteju to storage tanks at the head of the mill. Gravity feed lines take these reagents to feed points. The Xanthate (Z-11) consumption approximates 0.01 pound per ton.

Dowfroth 250 is pumped to storage tanks also and fed by gravity to the pulp distributor boxes. About 0.02 pound of this reagent is used per ton of ore.

Adjustable stroke feeders deliver flake calcium cyanide to the regrind mills.

Two man shifts per day are required for reagent preparation.

PILOT PLANT

This installation is in the southwest corner of the concentrator building adjacent to roadways so that truck-loads of ore can be dumped near the crushing equipment.

The crushing process requires one man feeding the coarse crusher and an attendant at the head of the system to sample screen undersize, check on the circulating load and turn the 10,000 pound capacity ore bin to obtain a maximum filling.

Great latitude in flowsheet selection is available through the use of pumps, airlifts and gravity. Grinding operations have been limited to a primary grind with balls and the regrinding of concentrates.

Much of the work of the pilot plant has been directed towards predictive procedures in regards to various ore types.

Data are presented below in reference to three varying ore types to illustrate the degree of correspondence between pilot plant and actual mill results, particularly in respect to concentrate grade.

	Low Pyrite Ore		Medium Pyrite Ore		High Pyrite Ore	
	Mill	Pilot Plant	Mill	Pilot Plant	Mill	Pilot Plant
Heads:						
% Cu	0.73	0.75	1.23	1.33	1.08	1.02
% Pyrite	0.73	0.73	2.1	2.38	17.4	16.8
Concentrates:						
% Cu	32.32	33.74	37.36	38.00	12.55	11.92
% Insol	9.5	6.7	9.8	7.0	4.3	4.1
% Fe	26.4	26.6	19.2	20.1	35.8	37.1
% Pyrite	3.4	5.8	41.3	43.3	77.0	79.8
Fe/Cu Ratio	0.82	0.79	0.51	0.53	2.85	3.11
Ratio of Concentration	48.36	47.46	35.08	31.56	14.53	14.80
Percent Extraction	91.55	94.78	86.57	90.54	79.71	78.97
Rougher Alkalinity Grains of Lime	8.7	10.2	1.5	10.1	-	9.9
Plus 65 Mesh Rougher Tail	25.7	10.3	6.6	8.3	-	5.0

Treating samples from various ore bodies, the pilot plant has illustrated convincingly that the greatest variable is the ore itself. The variations in metallurgy resulting from changes in flowsheet or reagents are of secondary importance.

UNITED STATES
DEPARTMENT OF THE INTERIOR
MINING ENFORCEMENT AND SAFETY ADMINISTRATION

HEALTH AND SAFETY REPORT

REPORT OF NONFATAL MACHINERY ACCIDENT
NEW CORNELIA
PHELPS DODGE CORPORATION, NEW CORNELIA BRANCH
AJO, PIMA COUNTY, ARIZONA

January 28, 1978

by

Chester A. Pascoe
Metal and Nonmetal Mine Inspector

Vernon R. Gomez
Metal and Nonmetal Mine Inspector

METAL AND NONMETAL MINE HEALTH AND SAFETY
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Identification No.: 02-00156
Report Issued: February 24, 1978

INTRODUCTION

This report is based on an investigation made pursuant to clause (1) of Section 4 of the Federal Metal and Nonmetallic Mine Safety Act (80 Stat. 772).

A State Plan Agreement was in effect in Arizona during this investigation.

Jose O. Dorame, shovel repairman, age 36, Social Security Number 526-56-4869, was seriously injured at approximately 9:15 a.m., January 28, 1978, when he became entangled in a shovel drive mechanism. Dorame had been employed by the Phelps Dodge Corporation, New Cornelia Branch, for 9 years. He had worked as a shovel repairman for the last 7 years. An investigation was started on January 30, 1978. The accident scene had been preserved.

Information contained in the report was obtained by interviewing company employees and officials and visiting the accident site.

GENERAL INFORMATION

The New Cornelia open pit copper mine, owned and operated by the Phelps Dodge Corporation, New Cornelia Branch, was located near Ajo, Pima County, Arizona. Total employment in the mine division was 360. The mine operated 11 days on, 3 days off, 3 shifts a day. Mechanical repair and maintenance crews worked on the equipment during the 3 down days.

Operating officials were: D. H. Orr, manager; A. L. Alexander, general superintendent; Charles V. Troutman, mine superintendent; and Thomas E. Diehl, safety supervisor.

Participating in the investigation were:

<u>Phelps Dodge Corporation</u>

Charles V. Troutman, mine superintendent
Edward Hare, pit mechanical foreman
Floyd Coody, shovel and drill repair foreman
Thomas E. Diehl, safety director
Art Fullager, assistant safety supervisor
James Hightower, shovel repairman, leadman
Richard A. Daniels, shovel repairman, helper
Miguel L. Perez, shovel repairman, helper

<u>Arizona State Mine Inspector's Office</u>

Willie J. Davis, deputy State mine inspector

Mining Enforcement and Safety Administration

Chester A. Pascoe, metal and nonmetal mine inspector
Vernon R. Gomez, metal and nonmetal mine inspector

The last regular inspection of this operation under P.L. 89-577 was completed January 20, 1978.

PHYSICAL FACTORS INVOLVED

The machine involved in the accident was a P&H model 1800, 9-yard electric crawler mounted shovel. The meshing teeth on the horizontal propel pinion gear and the crawler drive gear were 2-1/2 to 2-3/4 inches high, 2 to 2-1/4 inches thick at the base and 1-1/2 to 1-3/4 thick at the top. The horizontal propel pinion gear was 19 inches in diameter and 10 inches wide. The crawler drive gear was 36 inches in diameter and 7-1/2 inches wide. The protective casing was not in place over the gears. The shovel working weight was approximately 560,000 pounds. There were 22 inches of clearance between the top of the crawler unit and the bottom of the shovel hoist house where the victim was located when the shovel was put into motion.

DESCRIPTION OF THE ACCIDENT

Jose O. Dorame (injured), shovel repairman, reported for duty January 28, 1978 at 7 a.m., his regular starting time after picking up the equipment needed to finish the repair job that had been started 2 days earlier. Leadman James Hightower, Dorame and two shovel repairmen helpers, Richard Daniels and Miguel Perez, drove to the No. 28 shovel on the 980 level of the pit. Work proceeded normally until the new hydraulic steering unit had been installed and the crew had started checkout procedures. At this time, Hightower was standing in the operator's cab moving the shovel back and forth while attempting to activate the steering clutch. He was watching Dorame through the rear window for signals. The shovel house and dipper were positioned at an acute angle (approximately 50° to the right) to the crawler frame. Dorame was standing several feet behind the left crawler. Perez was positioned in a safe location to the right of the shovel and Daniels had walked out in front of the shovel, as instructed by Dorame. Hightower had been propelling the shovel back and forth for 3 or 4 minutes when Daniels signaled that the clutch was not operating. Dorame relayed the signal to Hightower. Upon receiving the signal, Hightower turned and sat in the operator's seat, out of visual contact with Dorame. He started swinging the shovel to the left as he again propelled the unit ahead in an attempt to cause the low voltage rings to make electrical contact and energize the hydraulic motor. The shovel was moving forward when Daniels spotted Dorame on the crawler unit under the shovel house and heard him shout. Daniels started throwing rocks at the shovel cab to get Hightower's attention. Hightower, hearing someone shouting but not understanding what was being said, shut off the power and dismounted from the shovel. When he saw that Dorame's leg was caught between the horizontal propel pinion gear and the crawler drive gear, he immediately returned to the controls and backed the shovel up to release him. Perez signaled when Dorame was free of the pinch point. Hightower shut down the unit and returned to Dorame. A preliminary check showed that Dorame's leg had been crushed and severed at about mid-calf. A tourniquet was not applied as the bleeding was minimal. Hightower lowered Dorame from the crawler unit and placed him in the service truck. Daniels used the service truck's two-way radio to notify a company official. The shovel repair crew transported Dorame to the company hospital, arriving at 9:35 a.m. After receiving medical assistance, he was taken by ambulance to the St. Joseph's Hospital in Phoenix, Arizona. While being transported, Dorame stated that he had climbed onto the unit to check the hydraulic pump to see if it was running. He also stated to the inspection party during the interview at the hospital that he had given Hightower a "thumbs up" stop or spot signal before climbing onto the crawler unit. Hightower, at a later interview, stated he had not seen or received a stop signal prior to the time of the accident.

It could not be determined by the inspection party if Hightower had missed or misinterpreted the stop signal. Reportedly, Dorame was wearing a heavy pair of leather welding gloves that may have made his signals less clear.

It was determined that during the period of time that it took Hightower to position himself in the operator's seat and put the shovel into motion, Dorame climbed over the left crawler into a leaning position towards the center of the shovel. He had placed his weight on the left foot which was positioned at or near the pinch point between the two gears, and the downward motion of the gears drew his leg between the meshed gears.

CAUSE OF THE ACCIDENT

The direct cause of the accident was the failure to lockout the electrical equipment or take other measures to assure that the equipment would not be energized without the knowledge of the individual working on it. A contributing factor was the failure to replace the gear case (rock guard and gear cover) that had been knocked off during loading operations prior to the hydraulic motor failure.

RECOMMENDATIONS

55.12-16(M) Electrically-powered equipment shall be deenergized before work is done on such equipment. Power switches shall be locked out or other effective measures taken which will prevent the equipment from being energized without the knowledge of the individual working on it.

55.9-5(M) Operators shall be certain that all persons are in a safe position before starting or moving equipment.

55.14-6(M) Guards and covers shall be kept in place when equipment is being operated, including moving parts that would normally be guarded by location.

ACKNOWLEDGMENT

The cooperation and courtesies extended by company officials and employees during the course of this investigation are gratefully acknowledged.

/s/ Chester A. Pascoe

Chester A. Pascoe
Metal and Nonmetal Mine Inspector

/s/ Vernon R. Gomez

Vernon R. Gomez
Metal and Nonmetal Mine Inspector

Approved: for Robert E. Riley
Subdistrict Manager

Liaison Officer - Arizona
U.S. Bureau of Mines

AZ-1

NEW CORNELIA (F) PIMA

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NEW CORNELIA (f)

No. 44
by
Raymond Grant

Atacamite is not a very common mineral in Arizona. I have checked by x-ray diffraction a number of specimens called atacamite and almost always found them to be brochantite. The most recent specimen I checked was collected on our field trip to Ajo, and it is also brochantite. I have also checked several different samples from the Sacaton Mine near Casa Grande, all of which are brochantite. Although many people claim to have found atacamite at the Sacaton Mine, the only atacamite that I have from Arizona is from the San Manuel Mine near Mammoth. The Mineralogy of Arizona lists eight localities for atacamite and a couple of dozen for brochantite in Arizona, so atacamite is by far the more rare of the two look alike minerals. Sterling Cook discussed the mineralization at the Santa Cruz Porphyry Copper Deposit (in Pinal County west of Casa Grande), in a paper presented at the Geological Society of America meeting in Denver last fall. He described a large deposit of atacamite and suggested that it might be the largest in the world. This deposit - found by drilling is buried1000 to 1500 feet below the surface, so don't pack your bags for the collecting trip yet! It is not known if or when this deposit will be mined, but perhaps future mineral collectors in Arizona will have access to all the atacamite they can carry.

One last note on Ajo - Jim Thomas gave me information on some minerals which are forming in the pit where ground water is seeping from the walls. These minerals are forming colorful crusts on the walls and in small water holes. At one place there is bright blue and green waterfall. The waterfall was made up of chrysocolla and malachite. Along the wall next to the waterfall a lime green mineral, cuprian katoite is forming. Katoite, a calcium aluminum silicate hydroxide, is a new mineral for the Arizona list. This mineral forms a series with grossular garnet and it seems unusal to find it under such circumstances. With the katoite are atacamite (there really is some there) gypsum and a little epsomite. One water hole contains gypsum, brochantite, and epsomite, and another seep in the pit produced meta-alunogen which is also a new mineral for the Arizona list. All of the above minerals were identified by Sid Williams.

ROCKY MOUNTAIN FEDERATION GEM & MINERAL SHOW is July 14, 15 & 16, 1989 in Stillwater, OK. at the Payne County Fairgrounds.
For information contact Dan Lingelbach, Chairman, 1116 South Gray, Stillwater, Oklahoma (405) 372-8635