STORIES OF ARIZONA COPPER MINES

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By
Frank J. Tuck

Arizona Department of Mineral Resources
Frank P. Knight, Director

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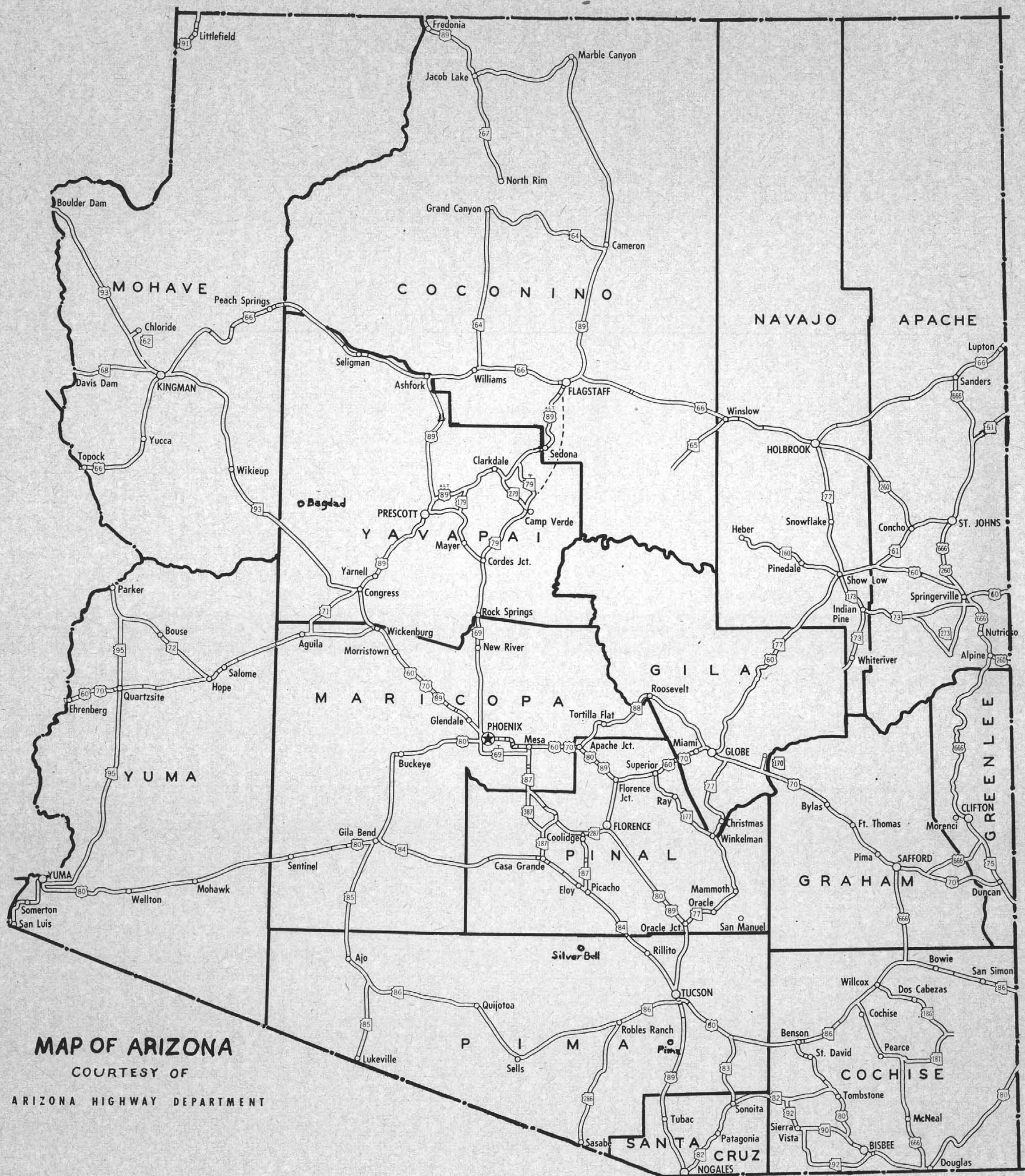

MAP OF ARIZONA

COURTESY OF

ARIZONA HIGHWAY DEPARTMENT

STORIES OF ARIZONA COPPER MINES

The Big Low-Grades and The Bonanzas

Low Grades	Bonanzas
Ray Inspiration Miami Castle Dome Copper Cities New Cornelia Morenci Bagdad Silver Bell Lavender Pit San Manuel Pima	Bisbee and the Copper Queen Magma United Verde & United Verde Extension

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INTRODUCTION

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"Stories of the Conversion of Copper Rock to Copper Metal," the lead-off story in this book, led to the suggestion that it might be of interest to many people if stories of each of the large low-grade copper mines and the four big bonanza mines were compiled by this Department. Data for these stories have been obtained from Rickard's "History of American Mining", Parsons' "Porphyry Coppers", Joralemon's "Romantic Copper", the Magazines "Pay Dirt", "Mining World", "Engineering and Mining Journal", and "Mining and Metallurgy", Bulletins of the Arizona Bureau of Mines and the U. S. Bureau of Mines, and the Annual Reports and special brochures of the Mining Companies.

Many of these stories were written in 1952, but they have been brought up to date by giving the metal production up to the end of the year 1956. Also, in a few cases some important changes have occurred in the matter of mining and metallurgical improvements, and these have been duly recorded.

The pictures used in this book have been furnished by the companies whose mines are described. Our thanks are also due them for their assistance in the preparation of these stories.

Frank P. Knight
Director

body a diabase[7] sill that slopes gently to the east and north was more highly mineralized than was the surrounding schist. Chalcopyrite[8] associated with the pyrite makes this diabase considerably higher in copper than the corresponding primary schist protore, but it was not of economic importance until recently, when open-pit operations and metallurgical improvements converted it to a profitable ore.

CONCENTRATION

Because the proposed concentrator would need a good source of water and a large tailings disposal area, it was decided to locate the mill near the junction of the Gila and San Pedro Rivers, where there was a broad valley as well as good water possibilities. An eight-section mill was constructed, and production of copper started in 1911. A railroad was built from Ray to connect with that of the Arizona Eastern Railroad at Ray Junction, eight miles away. From there the ore was hauled eighteen miles to the mill by the Arizona Eastern Railroad. A subsidiary of the Ray Consolidated Copper Co., called the Ray and Gila Valley Railroad hauled the ore from the mine to Ray Junction. The copper company also had to construct three miles of track from the Arizona Eastern Railroad at Hayden Junction to the mill. By this time, the millions of dollars required for mine development and mill and railroad construction were exhausted, and the American Smelting and Refining Company, assumed the task of constructing the needed smelter, the Smelting Company contracting to smelt the copper company's concentrates and ship the blister copper back to the A. S. & R. Co. Refinery at Perth Amboy, N. J. The smelter was located near the mill in the new town of Hayden, Arizona.

It was late in 1912 before the mill reached its projected capacity of 8,000 tons daily, and with copper at sixteen cents, the Ray Mine made a profit. Of course, at this time, it could merely begin to return something on the enormous investment. The first dividend was paid in June, 1913. By this time about 30 miles of underground work had been done, simply for exploration, and about 80,000,000 tons of ore developed. This large development was necessary to assure a reasonable return on the large amount of capital expended in the erection of mills and works. Remember the failure of the English Company because of inadequate sampling.

In the early days of the Ray mill operations, the method of concentration then in vogue was crushing and grinding with gyratory crushers, rolls, and chilean mills, to about 1/16" size. This in order to free the particles of copper mineral from the worthless portion of the rock. This mineral, being heavier than the rest of the rock crushed to the same size, had the property of sinking in water faster than the lighter particles, and when subjected to a shaking action on tables equipped with riffles, the copper mineral was separated (concentrated) from the worthless portion (the tailings) and became high enough in grade, to make a suitable smelter feed. This process was known as gravity concentration. Naturally grinding the ore to 1/16" size resulted in sliming or pulverizing a considerable portion of the copper mineral, which became too fine to permit taking advantage of its relative specific gravity and was lost into the tailings flowing over the table riffles. The result was a recovery of not over seventy percent of the original copper in the ore.

In 1914 and 1915, technical research developed a process for increasing the recovery of copper sulphide (which constituted the greater proportion of the copper mineral in the Ray ores). This process (called the Flotation Process) was the reverse of the gravity concentration process, in that it floated the heavy sulphide mineral, and sank the light worthless material, maka successful separation and a higher grade concentrate. This was accomplished by aerating the ore pulp, adding oil which performed the function of converting the air bubbles into a stiff froth, and at the some time attaching itself to the copper sulphide particles, for which it had an especial affinity, due to the metallic surface of the mineral. The air bubbles, so filmed and so coated with the copper mineral, rose through the pulp and floated off the sides of the flotation machine. The worthless earthy material in the pulp flowed through the machine to waste. As the flotation process increased copper extraction from sixty and seventy percent to about ninety percent, this revolutionary advance in metallurgy converted what had been originally classed as waste into pay ore, increasing enormously the developed mine tonnage, and radically extending the life of the mine. Where originally two percent was the yardstick for ore classification, the measure has been gradually reduced to one percent.

STORIES OF CONVERSION OF COPPER ROCK TO COPPER METAL

Almost ninety percent of Arizona's copper production comes from the large low-grade mines of the state, namely the Morenci Mine, the New Cornelia Mine and the Lavender Pit Mine of the Phelps Dodge Corporation, the Ray Mine of the Kennecott Copper Corporation, the Inspiration, Copper Cities and Miami Mines in Gila County, the Silver Bell Mine of the American Smelting and Refining Company in Pima County, and the San Manuel Mine of the Magma Copper Company in Pinal County. In recent years, the ore in these mines has contained about 18½ pounds of copper per ton, and has yielded less than 15½ pounds per ton, with about thirteen cents per ton in gold and silver. In all cases, the mining claims were on federally owned land, and were duly patented according to United States mining laws.

Over three hundred million dollars had to be spent on the above properties before they began to produce copper and return a profit to the investors. It took vision and courage, as well as capital to convert these large copper deposits into profitable enterprises. If it had not been for the application of brains and capital to the development of this copper, these properties would be so much worthless rock in mountains of scenic value only. And if it had not been for this copper one wonders whether this Republic could have survived the last two World Wars. It certainly seems fair to expect Arizonans to pause and reflect on the matter of taxation of these big copper producers. They should not be treated like the proverbial goose that laid the golden eggs.

Many Arizonans are claiming that the mining industry is depleting natural resources originally belonging to the state; and for that reason a severance tax, under the guise of a sales tax has been levied upon the industry, to recompense the state for the loss of its natural wealth. Although forty-five years ago, the mining industry had created an estimated 20-year supply of copper ore, it has not only been mining it for forty-five years, but it still has an estimated 15 years' supply for future use. How this can be called impoverishing the state is difficult to imagine. On the contrary, the big copper producers have taken federal lands on which no taxes were being paid, and have put them on the tax rolls, thus contributing to state tax revenue.

A prime example of the conversion of worthless rock to copper metal is the San Manuel Mine in the Mammoth District of Pinal County. Total capital expenditures on this property to the end of 1956 were $102,589,445, and over twelve years of development were required before production began in January, 1956. And the ore-body developed contains the amazingly low content of 15 pounds of copper per two thousand pounds of rock.

It took six years and the investment of seventy-six million dollars to make the "Clay Ore-Body" at Morenci a profitable enterprise. It took six years and $15,000,000 to make the Ray Mine a dividend-paying proposition. It took six years and $15,000,000 to convert Inspiration into a dividend-paying mine. It took five years and $15,000,000 to make the Miami Mine pay. It took five years and $25,000,000 to make the New Cornelia Mine. It took four years and $12,000,000 to make the Castle Dome Mine return a profit. It took $18,000,000 and almost eight years to churn-drill and prepare the Silver Bell Mine for production. Likewise, eight years and $15,000,000 were expended in the preparation of the Copper Cities Mine for full production in 1954. And, finally, an expenditure of $25,000,000 and six years of preparation were required to put the Lavender Pit into production in 1954.

Before the big copper producing properties were developed they had been operated as small mines for many years, during which time, the higher grade portions of the ore-bodies near the surface were mined out, leaving the low-grade for science and capital to develop. Large-scale operations were necessary to make the ventures profitable. Churn drilling was essential to determine the extent and grade of the ore-body, after which shafts, drifts, crosscuts and raises had to be driven to block out the ore and prepare it for extraction. This drilling and development usually delimited the ore-body by classifying as ore only that which could be mined, milled and smelted at a profit. Naturally, improvements in mining, milling and smelting, as time went on, changed what had been originally classed as waste into profitable ore. In many cases the life of the mine was doubled by the discovery of new technical processes. Hence a mine which had originally a 20-year reserve of copper ore, remained in business double that length of time. In some cases, additional drilling on the fringes of developed ore-bodies, showed many years' supply of what would have been originally classed as waste, but, with new processes, became pay ore.

Although the open pit mines did not require the shafts, drifts, crosscuts and raises of the underground mines, they did call for the stripping of millions of tons of waste rock overlying the ore-body. In most cases this amounted to more than twice the tonnage of ore mined.

The result of all this alchemy, or the conversion of worthless rock to valuable copper metal, has been the creation of millions of dollars of taxable wealth in the State of Arizona.

The mining industry is the chief primary industry of Arizona and its ramifications extend to all parts of the State. There are many industries and professions in the large cities of Phoenix and Tucson which derive their income from trade with and services for the miner, millman and smelterman, and their families. The foundries of Phoenix are almost one hundred percent dependent on the mining districts for their business. The copper miner is the highest paid wage earner in the State, and he spends practically all of his earnings within the State. The railroads get the major part of their revenue from the mines and smelters in the form of freight on ores, concentrate and blister copper. The power and telephone utilities derive much revenue from mines. Many state and federal employees in Arizona are paid out of the taxes which the mining companies pay. The wholesale and retail stores in Phoenix and Tucson get considerable business from both the mining companies and their employees in the mining districts. The farmer and stockman raise food for the miners.

Thus it is demonstrated that the mining industry plays a vital and important part in Arizona's economy. It's ramifications extend in every direction. Contrary to the "popular" belief that the mining industry is exhausting the State's natural resources, history has shown that the industry actually has created resources where none previously existed.

Mines are made, not found. It has been almost forty-five years since a "bonanza" has been discovered. All the big mines in Arizona nowadays are the product of the application of venture capital in large amounts, the use of engineering skill in the invention and construction of labor-saving machinery and processes, and finally the business acumen of seeing into the future. A great industry has been developed, and with proper understanding and equitable treatment, still has tremendous potentialities of remaining vital to the state's economy indefinitely into the future.

THE STORY OF THE RAY MINE

The Ray Mine of the Kennecott Copper Corporation is today producing copper at the rate of over one hundred million pounds per year, but it has reached that stage after more than forty-five years of continuous technical development and operating economies. Its success did not come because the State of Arizona handed it a mountain of copper ore and said "Here lie untold riches; all you have to do is dig it out". Application of brains and the investment of much capital were first required before the mountain would give up its riches.

HISTORY

Ray is about eighty miles east and slightly to the south of Phoenix and about the same distance north of Tucson, in what is called the Mineral Creek Mining District. This district was organized by silver prospectors in 1873. A five-stamp mill was built in 1880 by the Mineral Creek Mining Company. There is a record of some copper mining being undertaken by the Ray Copper Company in 1883. The next note was of small scale operation in 1898. In 1899 the Ray Mine was acquired by an English Company, the Ray Copper Mines, Ltd., capitalized at 260,000 pounds sterling. This company built a 250-ton mill at Kelvin and blocked out ore at the mine. It failed because of inadequate [illegible]

About this time, 1899, Daniel C. Jackling was doing some pioneer mill testing of a low-grade porphyry ore at Bingham, Utah. He proved to the satisfaction of interested capital that by the introduction of large scale open-pit mining, and the erection of a concentrator, he could mine and treat rock containing two percent copper (40 lbs. per ton), recover 25 to 28 lbs. of copper for every ton treated, and concentrate it to a profitable smelting feed. Mr. Jackling's success in Utah started the search for similar large ore-bodies in Arizona. In 1906, his associates Philip Wiseman and Seely Mudd obtained options at Ray, and in 1907 Mr. Jackling started extensive development work on the Ray property. The Ray Consolidated Copper Company was organized, and a thorough program of churn-drilling was undertaken, in order to determine the amount and grade of ore it would be possible to mine on a large scale. About 50,000,000 tons of 2 per cent ore were blocked out, and Mr. Louis S. Cates was placed in charge of operations. Mr. Cates developed the mining system to be used at Ray, and it later became the first copper mine in the world to produce 8,000 tons or more of ore per day by caving methods.

GEOLOGY OF THE RAY ORE DEPOSIT

The geology of the Ray District has been excellently described by F. L. Ransome.* For the non-technical lay reader, the following may serve as a thumb-nail description of the deposit with a glossary added to define some of the more technical terms.

The ore deposit is a secondary enrichment of disseminated chalcocite,[1] associated with and partially replacing primary pyrite[2] in the district's chief rock, known as Pinal schist,[3] and also to a slight extent, in intruded porphyries. It is generally referred to as being a low-grade porphyry deposit. The ore-body proper is a flat-lying mass, irregular in outline, and of variable thickness. The long axis extends roughly east and west for about 7,000 feet. It ranges in width from about 200 feet at the center to over 2,000 feet near the eastern and western extremities. The central constriction divides the ore into two sections which are called the "Eastern ore-body" and the "Western ore-body". The thickness of the ore as determined by drilling and development averages about 120 feet and ranges from 15 to more than 400 feet.

The area of oxidized capping[4] is somewhat more extensive than that of the ore, but has the same general shape. Around the margin of the ore many of the drill holes pass directly from the oxidized capping into the unaltered primary protore.[5] The thickness of the capping varies greatly but its average is about 225 feet.

Intrusions of porphyries[6] produced numerous small irregular fissures which were permeable to the ore solutions, downward flowing waters that had picked up copper in the oxidizing capping and deposited their copper load on the primary pyrite in what is now the ore-body. The replacement of the pyrite was not always complete. This phenomenon is interestingly shown by examination of minute (200-mesh) particles of what appear to be pure chalcocite under the microscope but when further pulverized disclose a kernel of pyrite within a chalcocite shell.

Under the greater portion of the Eastern ore-

The last few years have shown similar advances in mining technology, especially in the operation of open-pit mines. These advances have permitted the removal of larger proportion of overburden, and the economical handling of lower grade ores. There again the Ray mine benefitted, and additional tonnage was placed in the Ray reserves. Kennecott Copper Corporation, which had taken over the Ray mine in 1937, decided in 1948 to conduct open-pit operations on a section of the ore-body, in conjunction with the underground mining. The tonnage of the latter was reduced to 5,000 tons, and the open-pit was developed to produce 10,000 tons daily. The mill was enlarged to handle 15,000 tons, by the addition of four large ball-mills. Incidentally, ball-mills had long since taken the place of the old chilean mills, and rod-mills had replaced the rolls for fine-crushing and grinding, and both changes played their part in improving the economy of the mill operation. Finer grinding was accomplished which freed more mineral for flotation recovery.

Final conversion of the Ray Mine from an underground to an open pit operation was completed toward the end of 1954 and all underground mining was terminated January 28, 1955.

Another source of income from the mine might be mentioned here, and that is the precipitation of copper, from mine waters, on scrap iron. With the caving system of mining, the ore chutes are sealed off as soon as the oxidized capping or the broken protore begins to appear in the ore drawn from the chutes. This leaves a large amount of low-grade, copper bearing broken rock in the mine which is subjected to a slow leaching by downward percolating waters. These copper-laden waters are pumped out of the mine and passed over de-tinned scrap iron which precipitates the copper as cement copper. The copper precipitates, carrying eighty percent copper, are dried and shipped to the smelter at Hurley, New Mexico, where they are fire-refined. These precipitates accounted for the production of a half-million to a million pounds of copper monthly.

Leaching of the caved areas of the old underground workings was begun in 1955, and is resulting in the recovery of increased amounts of precipitate copper. Production of this copper in 1955 was 7,546 tons, as compared with 3,644 tons in 1954. In 1956, it was increased to 14,934 tons, or 2½ million pounds per month.

Improvements such as the open-pit development, additions to the concentrator, and power development, cost the Company over five million dollars in the period of conversion to open-pit mining. Other millions had been spent in the earlier years when flotation took the place of gravity concentration, when ball-mills were substituted for chilean mills, and later when rod-mills took the place of the fine-crushing rolls.

Mill metallurgy was improved in 1956 by the finer grind made possible by the larger ball mill motors installed during the year.

At Kennecott's new research center in Salt Lake City, a method has been developed to increase the amount of copper recovered from the refractory ore of the company's Ray division. This method indicated that recovery could be increased by 12 percent, and a five million dollar installation at Hayden was decided upon. The process involved the production of sponge iron and sulphuric acid from the pyrite which up to now had been rejected in the mill tailings. The acid is to be used in dissolving the oxidized copper in the ore, and the sponge iron is to precipitate the dissolved copper; the resultant precipitation of metallic copper is to be floated in the mill circuit.

Progress has been made on the $40,000,000 program, announced at the last annual meeting of stockholders, for increasing the productive capacity of the Ray Division by 20,000 tons of copper annually. Plans for relocating the various surface facilities to permit enlarging the pit, and for expanding the capacity of the mill are well advanced. The program also provides for the construction of a smelter to process the copper concentrates and precipitates produced at this division. This work has previously been done by a custom smelter on a cost-plus basis. The smelter is scheduled for completion in 1958.

All of which demonstrates the constant need of setting aside a portion of profits in order to keep abreast of technical progress. It would have been economic suicide to have distributed one hundred percent of the Company's earnings in the form of dividends, and then have no money to spend on keeping up to date.

And so we have seen how Mr. Jackling started to develop the Ray mine in 1907, and how the mining company finally started to make money late in 1912. During these five years, the Company had expended $15,000,000 in churn-drilling, shaft-sinking, driving underground work-

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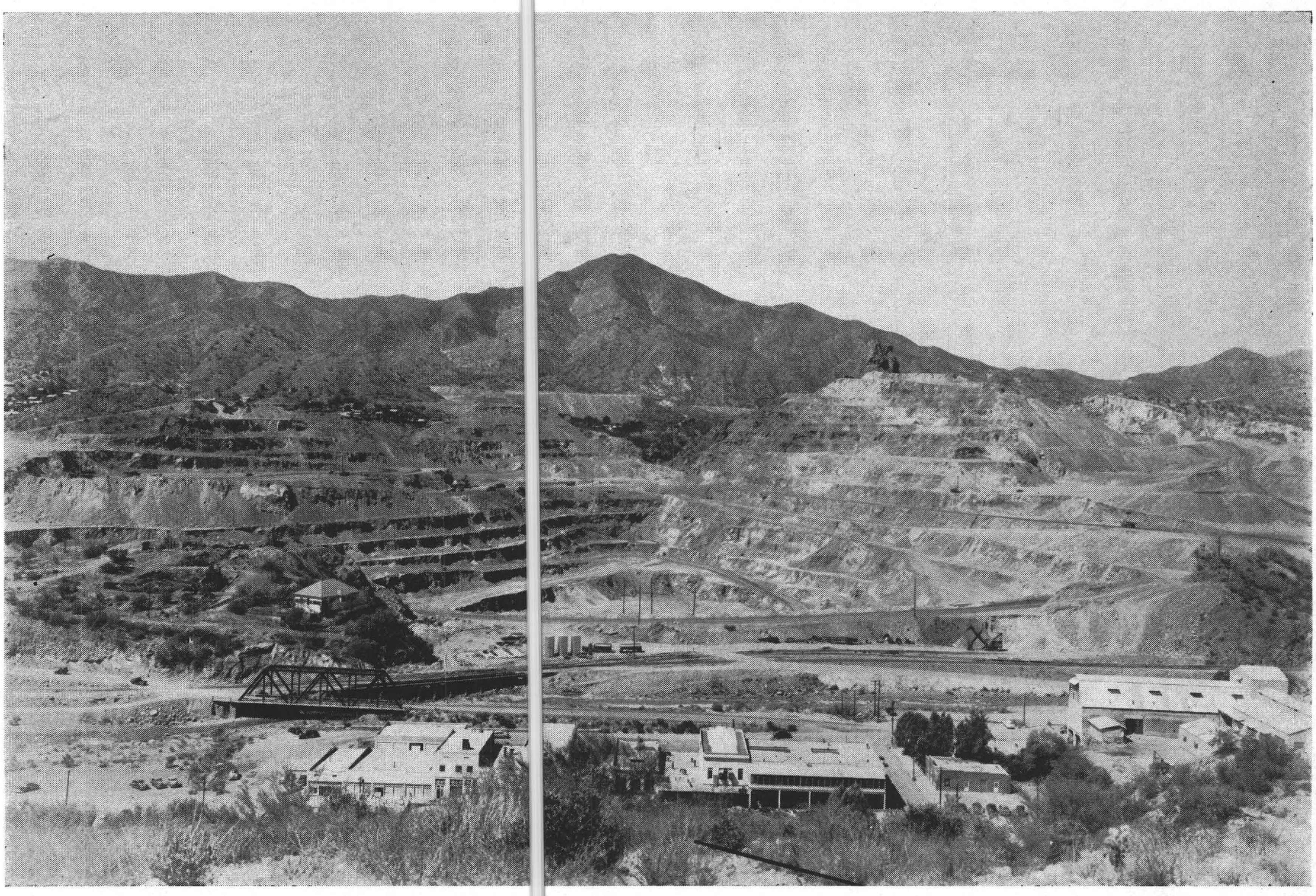
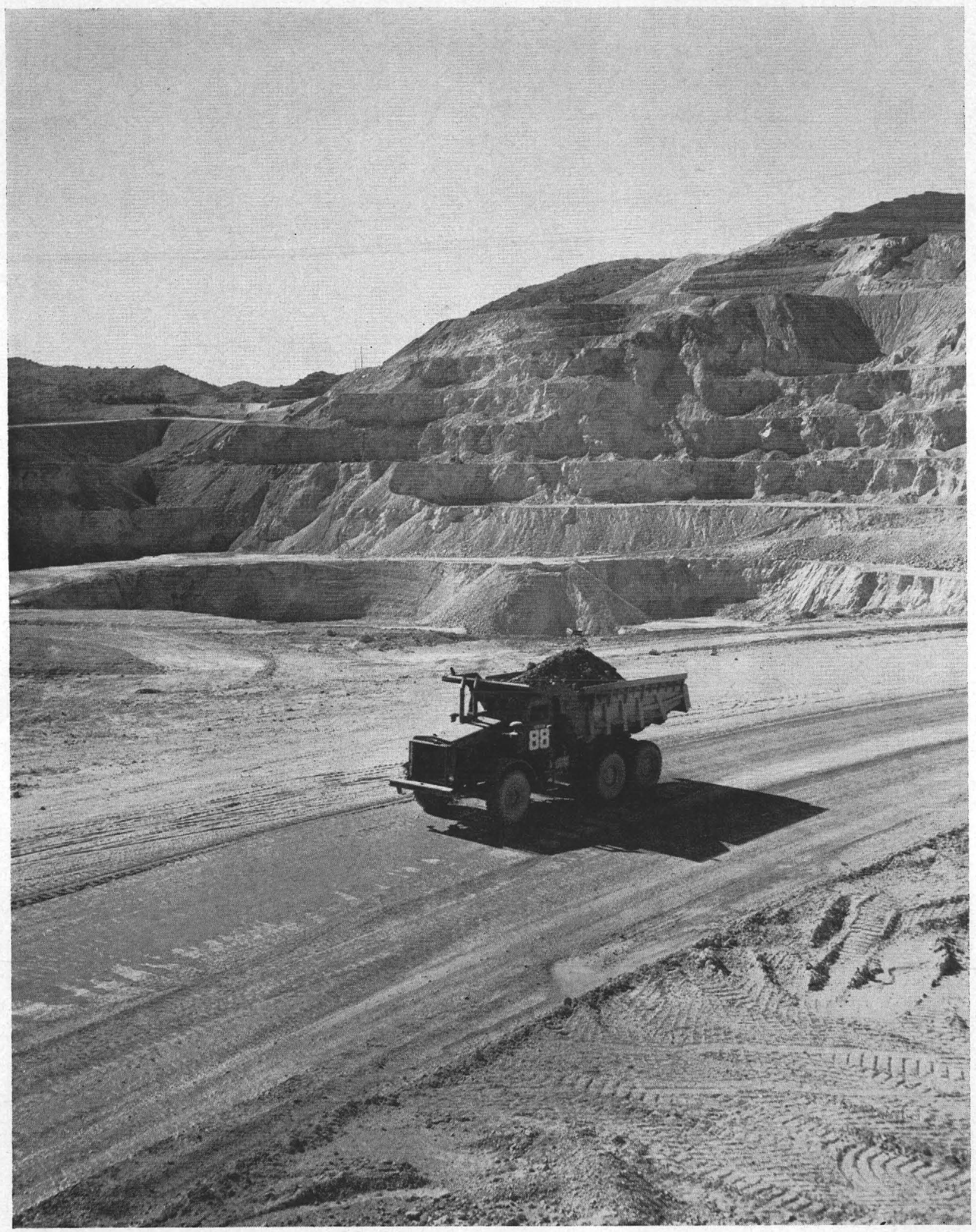
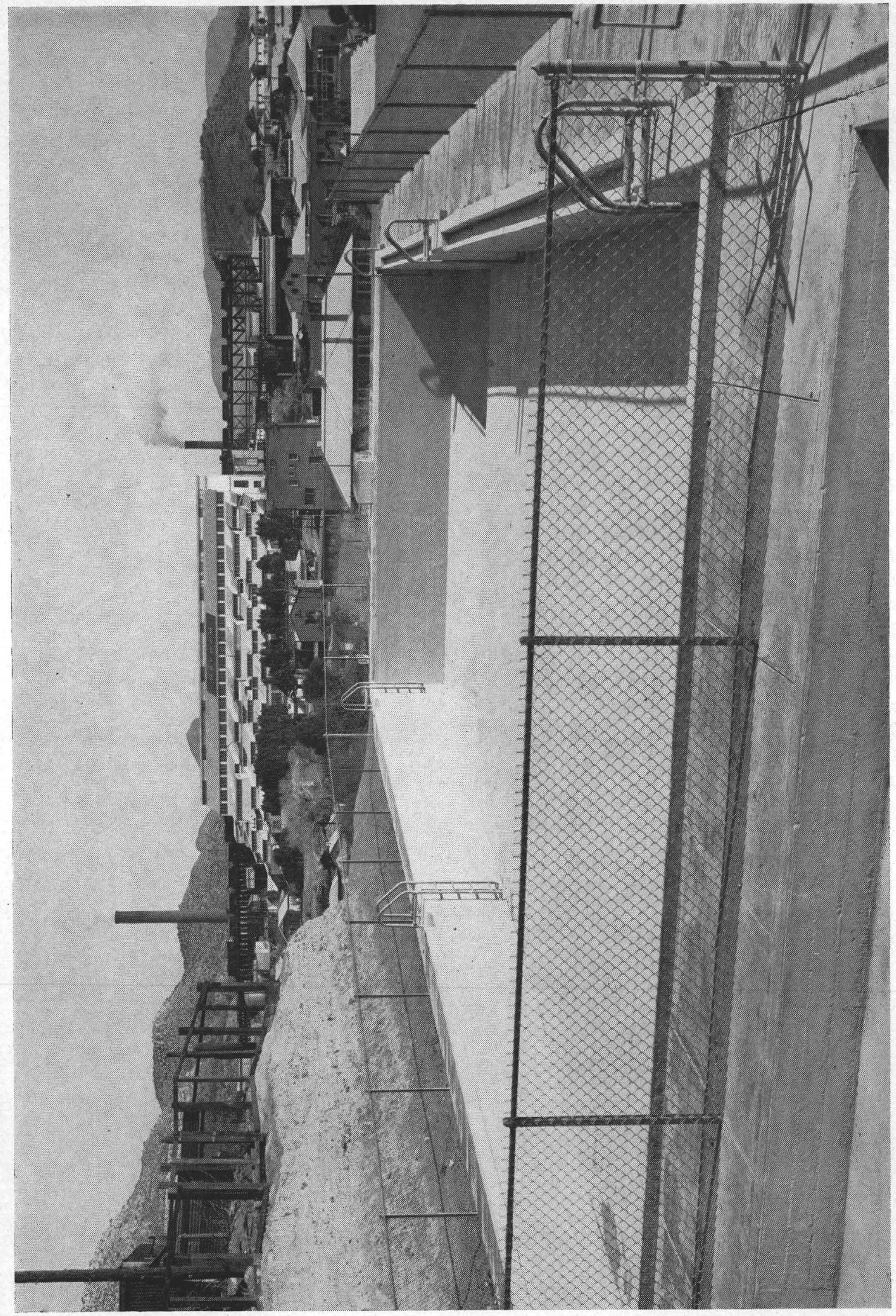


View of Ray Pit, September 2, 1952. Kennecott Copper Corporation.



Thornton Pit, Inspiration Consolidated Copper Company.



View of Hayden Mill. Kennecott Copper Corporation.

ings, building a railroad and a concentrator, together with all the other industrial buildings required for such a big undertaking. In addition to all this, the American Smelting & Refining Co. had to build a three-million dollar smelter to take care of the mining company's product, and it also placed a five-million dollar refinery at the service of the mining company, for copper concentrates and even blister copper are not the end-product of the project. During all this time, there were many periods when the mining company lost money, due to the low market price of copper, which after all was one of the hazards the mining industry had to face, a hazard over which the mining company had no control. The problems were not all geological, metallurgical and mechanical; there were labor and business problems to be handled. For example, the depression of the thirties caused a complete shut-down of four years' duration which came close to a complete abandonment of the Ray property. It took large expenditures to keep the underground workings in half-way decent condition for future resumption of operations. Furthermore, the oxidation of the exposed mineral in the miles of underground openings resulted later in reduced recovery by the flotation process, which has been successful only in treatment of clean sulphide mineral.

The total production of copper, gold and silver since the beginning of operations by the Ray Mine in 1911, through the year 1956, was approximately as follows:

Total Tons Ore Mined	107,316,278
Net Pounds Copper Produced	2,467,000,000
Net Ozs. Gold Produced (approx.)	31,000
Net Ozs. Silver Produced (approx.)	2,600,000

The Kennecott Copper Corporation's reports do not segregate the Ray Mine's financial operations from the combined operations of the company's huge holdings, but assuming Ray has averaged slightly less than three cents profit per pound of copper, for the payment of dividends over its 45 years of operation, the Ray mine has probably contributed 70 million dollars toward Kennecott's dividend's. This would be slightly less than ten percent annual return on the original 15.6 million dollar investment. Not a fabulous return, but when one considers the enormous wealth in copper, gold and silver (over 460 million dollars) which has been created out of this tiny section of Arizona, it is a truly fabulous tale.

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* U. S. Geological Survey Prof. Paper 115,1919; U. S. Geological Survey folio 217,1923.

1 Chalcocite – Copper Sulphide – a secondary mineral containing 80% copper, and 20% sulphur.

2 Pyrite – Iron Sulphide – a primary mineral, containing 47% iron and 53% sulphur.

3 Schist – a metamorphosed sedimentary rock.

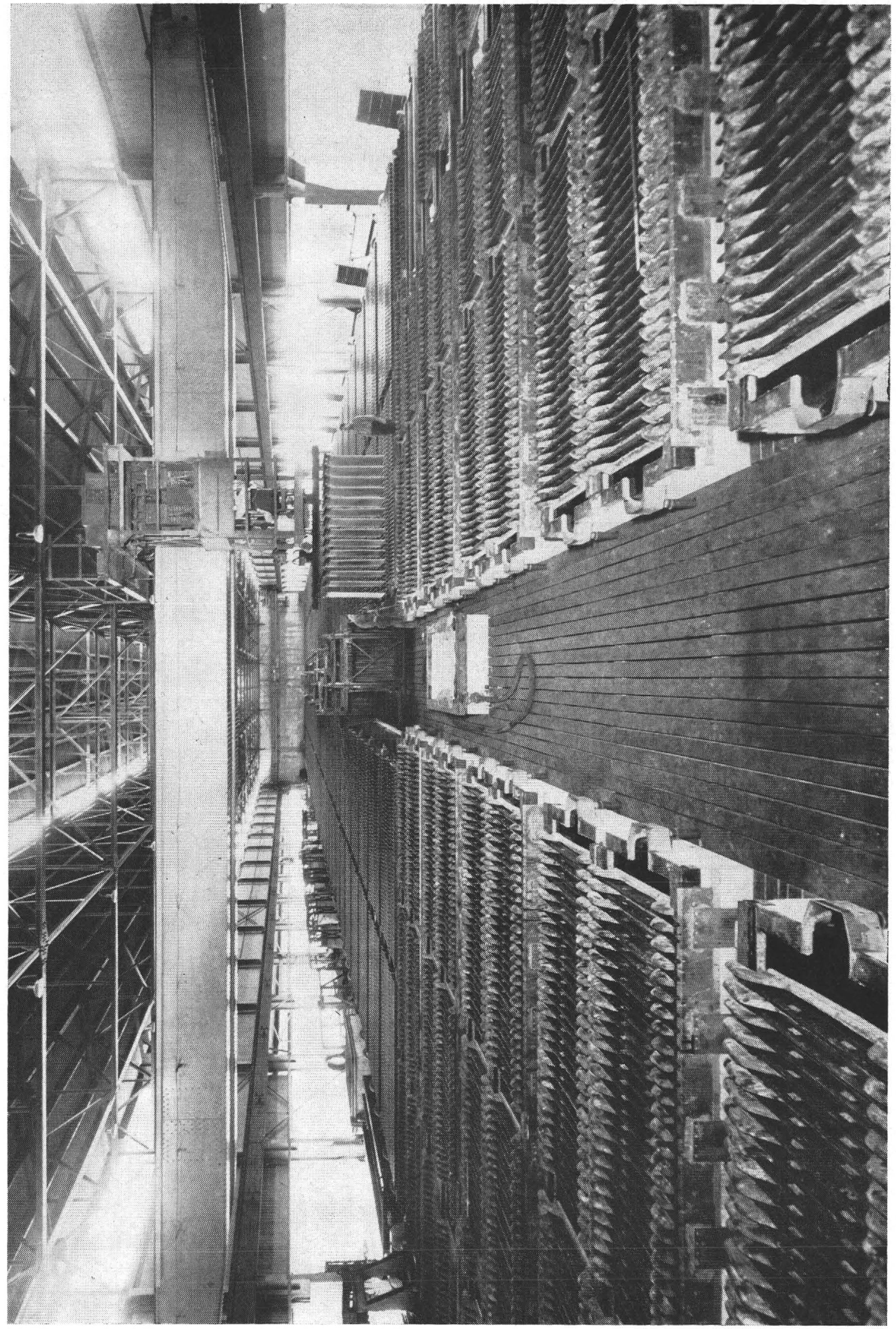
4 Capping – Leached material overlying the ore body. Also called overburden.

5 Protore – Metallized rock of a grade too low to be classed as ore.

6 Porphyries – Intrusive igneous rocks with distinct crystals imbedded in finer grained material.

7 Diabase – Intrusive igneous rock – dark gray or greenish colored – even textured.

8 Chalcopyrite – Copper – Iron Sulphide – a primary mineral containing 30% iron, 35% sulphur and 35% copper.



Inspiration Consolidated Copper Company electrolytic precipitation plant.

Miami Copper had considered the property as a possible future reserve, but about that time the government became vitally interested in increasing copper output. Consequently, arrangements were completed for the RFC subsidiary, Defense Plant Corporation, to provide the funds necessary to equip the property, and, late in 1941, Miami Copper exercised its option on the Pinto Valley holdings. These claims, together with the Continental group, were then deeded to Castle Dome Copper Company.

One of the most remarkable achievements of the entire operation was the speed with which the property was brought into production once the decision to go ahead was reached. The project was granted top priority by the government and the W. A. Bechtel Company commenced preliminary work early in January of 1942 as engineer-contractor. Seventeen months later copper concentrates started moving from the company's mill to the International smelter at Miami.

Castle Dome took the mine over from the contractor on April 19, 1943, and accepted the conentrator on June 10th of that same year. By this time the Bechtel Company had stripped the orebody of nearly 14,000,000 tons of waste, stockpiled 473,000 tons of ore, constructed a 10,000-ton flotation plant and built a 4½-mile paved highway to the property.

To provide the necessary water, a 16" combination steel and wood-stave pipe line was laid a distance of over 11 miles from the Old Dominion mine at Globe to Castle Dome and a 3,563,000-gallon reservoir was built. A power line was erected to connect the property with the Salt River Valley Water Users Association system.

The most remarkable achievement of this operation has been the fact that though the ore mined has contained only twelve to sixteen pounds of copper per ton, the Castle Dome Mining Company has paid in rental to the Defense Corporation a total of approximately sixteen million dollars, and has had net earnings of almost ten million dollars before depreciation and depletion.

Anticipating the exhaustion of the Castle Dome ore body, work preparatory to the Copper Cities mine development as an open-pit operation was started during the latter part of 1950. Exploratory drilling of the Copper Cities orebody had begun in 1943, was interrupted until 1946, and completed in 1948. Over 21 million tons of waste were removed before ore mining began in 1954. The Copper Cities Mining Company is a wholly owned subsidiary of the Miami Copper Company, and its property is located approximately 3 miles northeast of Miami, Arizona.

GEOLOGY OF THE MIAMI-INSPIRATION DISTRICT

The Pinal Range, which covers an area about 16 miles long and 12 miles wide, is made up largely of Pinal schist with considerable irregularly intruded quartz diorite and granite and also a younger intrusive, the Schultze granite. The disseminated copper deposits of Miami occur in the northeast corner of this area.

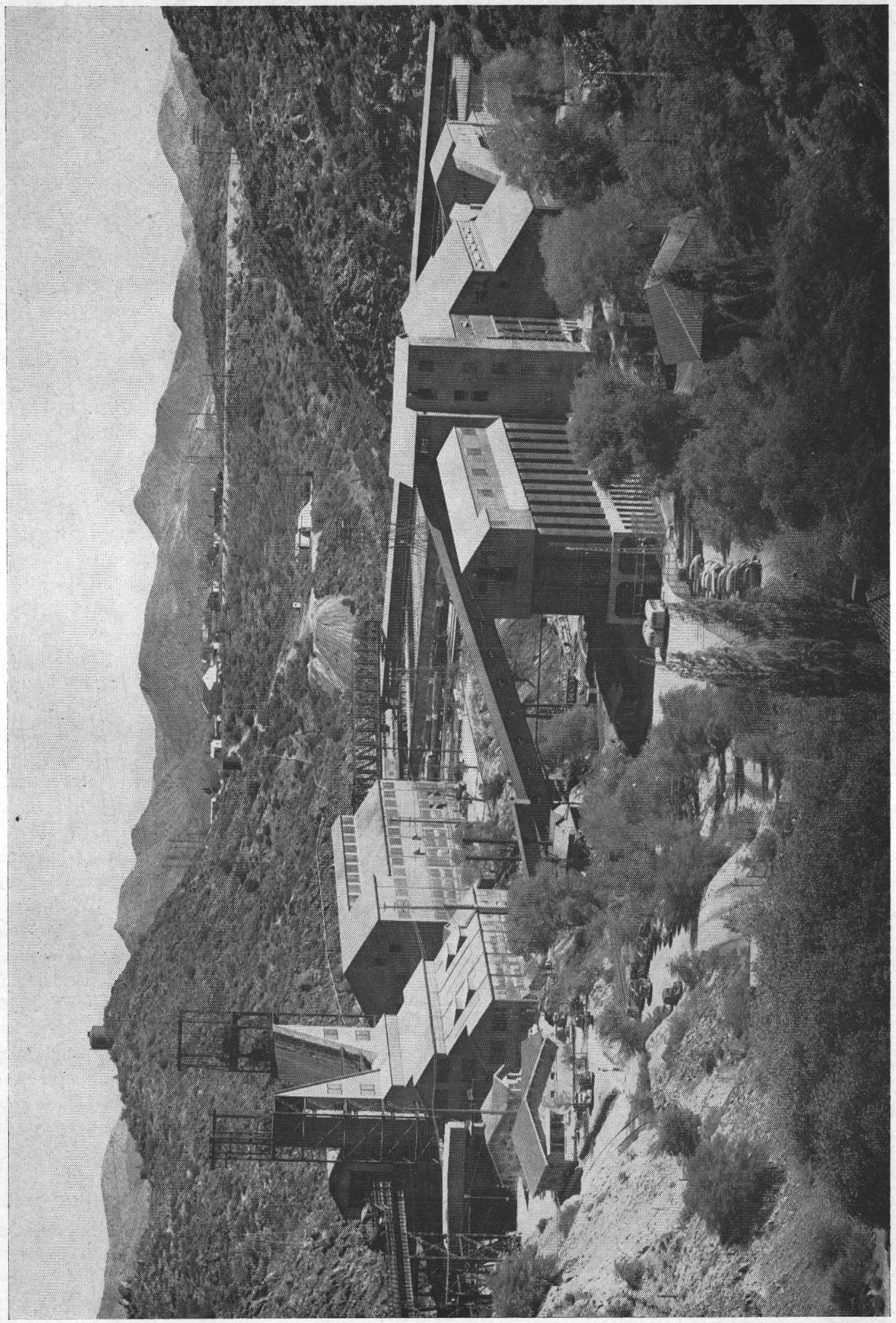
Probably the most important rock associated with the copper deposits of Inspiration, Miami and Castle Dome is the Schultze granite. This has been minutely fissured and the cracks have been filled with quartz and to a less extent with sulphides. The result is a very brittle and fragile mass that, with the crumbly character of the Pinal schist, is so essential to successful block-caving methods of mining.

The Miami district contains numerous faults[1] which have played an important part in the mineralization of the district. The metallic minerals of interest are native copper, native silver, molybdenite, galena[2], chalcocite[3], covellite[4], chalcopyrite[5], pyrite[6], cuprite[7], malachite[8], azurite[9], and chrysocolla[10].

The bodies of disseminated copper ore of Miami, Castle Dome and Inspiration may be characterized generally as undulating, flat-lying masses of irregular horizontal outline and variable thickness. As a rule these masses lack definite boundaries. Closely placed samplings and assays indicate a gradational passage from ore to country rock. The depth to the ore ranges greatly from place to place, as in many places the leached rock itself is overlain by dacite or Gila conglomerate.

In a general way the Miami ore-body is chiefly in schist, although a granite-porphyry dike

1 Fault — a fracture in the earth's crust accompanied by displacement of one side of the fracture with reference to the other.
2 Galena — Lead sulphide — 87% lead, 13% sulphur.
3 Chalcocite — Copper sulphide — 80% copper, 20% sulphur.
4 Covellite — Copper sulphide — 66.5% copper, 33.5% sulphur.
5 Chalcopyrite — Copper Iron Sulphide — 35% copper, 30% iron, 35% sulphur.
6 Pyrite — Iron Sulphide — 47% iron, 53% sulphur.
7 Cuprite — Copper Oxide — 89% copper, 11% oxygen.
8 Malachite — Copper Carbonate — Green — 57.5% copper.
9 Azurite — Copper Carbonate — Blue — 55.0% copper.
10 Chrysocolla — Copper Silicate — Green — 36.2% copper.



Inspiration Consolidated Copper Company main shafts in leaching plant area.

THE STORY OF THE MIAMI-INSPIRATION DISTRICT

The Miami-Inspiration Copper District is averaging a production of over 80,000 tons of copper annually. Three large mines, the Inspiration, the Miami and Copper Cities are responsible for this. The Copper Cities Mine is wholly owned by the Miami Copper Company, and has replaced the Castle Dome which was exhausted in 1953. Although all four of these mines are miles apart, their mineralization is more or less related, the generally accepted theory being that the older formations were intruded by the Schultze granite, providing an avenue for secondary enrichment along the contact.

HISTORY[*]

The major developments in the Miami-Inspiration district have all happened in the twentieth century. At the beginning of the century, chrysocolla, a blue-green copper silicate mineral containing when pure about 36 percent copper, had been mined at the Keystone Mine, and soon after, a vein of chrysocolla was stoped at the Live Oak. Both of the veins were in granite porphyry and did not extend into the schist. Several years later the Woodson tunnel was driven in the north side of Inspiration Ridge. This tunnel cut disseminated chalcocite, a black-grey copper sulphide mineral containing when pure about 80 percent copper, and some crude ore was mined from a zone of stringers in the schist. In 1906 the General Development Company sank a shaft on the Captain claim and another on the Red Rock, the latter striking ore at a depth of 220 feet. The Miami Copper Company was organized in November of that year and development work was actively undertaken. By 1909 the railroad had been extended to Miami from Globe, and in 1911 the first concentrates were produced after an intensive construction period which saw the completion of a mill, power plant, and other surface equipment.

During this period the Inspiration Copper Company and the Live Oak Development Company were also engaged in development work. At Inspiration active development by shafts, drifts, and crosscuts, as well as churn drilling, was begun in 1909. Two years later, 21,000,000 tons of ore had been outlined. The Live Oak had by 1912 developed 15 million tons of ore despite the fact that much of the ore body lies deeper than at either Miami or Inspiration and is covered by porphyry and Gila conglomerate. The Live Oak and Inspiration merged in January, 1912 as the Inspiration Consolidated Copper Company with ore reserves of 45,300,000 tons averaging 2 percent copper.

Further developments and refinements in mining and milling methods have greatly increased the ore reserves of both major companies.

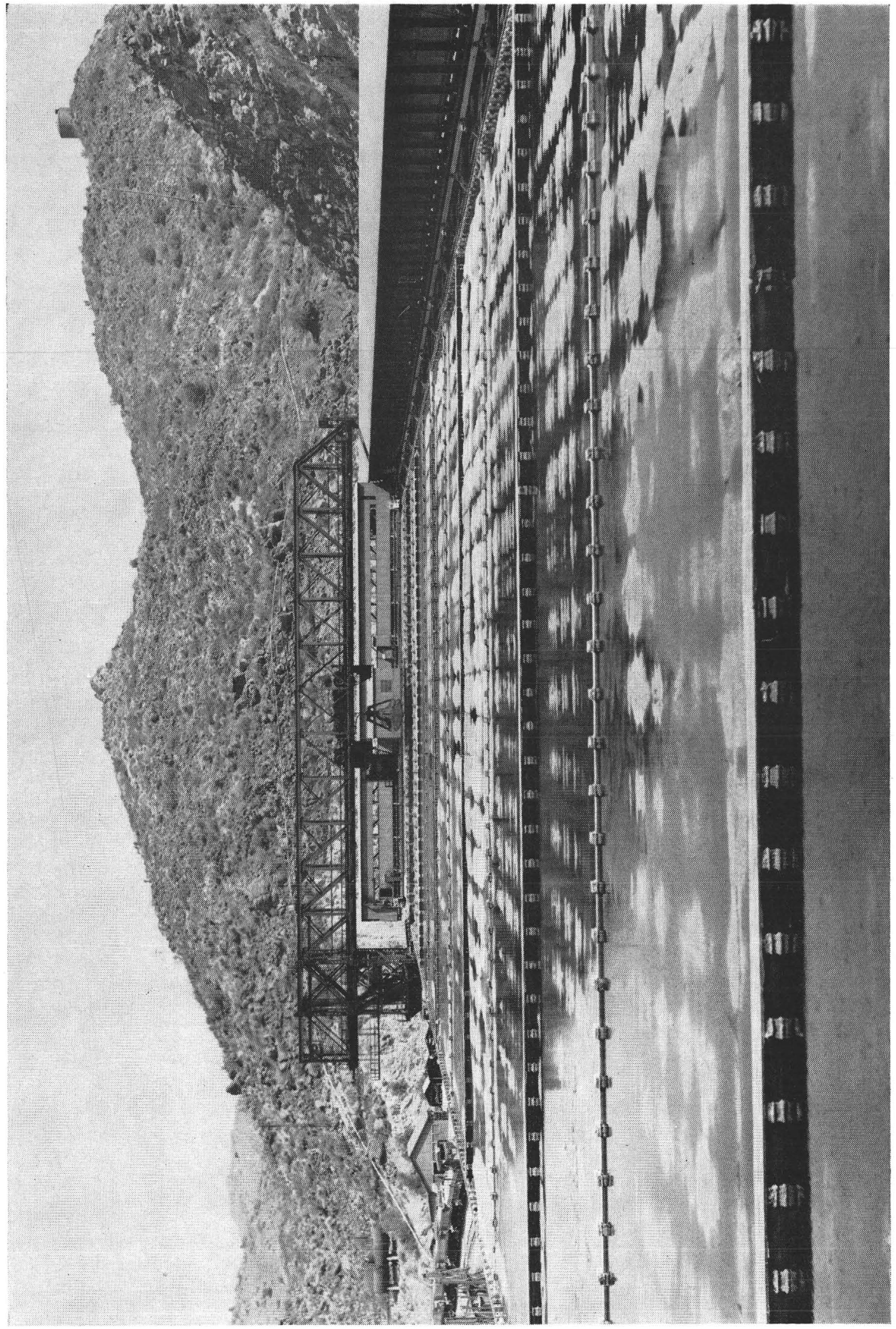
Between 1906, when J. Parke Channing examined the deposits at Miami and exploratory shafts were started, and 1911, when the Miami Copper Company began to produce concentrates, almost ten million dollars had been expended in the preparation for production.

Development of the Inspiration ore-bodies began in 1909 and about fifteen millions had been spent before the production of copper in 1915. In 1915 the International Smelting Company erected a three million dollar smelter at Miami.

The third big producer, the Castle Dome mine, is located about nine miles by highway west of Miami and some three miles north of Pinto Creek. The first systematic exploration work was initiated in the early twenties by the Pinto Valley Mining Company. Jackson Hoagland has written a good description of the Castle Dome operations and much of this history of the Castle Dome area has been taken from his description, written in 1946. The churn drilling conducted from 1924 until 1931 proved the existence of the deposit – and provided valuable information as to its size and grade. Subsequent mining operations by Castle Dome Mining Company verified the accuracy of the earlier determination.

Miami Copper first became interested in the region when it acquired the Continental group of claims adjoining the Castle Dome group through its purchase of the Old Dominion Company. Because the surface geology indicated the possibility of copper values underlying a considerable area, an option was acquired on the Pinto Valley Mining Company holdings and extensive surveys and churn drillings were undertaken to determine the extent and grade of the deposit.

[*] From a paper presented by G. R. Rubley to the A. I. M. & M. E. at Tucson, Nov., 1938.



Inspiration Consolidated Company leaching tanks.

per up to January 1, 1957, and has paid dividends amounting to $96,309,100, or 3.3 cents per pound of copper produced. The recovery of 19.3 pounds of copper per ton of ore mined makes Inspiration a marginal producer which can easily be affected by high wages and taxes.

In connection with the early development of the Miami-Inspiration district, the names of "Black Jack Newman", F. C. Alsdorf and F. J. Elliott, the latter a Phoenix attorney, should be mentioned as responsible for Mr. Channing becoming interested in the Miami property. Henry Krumb, W. B. Thompson and Dr. Ricketts were the men chiefly responsible for the development of the Inspiration. Needless to say the managers and staffs of the two companies furnished the brains which brought about the success of both ventures.

The four mines have been the producers of over 347 million tons of ore, from which have been recovered a total of 5,846,000,000 pounds of copper with a value of over 1,100 million dollars. A result far beyond the dreams of Parke Channing and Henry Krumb!

Most of the eleven hundred million dollars benefitted the State of Arizona in the form of wages for its citizens, education for its children, a market for its farmers, and a higher standard of living for everyone. It has been determined that "for every man engaged in mining and allied industries, 2⅓ jobs were created in service industries and (on the basis of average family size) a total of 12 local persons are thereby supported". Every miner, every millman and every smelter man who has taken part in this creation of wealth may take just pride in his share of such constructive work.

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cutting the schist has likewise been metallized. The Inspiration ore-body is also mainly in the schist, although in places this schist occurs beneath an intrusive sheet of the porphyry. The predominant feature of the Castle Dome ore-body is the Dome or Turtleback fault which divides it into two parts. To the east of this fault the ore is largely of a soft nature with chalcocite the predominant copper-bearing mineral. To the west is a harder ore in which chalcopyrite is the principal source of copper.

OPERATIONS AT MIAMI

The Miami Copper Company's property has been an underground mining operation with a block-caving system of mining to take out the ore. When the 6,000 ton mill was ready to start in 1911, gravity concentration was standard practice, and the mill was equipped with chilean mills for fine-crushing, and tables for concentration. The chilean mills were soon replaced by Hardinge ball and pebble mills, and a short time later steel balls replaced the pebbles. These technical improvements continued with the adoption of flotation. Indeed, the Miami Copper Company, like the other big copper companies, was continually spending money to enable it to profitably treat a gradually lowering grade of ore. In recent years it is now possible to make money in the treatment of ore containing as low as .60% copper (12 lbs. per ton). When the grade of ore dropped below 1 percent, milling capacity was increased to 17,500 tons per day.

It was necessary to do this or suspend operations entirely. A plan of mining operations was worked out on paper by Mr. Maclennan and his associates. They showed the directors of the Miami Company that it would be possible to mine this low-grade ore at a cost well below 50 cents per ton, and the directors authorized the expenditure of almost four million dollars to effect the expansion in plant capacity from 6,600 to 17,500 tons daily.

The production of copper at a cost of 10 cents per pound from an ore giving a net yield of only 10.55 lbs. per ton had never been achieved before. Economies effected both in mining and in concentrating as between 1923 and the later date are due in part to the increased tonnage, but improved efficiency in many directions likewise is a factor. It is difficult to refrain from using extravagant adjectives to describe such figures as 35.7 cents per ton for mining and 24.9 cents for concentrating. The tailings discarded from the concentrator during the first three years of operation averaged 14.52 lb. of copper per ton. In November, 1930, the ore as mined and treated contained less copper than the ton of tailing rejected 15 years earlier.

The Miami ores contain very little gold and silver but since 1938, commercial quantities of molybdenum have been recovered from the copper ores, and have been a factor in keeping the mine in the profitable class. Leaching of the oxidized portion of the mixed ores produced by the mine, has also been employed by the Company in attaining the economic success of its operations. Fifteen percent of Miami's copper production is being obtained from copper solutions. The Miami Copper Company has been a shining example of how a combination of capital, progressive business acumen and technical brains has converted common rock into useful metal.

Miami's concentrate is smelted at the International Smelting and Refining Company's copper smelter located in Miami, Arizona; sometimes at Phelps Dodge Smelter at Douglas. The blister copper is refined either at the Raritan Copper Works in New Jersey, or at the Phelps Dodge Refinery in El Paso. The refined copper is sold by the Adolph Lewisohn Selling Corporation.

Up to January 1, 1957, the Miami mine has produced 146,363,796 tons of ore from which have been recovered over 2,286 million pounds of copper, which, together with a production of 4,427 ounces of gold, and 636,492 ounces of silver, and 9, 251, 193 pounds of moly, had an estimated gross value of $425,000,000.

Mineable ore reserves, at January 1, 1957, were estimated to be 12, 840,000 tons. These do not include any of the material to be leached.

Extensive research on the non-sulphide content of the Miami ores has indicated that recovery could be improved by a leach precipitation and flotation recovery of the oxide content. An additional mill circuit is scheduled to be completed during the second quarter of 1957.

OPERATIONS AT INSPIRATION

The Inspiration Consolidated Copper Company's plant at Miami, Arizona, was designed and built to make possible the profitable working of a low-grade, finely disseminated copper deposit containing 100 million tons of ore averaging 1.54% copper.

From the beginning it was evident that the plant could not be kept integral but that a break would have to be made somewhere in the flow-sheet, removing at least the concentrator to a site more suitable than any available near the mine. It was finally decided to do the coarse crushing at the mine, to store the crushed rock in a bin from which it could be loaded into railroad cars and haul it to the concentrator, an excellent site for which was available about 1¾ miles from the mine.

The original intention was to equip a plant to treat 7,500 tons of ore per day, but through the acquisition and proving up of additional ore reserves, the introduction of the Ohio caving system, and the excellent results in the test mill (which made it possible to treat a lower-grade ore than had been thought possible) it was evident that a plant of much greater capacity should be supplied. It was, therefore, decided to treat approximately 15,000 tons of ore per day.

A gravity test mill was erected and placed in operation near the Joe Bush shaft in November, 1910, and its operation was continued until August, 1911. Soon after, flotation began to attract considerable attention, and a 600-ton test mill was designed and erected in 1913. That the large-scale test-mill method for working out flow-sheets for large plants is the only logical method, is evidenced by the fact that in nearly every stage of treatment either an entirely new machine has been adopted or a new application has been made of a standard machine; the result in each case being increased efficiency or a more economical arrangement. It may be interesting to note that six complete designs for the concentrator were executed, the idea being to keep this work abreast of the developments brought out by the test-mill.

The concentrator was no sooner erected than very marked changes in grinding machinery began to develop, the ultimate result of which was another altogether new arrangement for the entire mill.

As a result of preliminary studies, a dual arrangement of the mine plant was evolved. To insure continuity of service two shafts were used, and the whole mine plant was made duplicate in arrangement. A water supply for the concentrator was developed at Wheatfields, about 12 miles from the mill site, and later, wells were sunk on the flat below the tailing storage site. The best location was determined to be about 2½ miles from the mill, at the junction of two fair-sized drainage channels receiving their supply from the Pinal Mountains about 10 miles away and 4,000 ft. higher.

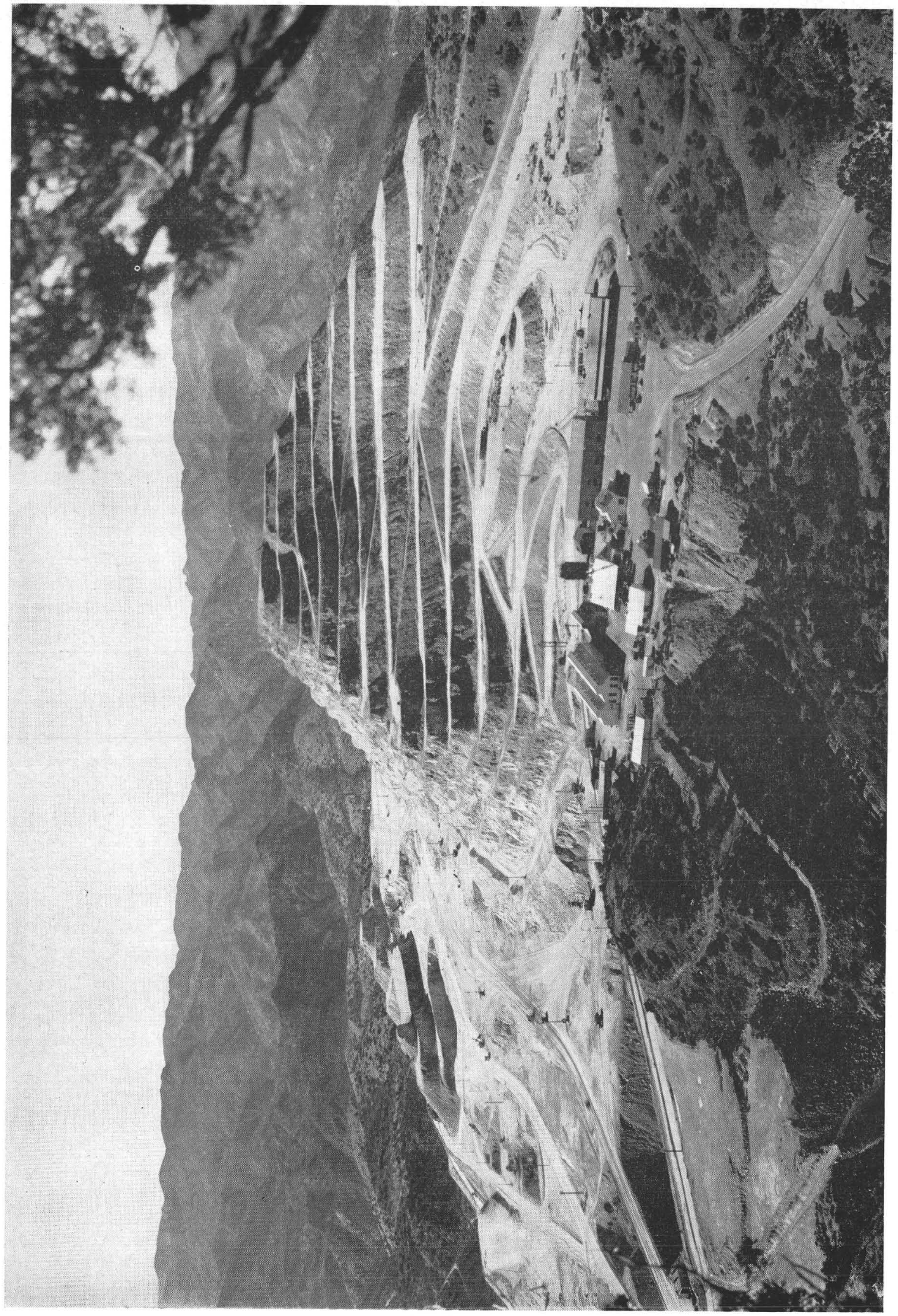
Electric power was obtained from two sources. The Reclamation Service of U. S. Government at Roosevelt Dam, 40 miles away, furnished some of the power, and in conjunction with the International Smelting Co., the Inspiration built a power house that utilized reverberatory waste heat and also produced power from oil-fired boilers (later gas-fired).

Throughout the early years of mill operation, research and experimentation developed improvements, until in the early twenties, when the Inspiration ore being mined at that time, began to show larger proportions of non-sulphide copper which was not amenable to efficient treatment by flotation. A search was made for a process that would successfully treat such mixed ores. The main sulphide copper mineral was chalcocite and the principal non-sulphide, chrysocolla. Laboratory and test-plant investigations conducted by G. D. Van Arsdale, together with the Inspiration staff, proved that such mixed ores could be successfully treated by leaching with ferric sulphate. Many millions of dollars were expended in these tests and in the construction of a suitable leaching and precipitation plant. And since 1926, this method of treating the Inspiration ore has been standard practice.

Inspiration's concentrate, when produced, is smelted at the International Smelter in Miami, and the blister copper is refined either at its own plant in Inspiration or at the Raritan Copper Works in New Jersey.

An open-pit development and construction program was completed in March, 1948, and since that time more and more of the ore has come from the open pit. In 1949 all necessary work underground was completed for leaching in place certain mined out and caved areas in the mine to recover part of the remaining copper. Production from this source began in 1950. In 1956, this production was 9,811,822 pounds, as compared with 11,860,313 pounds in 1955.

Underground mining was completely suspended in August of 1954. The 7½ miles of underground openings which remain are used for



Castle Dome Mining Co.'s open pit and shops.

which began in December, 1953, its transportation and installation at Copper Cities, had on August 2, 1954, reached the stage where partial production was possible. The last two sections of the mill were in operation on November 16, 1954.

Almost identical in tonnage and grade with the original Castle Dome orebody, the Copper Cities project dates back to some long-range thinking and consolidation of Miami's holdings with the Porphyry Reserve Group in 1941. The deposit is a typical low-grade dissemination of chalcopyrite and chalcocite in quartz monzonite and quartz monzonite porphyry. It is bounded on three sides by faults – to the north the Drummond, on the south the Coronado, and the Sleeping Beauty cuts it off on the west.

In September, 1954, Copper Cities Mining Company repaid in full the $7,500,000 borrowed up to that time from R. F. C. under the loan agreement of November 15, 1950. The 1954 Annual Report further states that the "funds for this refinancing were made available from the proceeds of a $4,500,000 bank loan at a lower rate of interest, and through advances from Miami Copper Co. Through December 31, 1954, a total of $13,718,000 was expended on the Copper Cities project. Of this amount $4,500,000 came from the proceeds of the bank loan above mentioned, and $9,218,000 was provided by Miami Copper Co. It is estimated that about $150,000 will be required to complete the necessary facilities at Copper Cities."

Fresh water for the project is supplied from two sources, one of which is the Old Dominion Mine near Globe. Water is pumped from the mine shaft to the Copper Cities pumping plant at Burch. The second source comes from a water development across the Miami Wash at Burch. An 8 x 8 foot shaft was sunk 190 feet to solid conglomerate below the water-bearing sands, and a drift was driven westerly under the dry wash. Churn drill holes were drilled through the sands into the drift, and were cased with perforated stainless steel pipe. Water is collected in the drift and pumped with three deep well pumps from the shaft to a water treatment plant.

Following is record of operation at Copper Cities since the beginning of production – according to Annual Reports:

	Tons Ore Mined	% Copper	Lbs. Copper Produced	Ounces Gold Credit	Ounces Silver Credit
1954	996,160	0.783	12,514,108	231	12,529
1955	4,004,052	0.824	55,097,164	356	38,824
1956	4,167,147	0.795	55,833,935	196	36,702
	9,167,359	0.806	134,445,207	783	88,055

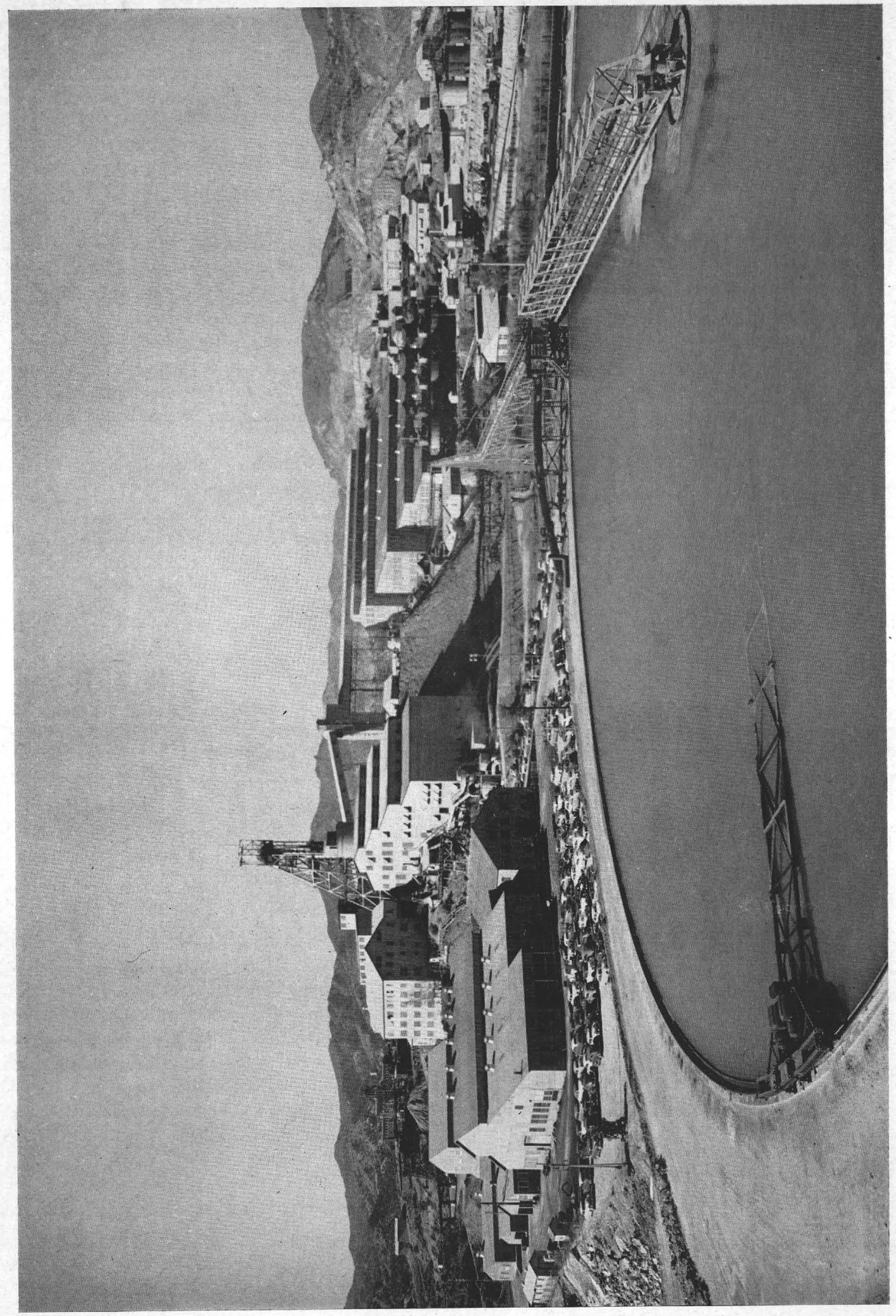
The Company estimates that as of January 1, 1957, mineable reserves amounted to 36,600,000 tons. Approximately 9,500,000 additional tons were proven by drilling during the year 1956.

CONCLUSION

The above facts tell the story of how intelligent observation and scientific reasoning can be brought to bear even on the exploratory phase of mining which has seemed usually so haphazard. In the case of the Miami mine the sum of $400,000 was risked to ascertain whether there was enough ore to constitute a profitable mine; after that point was passed, the further development underground served merely to emphasize the bigness of the orebody and the consequent need of making financial provisions for operations on a big scale. The story of the Miami and the Inspiration suggests also that the successful exploitation of an orebody may involve operations on a scale so big as to require the expenditure of sums of money that make the original purchase of the bare ground seem very cheap; it indicates that a mining claim without the intelligent use of capital is only second-rate scenery.

The Miami Copper Company has produced a total of 2,932,295,308 pounds of copper from its three mines, up to January 1, 1957, and has paid dividends amounting to $59,176,828.10, or two cents per pound of copper produced. The recovery of 14.9 pounds of copper per ton of ore mined indicates the extraordinarily low margin under which this company has been operating. In recent years this recovery has been less than 12½ pounds of copper per ton!

The Inspiration Consolidated Copper Company has produced 2,913,876,747 pounds of cop-



Miami Copper Company's mine shaft and concentrator.

the underground haulage of open-pit ore and drainage of leaching-in-place solutions.

By January 1, 1957, the Inspiration mine had produced 150,756,280 tons of ore, from which had been recovered 2,913,877,000 pounds of copper worth about 524 millions of dollars. Since the beginning of operations the Inspiration mine has paid dividends amounting to $96,-309,100, which is 3.3 cents per pound of copper produced. The Company's mining engineers estimate that at December 31, 1956 the proven ore reserves in the Inspiration Mine contained approximately 953,000,000 pounds of recoverable copper.

In 1955, the Inspiration Board of Directors approved final plans for the conversion of the Company's Metallurgical plants to the so-called "Dual Process". In this process the ore will first be leached with sulphuric acid in the leaching plant to recover its oxide copper content. The washed and drained residue from such treatment will be transferred to the concentrator where, after fine grinding, the copper sulphide values will be recovered by flotation.

Although the rehabilitation and re-equipment of the concentrator, (which have cost over six million dollars) were not entirely complete in December of 1956, operations of the "dual process" began early in January, 1957, marking the beginning of another new era for the Inspiration Mine. A greater annual rate of copper production is anticipated.

CASTLE-DOME OPERATIONS

Before the mine exhaustion in 1953, Castle Dome Copper Company mined and milled over 12,000 tons of ore daily. The mine was a typical open-pit operation with the latest and most modern equipment known to the industry. Electric churn drills, electric shovels, and diesel trucks were used. The concentrator was also one of the most modern and efficient in the industry. Its simplicity of design and operation permitted the use of women as operators, which was one reason why this property was not as seriously affected as others by the labor shortage problems during the war. Automatic feed control, first conceived by F. W. Maclennan, and worked out by Miami and Castle Dome staffs together with Westinghouse Electric and Mfg. Co., increased the plant's efficiency both as to tonnage and metallurgy. Tied in with the feed control was a water control which adjusted the flow of water into the mill, maintaining a constant density. The importance of this control to an operation like Castle Dome becomes apparent when it is realized that no attempt was made to control the hardness and grindability of the ore mined and delivered to the concentrator for treatment. The ore was dumped into the coarse ore pocket as it best suited the mining operation. At times it carried 1 percent copper and others 0.4 percent. Moreover, on one day it came from the eastern portion of the ore body where the ore was softer, and the next from the western side where it was harder.

Although ore reserves were exhausted on December 4, 1953, the Castle Dome Mine has continued to produce copper by leaching of the mine dumps.

A detailed summary of Castle Dome operations is as follows:

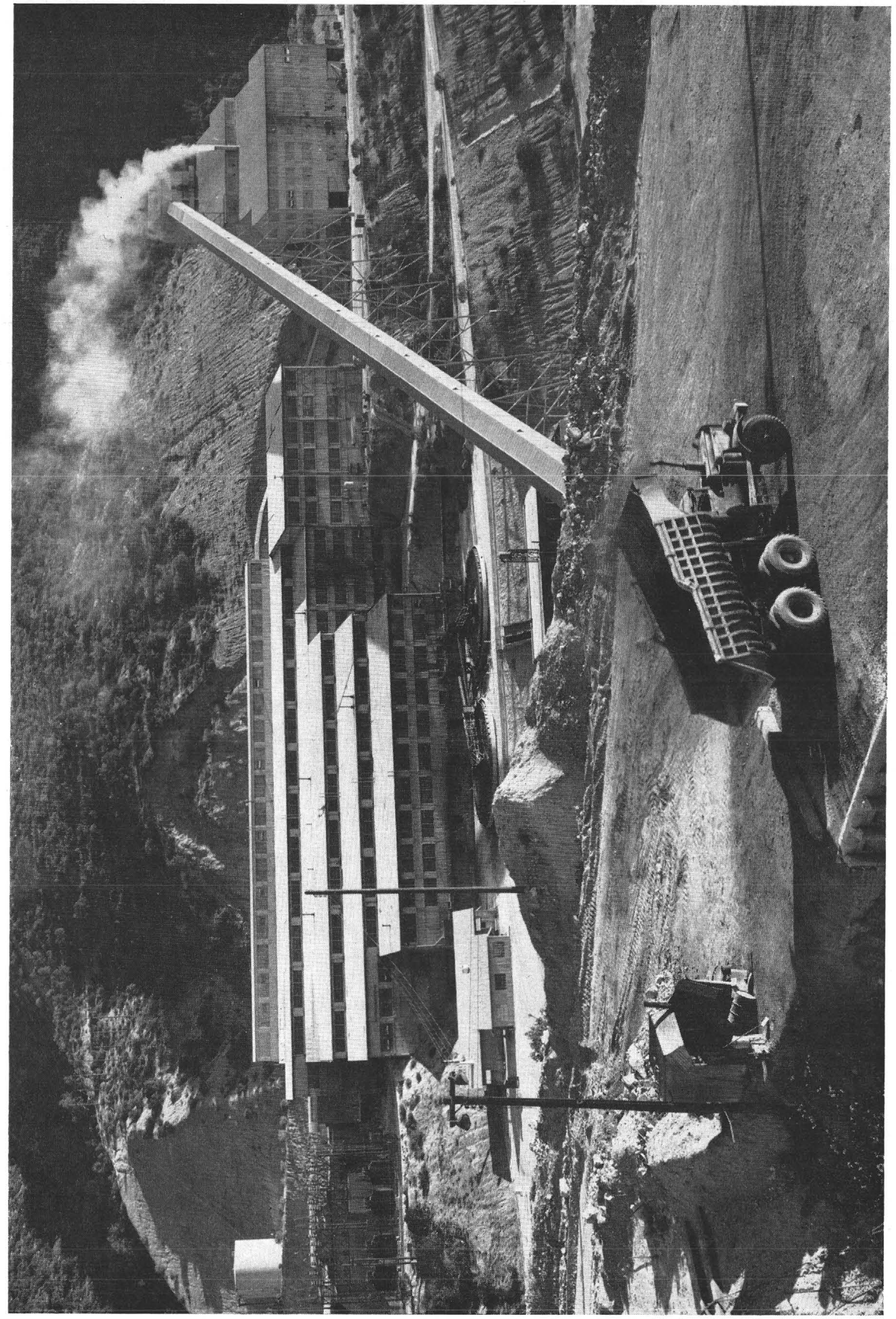
Milling started	June 10, 1943
Milling completed	December 5, 1953
Grade of Ore	0.725 percent copper
Sulphide	0.689 percent copper
Oxide	0.036 percent copper
Tons of Ore Milled	41,442,617
Pounds of copper recovered	514,390,317
Net recovery	12.412 pounds per ton
Tons of waste handled	48,484,188
Stripping ratio	1.17 to 1.00
Ounces gold produced	9,385
Ounces silver produced	583,068
Additional copper produced by leaching	8,277,929
Estimated gross value of metal production	$101,000,000

OPERATIONS AT COPPER CITIES*

After four years of detailed planning and accurate timing, Miami Copper Company made a well-coordinated move of mining and milling facilities from its depleted Castle Dome Copper orebody to the new Copper Cities project located three miles northeast of Miami, Arizona.

The overall plan involved moving a 12,000-ton plant, 52 pieces of mining equipment, and personnel from Castle Dome to Copper Cities, a distance of 15 miles, with a minimum of lost time and production. As stripping ratios decreased at Castle Dome and equipment became surplus, men and facilities were transferred to Copper Cities to accelerate work already underway. The dismantling of the Castle Dome plant,

* Mining World, April, 1954.



Castle Dome Mining Co.'s crushing plant and concentrator.

THINGS TO DO TODAY

Page 22 — last ¶ "benefitted"
Page 76 - last line "April, 1957"
Page 27 - Heading Merenci
-Page 54 - second ¶ "seperate" ✓
- Page 58 - Second ¶ 2nd Col "anv"
- Page 60 - Second ¶ "precipitious"
Page 63 - Quote ¶ - Line out of place
Page 63 - Last ¶ "Porphyry" lcP.
Page 63 - Firstline - "Porphyries" lc P.
Page 72 - Second ¶ "data <u>was</u>"

Page 6 - line 7 "benefitted"

WEDNESDAY, JULY 17, 1957

JUNE

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
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30						

JULY

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

AUGUST

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
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11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

198th Day Patented 167 Days to Come

for the record...

Introduction (28")	25"
Ray (64)	57 + Head + Cut
Miami Insp (113")	100 " "
New Cornelia (51")	45 " "
Morenci (101)	90 " "
Bagdad (54)	48
Lavender (53)	47 " "
Silver Bell (42")	38 " "

Type in booklet runs
7.7 words per line
6 lines to inch
46 words per inch

Pay Dirt type runs
6.5 words per line - 8 lines to inch
52 words per inch

could be better applied than in handling these vast quantities of very low-grade ore with which large areas of the rocks of this territory are permeated.

The new enterprises which the high price of copper has tempted Eastern Capital to invest in, have as yet increased the Territory's production to a very insignificant extent. Most of them, it is fair to assume, will never do otherwise. Those that have some substantial basis for existence will, before they become profitable, confirm the experience of all those who have had to do with copper mines, that an outlay of money, worry and experience that finds no place in the promoter's prospectus, will have to be made before returns, in cash, balance expenditures."

When in 1897, Dr. Douglas became president of the Detroit Copper Co., he put Charles E. Mills in charge of operations at Morenci. An era of expansion and improvement at both properties commenced under the direction of Mills and Colquhoun. When it became necessary to exploit the leaner sulphide ores, Colquhoun constructed No. 6 concentrator, first operated in August, 1906. The two companies continued their separate existence, though in 1917 the Detroit Copper Company had come to be called the Morenci Branch of the Phelps Dodge Corporation. In 1922 the A. C. Company was absorbed by Phelps Dodge, and virtually the entire district came under a single control. Included also were the properties of the Shannon Copper Co. at Metcalf, which had been acquired by the A. C. Company in 1918.

From 1907 to 1931 the mines now included in the Morenci Branch produced 953,500 tons of smelting ore and 31,100,000 tons of concentrating ore, with a yield of 1,222,200,000 lbs. of copper in the form of blister. They had been profitable ventures. But the greatest era of production lay ahead, in the Morenci orebody. To the engineers this deposit offered a most fascinating problem. It was possible to mine it with power shovels or even by underground methods. It also offered two methods of treating the ore: either by concentration of the ore and smelting of the concentrate, or by leaching and the production of pure electrolytic copper near the mine.

From 1929 to 1942 when regular production from the Morenci open pit commenced in January, Mr. Cates directed a thorough program of testing and development which culminated in the construction of a 25,000-ton concentrator and a smelter to handle its product at the mouth of Morenci Canyon 2 miles from the open pit. A more fortuitous date for starting this operation could not have been chosen, for it was the year of World War II, and Uncle Sam had need for every pound of copper he could get his hands on. In 1943, the Phelps Dodge Corporation in combination with the Defense Plant Corporation prepared for a daily production of 45,000 tons of copper ore, which was the designed capacity of the combined P. D. and Defense Corporation concentrators. The present capacity is 50,000 tons daily.

As may well be imagined, the long period of experimentation and planning, between 1929 and 1942, was marked by many failures and changes of plans. While the big problem was the choice of open-pit or underground mining, and leaching or regular concentration methods, there were many other worries facing the company. By no means the least was the uncertain future of the copper industry during the long depression period. Metallurgical problems, involving the choice of the proper equipment to use after the selection of the method of concentration, included the necessity for large-scale practical testing, and the choice was not an easy one. Then there was the smelting problem, for the character of the concentrates made by the mill naturally varied with the modifications of the crushing, grinding and concentration processes.

DESCRIPTION AND GEOLOGY OF THE MORENCI ORE DEPOSIT*

The Morenci open-pit mine is on the southwest side of Chase Creek and north of the area that had been most productive in the past – namely the Copper Mountain-Longfellow area. The ore body, as now defined has a maximum length of 4,400 feet and a maximum width of 2,800 feet. The mine is entirely within the quartz monzonite porphyry body, which is highly altered and fissured throughout the mineralized area. Different parts of the ore body have been developed by different methods. Some of the earliest openings followed the more prominent fissures for hundreds of feet. Later areas were developed by underground openings, and the latest developments were by churn drill.

* From a paper presented to the A. I. M. E. at Tucson, November 1-3, 1938, and Lindgren's Professional Paper A 3, 1905, U. S. Geol. Survey.

STORY OF NEW CORNELIA

For the last five years the New Cornelia mine at Ajo has been producing copper at the rate of over one hundred and thirty million pounds, annually, and has been second only to Morenci among the Arizona copper producing companies. Ajo is situated in low mountains in extremely arid desert country. By road it is 42 miles south of Gila Bend and 132 miles west of Tucson.

HISTORY*

It is claimed that the first mining of copper by Americans in Arizona was done at Ajo in 1854. The first shipment of ore, consisting of native copper and cuprite (an oxide of copper containing, when pure, 88.8% copper) came from what is now the Eastern end of the New Cornelia workings. It was hauled in ox-carts[1] to San Diego, 400 miles across the desert; later shipments were made only as far as Yuma; whence they were shipped to Swansea, Wales, for smelting.

The mine at Ajo, known successively as the Cornelia[2] and the New Cornelia, passed through the usual vicissitudes of fortune until in later days improved mining and metallurgical methods, preceded by diamond-drilling, created conditions favorable to the large scale exploitation of low-grade ore. Several companies and several distinguished engineers failed to bring the enterprise to fruition until, in 1911, on the initiative of John C. Greenway and the recommendation of Ira Joralemon the Cornelia mine passed into the possession of the Calumet and Arizona Mining Company. Greenway, aided by Louis D. Ricketts, as consulting engineer, made a complete success of the venture. As the oxidized material had to be removed before the sulphide ore could be mined, they started a series of experiments in 1912 to determine whether such oxidized material could be beneficiated profitably by some simple leaching process. The tests were made by James Potter and Henry Tobelmann, and after a one-ton plant and a 40-ton plant were operated, a 5,000-ton plant was built in 1917 and proved completely successful. Two years later, in 1919, an experimental mill was built to test the treatment of the sulphide ore by flotation. Then came the erection of a flotation plant of 5,000-tons capacity, designed by H. Kenyon Burch. This plant started in 1924. By later remodelling, the tonnage has been stepped up to 29,000 daily capacity. These large-scale operations would have been impracticable if an ample supply of water had not been obtained. This was accomplished by sinking a two-compartment shaft 650 feet deep at a place six miles distant, where the water-table of the region was tapped originally by two pumps, with a combined capacity of 1,500 gallons per minute, and ultimately by five pumps with a combined capacity of 5,500 gallons per minute delivered to the reservoir at the mine against a total head of 1,375 feet. Without an adequate supply of drinking water for the large force of men employed and without plenty of water for metallurgical purposes, the New Cornelia enterprise would have been impossible. The finding, pumping, and distribution of this ample supply of water are not the least of the many engineering features that characterize this successful undertaking in the southwestern desert.

In July, 1917, the New Cornelia Company acquired the property of its neighbor, the Ajo Consolidated Company. The Ajo property had been purchased in 1912 from the Randall Ore Reduction Co. by Briggs and Gaskill for James Phillips, Jr. Diamond drilling was started in 1913 by E. J. Longyear & Co., and in due course 12,845,026 tons of 2 percent ore was proved. When the New Cornelia acquired the property the assured tonnage had increased to 21,000,000 tons of 1½ percent ore. The diamond drilling on the consolidated property was continued until 59,000,000 tons of 1½ percent ore had been proved. In November, 1918 the New Cornelia paid its first dividend. In 1929 it was merged with the Calumet & Arizona, and in 1931 it became the New Cornelia Branch of the Phelps Dodge Corporation. The leaching plant was abandoned in 1930 after treating 16,812,324 tons of 1.355 percent ore, from which about 345,000,000 pounds of copper had been recovered. The New Cornelia Copper Co. from 1918 to the time of its absorption by the Calumet & Arizona in 1929 paid $18,630,000 in dividends. Operations were suspended early in April, 1932 until July 1, 1934. In July, 1950, an eight million

* The story of Ajo has been recorded by Rickard in "A History of American Mining", by Parsons in "The Porphyry Coppers", by Joralemon in "Romantic Copper", and in U. S. Bureau of Mines Bulletin #405.

1 Tom Childs says mules and horses were used.

2 Named in 1900 for John Boddie's wife.

dollar smelter at Ajo began to treat the New Cornelia concentrates which had hitherto been shipped to Douglas.

GEOLOGY AND ORE BODY*

The ore body occurs almost wholly in monzonite porphyry which has intruded into volcanic lavas and tuffs. Some of the volcanic rocks are also considerably mineralized. The ore body is crudely elliptical in shape, about 3,600 feet long by 2,500 feet across. The average thickness is 425 feet, and the maximum about 1,000 feet. The primary ore consists chiefly of chalcopyrite, with bornite and a little pyrite, and these minerals are distributed both in veinlets and in grains scattered through the altered monzonite.

The ore body was oxidized to a surprisingly level plane near the present water table, at an altitude of about 1,800 feet. Except for local variations of as much as 50 feet, the transition from sulphide to the oxidized zone was about as sharp as could be mined by steam shovel. The depth of the oxidized ore ranged from 20 to 190 feet, with an average of about 55 feet. The minerals of the oxidized ore were malachite with a little azurite and cuprite. A little chalcocite occurs close beneath the bottom of the oxidized zone.

The fact that in most of the ore body the tenor of the ore was essentially the same in oxidized and subjacent sulphide ore seems to show that there was little migration of copper during weathering but that the sulphides were oxidized in place. In this respect the Ajo ore body differs from the other great disseminated deposits of the Southwest, in each of which supergene chalcocite enrichment was essential to the production of commercial ore.

MINING, LEACHING AND CONCENTRATION

The deposit is mined by open-cut method, with power shovels operating on benches at vertical intervals of 40 feet. Inasmuch as the oxidized part of the ore body was practically as productive as the sulphide part, there was no stripping problem of the sort confronting most of the disseminated deposits of the southwest. To January, 1931, less than 7,000,000 tons of waste had been moved in the mining of 32,400,000 tons of ore, a ratio of 0.21 tons of waste to 1 ton of ore. Much of this waste occurred within the ore body and was not overburden. As the depth of the pit increased, however, a larger proportion of waste had to be moved in order to maintain a safe angle of slope.

Doubt as to the possibility of successfully treating the oxidized overburden had helped discourage J. Parke Channing and Seeley W. Mudd when they were considering separate parts of the property in 1909 and 1910. Dr. Ricketts has stated the essence of the problem that faced him and Greenway in the following short paragraph:

> "Greenway drilled the great ore deposit in 200-foot squares and about 50,000,000 tons of sulphide ore containing about 30 lbs. of copper on a 20-lb. minimum were developed. This ore was capped with some 10,000,000 tons of granitic material containing the same amount of copper in the form of malachite and chrysocolla. There was no known method of treating such lean oxidized material. The steam shovel was best adapted to mining the sulphide ore, but even so was estimated that it would cost, with interest, $5,000,000 or $6,000,000 to remove the overburden and throw it away. If, however, a process for treating this oxidized overburden profitably in a large scale could be devised, a large liability would be converted into a much larger asset."

It was easy to dissolve a substantial proportion of the copper contained in a few grams of ore with dilute sulphuric acid in a test-tube; and that the copper could be precipitated on scrap iron or by electrolysis was equally certain. But it took a great deal of painstaking experiment and research to prove that a commercial process for handling 5,000 tons of ore per day would be a success. This work, which continued from 1912 until 1916, finally developed a design for a large-scale plant, which accomplished what it was designed to do from the very start. Virtually no changes in equipment nor modification in procedure were found necessary. For example, during the first full year of operation, the leaching plant at Ajo averaged 5,000 tons per day with a recovery of 81 percent of the total copper content of the ore and 84% of the soluble copper.

The sequence of events from the standpoint of ore treatment, has been just the reverse of that at Inspiration, in that at Ajo the leaching plant has finally given way to a concentrator instead of largely displacing a concentrator.

* Described in Arizona Bureau of Mines Bulletin No. 145, pp. 87-89. Also Bureau of Mines Information Circular 6666 written by Geo. Ingham and A. T. Barr.

the recommendation of James Douglas, the Phelps Dodge Company advanced $50,000 toward the building of a new smelter by the Detroit Copper Co. and acquired a half-interest in the property. By 1883 a railroad was built from Clifton to Lordsburg, through which the Southern Pacific had been extended westward from El Paso. Early in 1886 Church built and operated the first copper concentrator in Arizona, treating oxidized ore averageing 6.5 percent copper, which at that time was not suitable for smelter feed. The recovery was only 55 percent and the concentrate averaged 23 percent copper. The plant had a capacity of 50 tons per day and consisted of a jaw crusher, a set of rolls, three revolving trommels and six jigs.

James Colquhoun, a young Scottish engineer, who was sent to America by the Scotch capitalists who had a big investment in the Arizona Copper Company, had watched this experiment with considerable interest because the ore on his property had also declined in copper content. A few months after Church's plant started to operate, Colquhoun built another and larger concentrator for his company on the same principle and with the same gratifying results.

But six years later, copper prices dropped to ten cents on the New York market, and Church's firm was obliged to shut down. The situation of Colquhoun's company was just as grave. The cessation of Church's ore shipment on the A. C.'s railroad to Lordsburg caused a serious loss of revenue, and production in its own mines declined as the dumps of low-grade ore were exhausted. The company treasury sometimes did not have enough cash to pay wages, and no hope at all seemed to exist for income to meet interest due on the million dollar mortgage. The mine appeared doomed.

As a last resort the Directors in Edinburgh asked Colquhoun to become general manager of the company. Fortunately, the new manager had an idea. The jigs on his concentrator worked well enough with six percent ore, but the only ore now available was the low-grade oxidized porphyry near the surface which could not be successfully treated by the old mechanical means alone. Fooling around with a forty-gallon barrel and a can of sulphuric acid, Colquhoun proved to his own satisfaction that the tailings could be leached. Unable to get financial backing for his idea, he built a plant with funds obtained by cutting into the slender reserves of high grade ore.

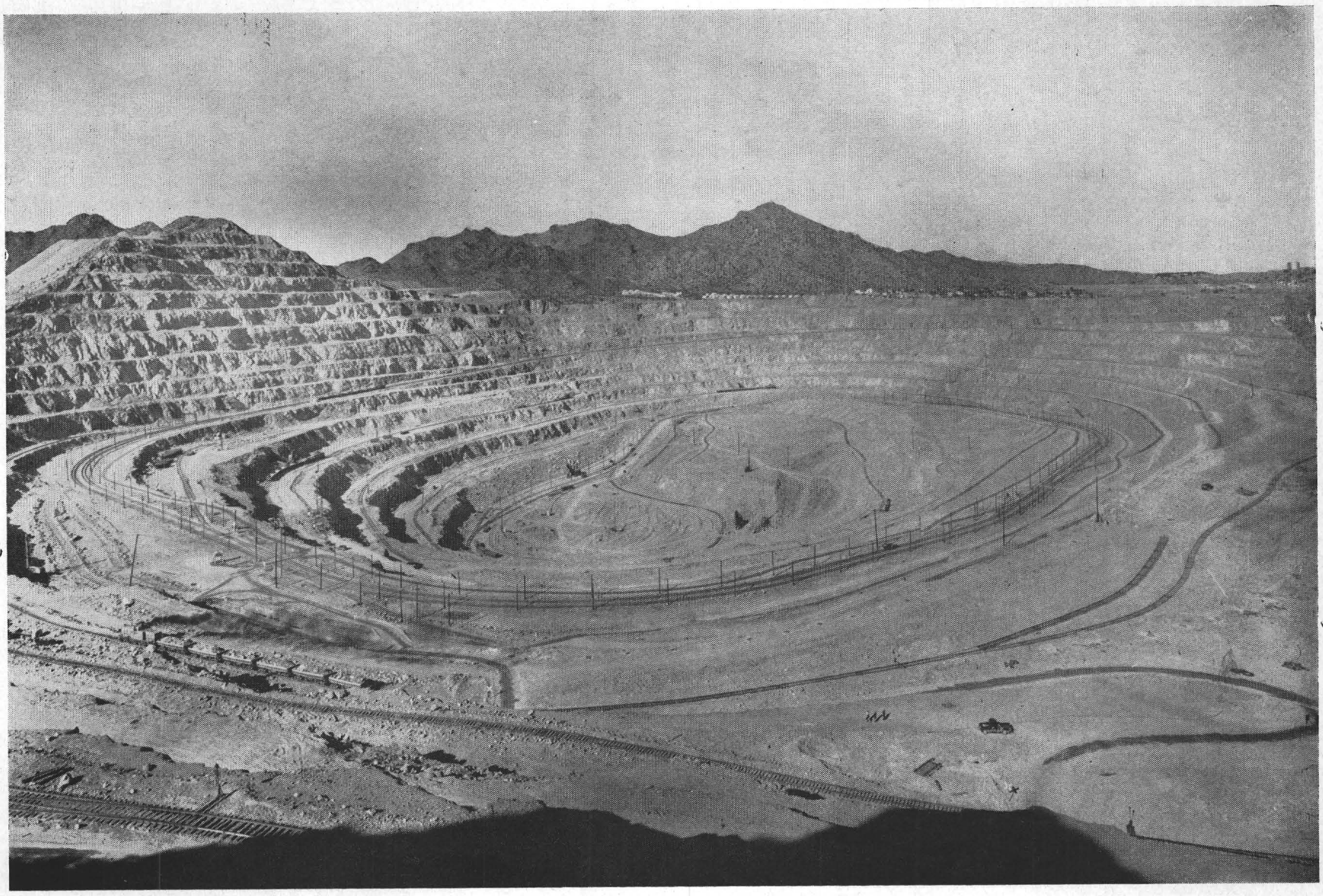
It was one of the most extraordinary plants ever erected under the direction of a mining engineer. The foundation was an old slag dump; the engine was an old machine from the mines; the copper for barrel ends came direct from the blast furnaces; mine timbers served as lumber; and iron and steel fittings were fashioned at a blacksmith's forge. When finished, the plant cost a hundred thousand dollars and had a capacity of a thousand tons a year. Extraordinary or not, it worked. Within a short time, production was increased forty percent, and the cost of copper reduced by two cents a pound.

By 1895 the company was not only able to meet payments on its mortgage, but declared a small dividend, the first in its history.

Under the management of James Colquhoun, the Arizona Copper Co. paid more than twenty million dollars in dividends. After World War I, the company was faced with the expenditure of several million dollars to allow the treatment of still leaner ore, and it sold out to Phelps Dodge Corporation for a large stock interest. The Phelps Dodge Company had purchased Captain Ward's Detroit Copper in 1895. All of these transactions by Phelps Dodge had been made on the recommendation of James Douglas. Clifton became for many years the greatest copper district in the Southwest.

In "Mineral Industry" for 1900, Dr. Douglas wrote regarding the outlook for copper mining in Arizona, as follows:

> "On the solution of the problem of how to handle economically the very large bodies of very lean aluminous and siliceous ores which exist in the southern counties of the Territory depends in great measure her future position as a copper producer. In Graham, Gila, Pinal and Pima Counties, and in fact throughout the whole of southeast and southwest Arizona, there are large areas of copper stained rock resulting from the decay of sulphide ores in a feldspathic gangue . . . . These lean surface carbonates all represent sulphides in depth. Experience heretofore tends to show that the average copper content of the sulphide ore is low, but, being capable of concentration, a comparatively lean average may be economically valuable. The iron of such concentrates supplies a flux to a limited extent for handling the siliceous and aluminous carbonates, and, when roasted, an acid solvent. There is no field where metallurgical skill



View of open pit copper mine, Morenci, 1952.

The new Phelps Dodge copper smelter at Ajo.

This concentrator, for treating the sulphide ore, originally had a capacity of 5,000 tons per day, and was put in operation during 1924. For six years both leaching plant and concentrator were operated. During 1928 and 1929 three additional units were constructed, essentially duplicating the five older units except that the rod mills used to crush the ore were longer. Balls replaced the rods in 1934, and in 1935 all mills were speeded up. This change, in conjunction with additions to the intermediate crushing plant, increased the capacity from 8,000 tons per day to 16,000 tons. It is now capable of handling 29,000 tons. The plant has kept up to date in its equipment, and continues to be among the leading concentrators in the country.

Well designed feeders and conveyor-belt systems for moving the ore from one machine to another; electric cranes to facilitate the repair of equipment, and a modern installation of dust-collecting equipment are features of the plant. The gyratory crusher, which eats up chunks of ore as big as can pass through the dipper, weighs more than 40 tons. A crane large enough to lift this machine is necessary to permit rapid repair work. Individual electric motors for the operation of each piece of equipment is a feature, as is also the use of machinery and devices for the automatic control of operations to the end that the requirements for labor are minimized. Entirely aside from the town itself, from the power plant, the leaching plant and various shops and auxiliaries, the concentrator and crushing plant represent an investment of almost seven million dollars. The new smelter at Ajo, constructed at a cost of over eight million dollars, began operations in 1950 and resulted in the saving of many hundreds of thousands of dollars annually in freight charges.

The New Cornelia enterprise has produced 3,156,000,000 pounds of copper from 200,146,000 tons of ore, up to January 1, 1957. This production, together with gold and silver values, had a gross value of 625 millions of dollars. As stated before, New Cornelia paid its first dividend in 1918, and from that time to the time of its absorption by Calumet & Arizona Mining Company in 1929, the company had paid $18,630,000 in dividends and had produced 620,000,000 pounds of copper. Its subsequent earnings have not been published separately from the total earnings of the Calumet & Arizona, and the Phelps Dodge Corporation, but based upon the early dividends, which averaged three cents per pound of copper produced, it may be conservatively estimated that the mine has earned $94,000,000 in dividends from 1918 to 1956 inclusive. In addition, it has ploughed back many more millions of dollars for additions to, and improvements of plant equipment. The company has about 1,400 employees on its payroll. It has built about 800 homes for its employees, and the taxes which the company has paid, have provided an excellent school system for the children of the community. The company also maintains a first class hospital for the community. Ajo is an unincorporated town with a poulation of slightly under 7,000 persons, and the livelihood of all these people is dependent in some way or another upon the New Cornelia mine. The Company's payroll last year (1956) was over eight million dollars.

Ore reserves are not published, but the mine is unquestionably good for many years' life. The erection of an eight million dollar smelter in 1950 indicates that.

The ratio of waste to ore has been roughly 1.50 to 1 the past four years. Before that, it ranged from less than .50 to 1 up to 1.20 to 1.

When one considers the many failures in the early attempts to make the mining district pay, (proving that it was no bonanza in its earlier years), New Cornelia is impressive as another example of how vision and capital have converted a mountain of rock into copper metal. It should be a source of pride for all the company employees to be a part of an enterprise which is creating wealth every day. New Cornelia is another Arizona mine that was made, not found — a monument to the memory of Capt. Greenway and Dr. Ricketts and to their worthy successors.

STORY OF THE MERENCI OREBODY

The Morenci Branch of the Phelps Dodge Corporation has averaged a production of 245 million pounds of copper per year since it began production in April, 1942. In 1950 it produced the amazing total of 309,353,406 pounds. This production is all the more impressive when one realizes that it equals the capacity production of the four new Arizona developments, San Manuel, Lavender Pit, Copper Cities and Silver Bell. The Morenci Mine is the largest copper-producing mine in Arizona. In addition to copper, the mine has produced as by-products, gold, silver and molybdenum concentrate.

The Morenci orebody, from which this copper has been taken, is located in the Eastern part of Arizona, about fifteen miles from the New Mexico border, and 70 miles by road from Lordsburg. Though the Morenci mine has produced some ore from rich fissures that traverse the deposit, it is essentially a district of low grade ore which was recognized as such as far back as 1904. Development work pushed spasmodically, increased the tonnage of known ore, but the average copper content was only a little above 1 percent, or 20 lbs. per ton, exploitation was not attempted. In 1929 when Mr. Cates resigned from Utah Copper to accept the presidency of the Phelps Dodge Corporation, his experience with the Utah Copper enterprise and the Ray Mine block caving development, naturally prompted him to push the exploitation of the Morenci orebody. Here was a problem worthy of his great abilities.

EARLY HISTORY OF THE DISTRICT

Rickard, Joralemon and Parsons have written interesting accounts of the early history of the Clifton-Morenci mining district wherein the Morenci orebody is located, and much of this story was gleaned from their writings. The district was first of the southwestern copper camps to become important. Spanish and Mexican explorers had reported the presence of copper in the precipitous mountains north of the Gila River early in the nineteenth century. In 1864, Henry Clifton and a group of prospectors from Silver City, New Mexico, rediscovered the rich copper carbonate ore, but the district was so remote they made no attempt to locate the mines. Six years later, a prospector named Isaac Stevens, together with Bob Metcalf and six others, found striking outcrops of beautiful green copper carbonates near the top of the limestone cliffs two thousand feet above the bed of Chase Creek. They located the first claims in 1872 and founded the town of Clifton in the deep canyon where Chase Creek and the San Francisco River came together.

A little one-ton adobe furnace was built by the Leszinsky brothers who organized the Longfellow Copper Company in 1873, to smelt the 20 percent ore from the Longfellow mine. They later built a larger blast-furnace plant at Clifton.

The first concentrator was built in 1886, but the ores were principally oxidized, and direct smelting ore still supplied most of the production. As early as 1893, the mining of somewhat leaner porphyry ores, containing copper in the form of sulphide mineral, chalcocite, was commenced; but these still were of comparatively high grade and the concentrators were plants of only 100 to 400 tons daily capacity. The backbone of operations was still the production of rich oxidized ores for direct smelting. They assayed 10 to 15 percent copper and the sulphide milling ores assayed 3 to 4 percent. Although the concentrating ore was typical of that in the Porphyry group of mines, except for its richness, Morenci can hardly be claimed to have been the pioneer in large-scale operations on lean copper ores, which honor unquestionably belongs to Jackling at Utah.

The Longfellow was the nucleus for the group that was subsequently acquired by a syndicate of capitalists who organized the Arizona Copper Co., Ltd., in 1884. The Humboldt and Morenci mines were included in the Company's holdings.

William Church, who came to Joy's camp (now Morenci) in 1874, obtained an option on four patented claims, including the Copper Mountain, and organized the Detroit Copper Mining Co., with Capt. E. B. Ward and some friends from Detroit. By 1880, enough ore was developed to warrant a smelter on the San Francisco River, three miles below Clifton. Indians frequently interfered with the hauling of ore from mine to smelter, so later a 20-in. gauge railroad was built, using the first locomotive ever operated in the Territory of Arizona.

The year 1882 marked the entry of Phelps Dodge Company into the Clifton district. On

THE LAVENDER PIT

Another Arizona Copper Mine — the Lavender Pit of Phelps Dodge Corporation — was formally dedicated on August 7th of the year 1954. A celebration marked the opening of the huge open-pit operation which required the expenditure of more than 25 million dollars to bring the mine to production.

The following statement by Robert G. Page, President of the Phelps Dodge Corporation, gives a good clear picture of the project:

Faith Can Move Mountains

The Lavender Pit — the new open-pit copper mine of Phelps Dodge Corporation at Bisbee — was officially opened on August 7. The Lavender Pit is an excellent example of the saying that large mines are made, not found. The presence of copper in the area which is now the Lavender Pit mine was known for many years. But during that long period it was not ore because it could not be mined profitably.

Mineralized rock is ore only when it can be mined and processed at a profit. The Lavender Pit material became ore only after gradual but continuous improvements in the art of mining, milling and smelting and in the size as well as perfection of modern tools and machinery. It became ore also only when more than $25 million was invested in stripping the mountainous overburden and building the huge industrial facilities.

The nature of the ore deposits in the Bisbee district has required for the most part mining by underground methods for the past 75 years. The underground ore deposits are small, scattered and at considerable depth. Under such conditions only high-grade deposits can be mined commercially.

Once before, in the '20s at Sacramento Hill, Phelps Dodge Corporation undertook to mine a low-grade ore body in the Bisbee district by open-pit methods. That small ore body was near the surface and its comparatively high-grade ore made the project feasible but only slightly profitable because the highly efficient open-pit practices now used had not then been devised.

In developing the Lavender Pit, Phelps Dodge has again tackled the problem of successfully mining a lower grade deposit. For an open-pit mine operation, the deposit is also small, though considerably larger than the Sacramento Hill project. About 3.5 tons of mined rock will produce only one ton of ore yielding metal valued at $3 to $5 depending on the variation in market price. That yield will have to pay for all expenses of mining, milling, smelting, refining, transportation, taxes, so forth; and it is also out of that low gross value that the funds must come to repay the initial cost of the project of over $25 million before a profit can be realized.

Perhaps it is not too much to say that the same kind of courage and vision, and the willingness to take risks, which characterized the Arizona pioneers — whether cattlemen, mining men or farmers — find expression today in this Lavender Pit project. Risk, of course, there is; but, most important, having calculated the risk, we have faith that the risk is worth taking in Bisbee and that another mine — even though mountains have to be moved — may be successfully created in Arizona.

Highlights Of The Project

Source: Pay Dirt For August 20, 1954

The project cost more than $25 million before a pound of copper was recovered.

It was entirely financed by Phelps Dodge Corporation without one cent of Federal financial aid.

The pit embraces an area of 155 acres.

The ore is low-grade and requires fine grinding.

Ore eventually will be mined from 16 benches 50 feet in height.

The lowest point in the pit will be 1,005 feet below the highest original ground contour.

The first blast to clear the waste material was set off in March, 1951.

First ore was delivered to the concentrator June 24, 1954.

During the preparatory period, 46,000,000 tons of overburden was mined and delivered to waste dumps.

During the life of the pit, 2.62 tons of waste and leach material must be mined to recover one ton of ore that will produce less than 16 pounds of copper.

The 50-foot benches are mined by drilling a series of 7⅞-inch holes about 60 feet deep and spaced at 14-foot intervals, 15 feet from the edge of the bank.

The holes are loaded with approximately 450

The primary mineralization, as shown in the deep levels, is quartz, pyrite, chalcopyrite and sphalerite veins with most veins containing much pyrite. Outcrops over the ore are largely leached of both iron and copper. Below the leached caprock, which has a maximum thickness of 500 feet, the ore consists of secondary chalcocite that has replaced pyrite extensively in the ore and decreasingly with increased depth or decreased permeability of the rock.

The mineralized body, in common with other disseminated deposits, can be separated into three parts or zones: (1) the upper or surface zone, which has an average thickness of 216 feet; (2) the ore zone, which is a network of fissures composed mainly of quartz and pyrite, the latter coated and replaced by varying degrees of chalcocite. The thickness of the ore body is irregular, but over much of the area is 500 to 700 feet; and (3) in depth many drill holes show a rather sharp drop from near 1 percent to ½ percent, there is no general record of the copper content of the underlying material. In this low grade material the copper is probably chalcopyrite.

THE MORENCI OREBODY DEVELOPMENT AND EXPLOITATION

When development of the low-grade ore body was first under consideration, careful estimates were made to determine whether it would be advisable to use underground methods or an open-pit. Thorough drilling and sampling were done to check the tonnage and grade. With underground mining, it would be necessary to confine operations to a smaller tonnage of the better grade of ore. In an open-pit a much larger tonnage of lower-grade material could be profitably extracted. After consideration of all the factors it was decided to make use of an open-pit.

Following parallel tests between a small pilot concentrating plant and leaching plant, it was decided to adopt the concentration method.

To mine by open-pit methods required the removing of a large amount of waste capping. This was estimated to require nearly five years preparatory work before uncovering enough ore to make possible a steady production of 25,000 tons per day. Also, plans were made for constructing a concentrator, smelter and power plant, and providing the many necessary facilities required to take care of this large production.

Louis Cates and the Directors of Phelps Dodge had to have courage to launch a $76,000,000 enterprise, and they made sure that this, the first major copper development in Arizona in 30 years, would be as well planned and well equipped as human ingenuity, experience and determination could make it.

It is fortunate that the Morenci enterprise had such exhaustive attention paid to every detail of its design for before the new smelter poured its first copper in April, 1942, the W. P. B. called on Phelps Dodge for an 80 percent expansion in output. Even this had been anticipated, and the plans were ready. Morenci quickly expanded its production, increasing each year until 1947 it attained one hundred percent expansion. This expansion program took another tremendous expenditure of many millions of dollars, provided by the Defense Plant Corporation, which leased the new sections of the concentrator to Phelps Dodge to operate. Thus it may be stated that it took over $76,000,000 to open up, develop and equip Morenci. Subsequently, the Defense Plant Corporation facilities were purchased by Phelps Dodge Corporation.

MINING

Pit benches, which are all carried at a uniform height of 50 feet, have been established at even elevations above sea level, the top bench being at elevation 5,500. The ultimate range of mining is estimated to be slightly in excess of 1,300 feet. The economical thickness of the orebody is 850 feet. When fully developed, the pit will be 5,800 feet long and 4,000 feet wide, and the final excavation will cover 350 acres.

During the early stages of the Morenci development, trucks, because of their flexibility, were best suited for the preparation of the mining benches. These operations included dumping of the waste rock in the deep rough canyons to be utilized later in the construction of track roadbeds. Soon most of the material was handled by standard gauge locomotives and dump cars. Diesel-electric and combination trolley-diesel locomotives are used. The track section between the pit and the crushing plant has been electrified.

On the established benches drilling for primary blasting is done with electric churn drills using 9-in. and 12-in. bits. Loading equipment

has been more or less standardized, all units being of the 5 cu. yard revolving type shovels using electric power of 2,300 volts. Ore is delivered to the crushing plant, about 2½ miles from the pit, in trains made up of eight 40 cu. yard cars. Traffic on the main haulage system is regulated by means of both hand-operated and automatic signal systems controlled from a central tower at the pit entrance. Established at 100-ft. intervals, each waste disposal dump serves two benches. A portion of the waste loaded in trains of eight 40-yard cars, moves in the opposite direction from the ore movement.
Average hauling distance is about 2½ miles.

CRUSHING, GRINDING, CONCENTRATION AND SMELTING

Primary and secondary crushing plants and concentrator are situated at the northern end of the plant site, where a natural slope provided adequate fall through these units. A level section extending to the south contains the smelter and bedding plant, power house, machine shops, warehouse and tailings dewatering plant. The entire system is a masterpiece of engineering design. The crushing plants and concentrator are almost entirely automatic in operation. The major buildings are accessible by rail and truck, and cranes available on the different floor levels, as well as elevators, facilitate secondary handling of materials, supplies and equipment. Treatment involves three-stage crushing, single-stage grinding, flotation, regrinding, cleaning, thickening and filtering concentrate. The first stage of crushing is a 60-in. gyratory. Reduction of the gyratory product is accomplished by 7-ft. standard cone crushers followed by 7-ft. short-head cone crushers. The final stage is a grinding operation in 10 x 10 ft. grate mills, using 2 in. and 3 in. grinding balls. Each mill operates in closed circuit with spiral classifiers.

Concentration is done by flotation in mechanical flotation machines. The tailings go to traction thickeners from which the thickened pulp goes to the tailing dams, and the overflow water is pumped back to the head-water tanks for re-use. The concentrates are given a re-treatment in additional flotation machines, called cleaners, which produce a suitable smelter feed. The tailings from these cleaning machines are reground in 8½ x 12 ft. overflow type ball mills, and returned to the primary rougher machines. The final flotation concentrates are thickened, filtered, and transported to the smelter bedding plant by a belt conveyor.

The smelting plant consist of a bedding plant, crushing plant, sampling tower, reverberatory furnaces, converters, anode-casting furnaces and and anode casting wheel. All equipment including the dust collecting system, is the last word in mechanical design.

The towns of Clifton and Morenci are up to date in every respect, with fine homes built by the Company for its employees. There is a modern hospital, fine club houses, churches and excellent tax-supported schools. According to the 1950 census the population of Clifton is 3,466 and Morenci 6,541. There are approximately 2,500 workers on the Morenci Branch Phelps Dodge payroll. The economic existence of both towns is entirely dependent upon the Morenci enterprise.

The 1956 annual report of the Phelps Dodge Corporation states that, at **all** of its operating properties in Arizona, the corporation has expended over $13 million for housing facilities, and owns 2,236 houses, 379 apartments and 174 dormitory units.

Total production from the Morenci Orebody from 1939-1956, incl. was as follows:

Total tons ore mined	207,283,300
Total lbs. copper recovered ..	3,587,344,000
Total ounces gold (approx.)	100,000
Total ounces silver (approx.) ..	6,500,000
Total tons Molybdenite concentrates .	5,405

Ore reserves are not published, but assuming the reported tonnage of 400 millions at the beginning of operations in 1942, to be a fair estimate, then there should be in the neighborhood of close to 200 million tons left since the removal of 207 million tons during the period 1942-1956 inclusive. The ratio of waste to ore has increased over the years from **less** than 1¼ to 1 ton of ore, to 2¼ tons waste to 1 of ore.

A total of approximately $76,500,000 had been expended for the purchase, development, capital additions and improvements on the Morenci enterprise to the end of 1951.

Although Mr. Louis S. Cates is acknowledged to be the guiding spirit that brought the Morenci enterprise to fruition, he very modestly gives all the credit to team work. Mr. Cates made the following remarks in the May, 1942 issue of Mining and Metallurgy:

record being made on each unit. Since truck pitting began, Bagdad has cut its mining cost by 40 per cent, more than doubled production.

Bagdad's sulphide-copper flotation mill has recently been revitalized in much the same way as the mine. The main feature of the mill improvement was a system of alkalinity (pH) control which boosted recovery of sulphide-copper by 10 per cent. This close pH control also involved additional controls of density and initial ore feed. The company's Mill Supt., Gaylen Guest, found that the optimum pH for flotation of Bagdad's ore was 11.5. The ore contained some zones and streaks with a high percentage of copper sulphate which is acidic. Whenever mill feed was from a copper sulphate zone, the pH fell to a much lower figure than the optimum 11.5. Guest found that with a regulated density control in the classifier circuit, and a frequently measured pH, the operators soon learned how to regulate lime feed to the ball mills in order to adjust the pH to 11.5.

Crushing and Concentration

The crushing circuit is designed for production of a minimum of fines with a resulting efficiency of grinding and reagent consumption. The system consists of crushing, screening to produce three products, and the crushing of the coarser two products to a minus ⅜in. size. The flow is over a 1½"-45° grizzly to a 16" gyratory set at 1½". Product and undersize over a double deck screen — oversize of top screen to cone crusher set at ½"—oversize of bottom screen to a cone crusher set at ⅜". Product of 1st cone crusher over ⅜" screen with oversize back to grizzly. Product of 2nd cone crusher and undersize of both screens to any of four 1950-ton ore-bins. Each ore bin feeds a grate discharge ball mill using 3" steel grinding balls; the grate discharge insuring a minimum of grinding. The ore does not require fine grinding as it does not contain a large quantity of barren iron pyrite which forces most porphyry-copper mills to grind their ore much finer. The flotation circuit consists of a rougher circuit of 3 parallel banks of six 66" mechanical cells. In each circuit the rougher tailing passes on to a bank of six 66" mech. cells. Tailings are pumped to the Marooney tailing dam which stores water for reuse. Fresh water is obtained from Burro Creek, nine miles away. It is pumped by two parallel pumps through a 10-inch line to a second tank at Boulder Creek, whence it is pumped to Bagdad through two parallel pumps and another 10-inch line.

Rougher concentrate is cleaned in three banks of two 56 inch flotation cells. Cleaner concentrate is thickened and filtered and trucked to the railroad siding at Hillside, whence it is shipped to the A. S. & R. Company copper smelter at El Paso. The thickened cleaner concentrate is sometimes treated before filtering, to remove molybdenite, which is found in rich streaks here and there in the mine.

With its mine and mill operating at top efficiency, and with large reserves of ore. Bagdad is making plans to raise production to 10,000 tons daily, and to install a plant for concentrate roasting, acid production, calcine leaching, and electrolytic precipitation. It promises to make Bagdad one of the major copper producers of the United States.

Mr. J. C. Lincoln, the president of the Bagdad Copper Corporation has this to say in his 1956 annual report to the stockholders—

"The pilot plant for the production of electrolytic copper has been a satisfactory operation for the last half of 1956. It was expected that trouble in the operation of the plant would develop, but these difficulties have been overcome and the plant now regularly produces about 3,000 pounds per day of electrolytic copper. This is the normal capacity of the plant. The sulfuric acid, which is a by-product of the electrolytic copper, has been used to produce several tons of cement copper from one of the dumps of oxide copper ore. To date we have produced twenty-five tons of cement copper from these dumps. When the electrolytic plant is finally completed, it is expected that the production of copper from our oxide dumps will produce about half as much copper as we can expect from the recovery of sulfide copper from the operation of the mill. This is another way of saying that the sulfuric acid produced by the electrolysis of two pounds of copper in the electrolytic plant will enable us to get an extra one pound of copper from our oxide ore dumps which we cannot recover at present.

It is planned to increase the output of the mill from the present capacity of 3,500 to 4,000 tons per day to 10,000 tons per day as soon as possible. It would be done by installing additional ball mills if necessary, but development work on the method of grinding ore with high-speed rollers is being done, as indicated in my letter of December 13, 1956 to Stockholders. To increase the capacity of the mill, it will be necessary to have additional water and a new well has been sunk that is expected to produce 500 gallons per minute."

stripping, trucked away waste, and trucked clean ore to the caving glory-hole.

Later in 1945, the company made a complete switch from block caving to open pit mining with truck haulage. By early 1947, a pit crusher system, glory-hole ore bin, and conveyer system to carry crushed ore from pit to the mill had been installed. Since early 1948 all ore mined has come from the pit.

In February, 1950, a mill expansion was completed which brought capacity up to 4,000 tons per day. New equipment in the pit, and advancement of pit development and stripping brought ore production up to 90,000 tons per month in 1950 and to approximately 110,000 in 1951.

In December 1955 the Company suffered a loss by the passing of E. R. Dickie, who was instrumental in the change over from underground to open pit.

Geology and Mineralization*

A conspicious feature around Bagdad is the red and brown iron stain on the rocks, particularly all exposures of the granite porphyry. Much of it is highly colored. This extensive staining indicates a rather widespread mineralization.

Prospecting in the mileralized granite porphyry has been mainly of two types, first, of the more prominent fissures, and, second, of disseminated deposits.

Development has been largely in the porphyry northeast of the junction of Copper and Marooney Creeks. The quartz monzonite-copper ore-body dips at 10 to 15° toward the northeast, averages about 170 feet in thickness and is capped in most places by 200 ft. or more of barren Gila conglomerate. The copper occurs mainly as copper glance (chalcocite) with smaller amounts of copper pyrites (chalcopyrite); average copper content is 0.9 percent. In some streaks and fissure fillings, the ore is rich enough in copper for selective underground mining. There are also some high-grade streaks and lenses of molybdenite. Molybdenite has not been noted in the copper veins, though it is possibly present.

Lying over the bed of sulphide ore is a 150-foot zone of copper-oxide mineralized quartz-monzonite not rich enough for conventional mining, milling or smelting but, once exposed by mining of the overlying overburden, this low-grade is rich enough to drill, blast, haul, stockpile and leach. However, because it is high in lime and low in pyrite, the low-grade must be leached with acidified water.

Like most of the copper deposits of the Southwest, the Bagdad deposit can be separated into three zones—namely, the oxidized zone, the zone of sulphide enrichment, and the primary lean sulphide zone. Generally, the amount of copper in the oxidized zone increases with depth, and in places just above the secondary sulphide zone it may approach the copper content of the sulphide zone. Ordinarily, however, it is distinctly of lower grade than the sulphide zone, and probably no large bodies of it would exceed 0.5 per cent copper. In total, however, a very considerable amount of the copper is in the oxidized zone.

The secondary sulphide zone consists of veinlets of pyrite and chalcopyrite partially replaced by chalcocite. The copper content of the enriched sulphide zone in general is highest just below the oxide zone and decreases gradually toward the primary zone. In the upper, richer portion of the secondary sulphide zone the average copper content is probably three to four times that in the primary zone, indicating a very considerable movement and enrichment of copper.

As in many deposits, the primary sulphide zone beneath the enriched zone has not been extensively prospected or developed. Pyrite and chalcopyrite are the sulphides present, and the copper content in general does not appear to exceed 0.5 per cent.

Bagdad's Pit-Mining Method

Benches are established at 45 and 50-foot vertical intervals. Stripping of waste starts at high elevations on the sides of Copper Creek Canyon. Ore, waste and low-grade are broken by 7" churn drills and rotary drills, loaded by electric shovels. Trucks carry sulphide ore to the pit crusher-plant, from where it is carried by a 1000 ft. long belt to the mill proper. Trucks carry low-grade oxide ore to extend the donwstream side of the new tailing dam; there is will be acid-leached at some future date. Trucks carry barren waste (mostly Gila conglomerate overburden) to a waste disposal area about ¾ of a mile northeast of the pit.

Three makes (five models) of rubber-tired haulage units are running an endurance test against one another, with a close cost-accounting

* Arizona Bureau of Mines Bulletin No. 145, by Butler and Wilson.

"Modern tchnical and mechanical progress has made the Morenci achievement possible. Hard and loyal efforts of many men have made it a reality. To the officers, engineers, miners, construction gangs, and all who have labored on this task sincere appreciation and thanks are given. Modern industry requires teamwork, of which all that has been done at Morenci is a conspicuous example.

Much help and valuable information have been secured from many sources, but notably from our two chief competitors. Over a long period the mining industry has maintained a most liberal attitude toward the exchange of technical data. To this attitude, I am sure, can be attributed much of the remarkable progress that has taken place in the last generation.

Through the kindness of Cornelius F. Kelly we were able to secure, as chief engineering and construction engineer, Wilbur Jurden, head of the engineering department of the Anaconda organization. To Mr. Jurden and to the Phelps Dodge engineering department, which he built up to design and construct the new reduction works, can be credited the efficient arrangement, convenience and economy of these plants. The concentrator, smelter, power plant, and other facilities have been located at an entirely new site so the design and layout were unhampered by the existence of older structures. The plants have started operation smoothly and with the necessity for only minor changes. Plans were made in New York, steel was fabricated in Kansas City, and equipment was manufactured and shipped from numerous points throughout the country. When one reflects that all these many parts have been brought together and erected into large plants with scarcely a hitch of any kind, a picture of modern engineering competency is presented.

In no less degree has the Kennecott Copper Corporation been most helpful in making available data and information that have been of great value and saved endless time. It is impossible to mention all who have assisted, but I want to name especially my old friends and former associates, Daniel C. Jackling and D. D. Moffat, both of whom have met with such success in developing and operating other open-pit mines.

The results of nearly five years of untiring work by the Phelps Dodge organization are now visible at Morenci. In looking at the open-pit now, it is difficult to realize the enormous amount of planning and engineering work necessary to create this mine with its orderly benches, roads, tracks, switchbacks ,and waste dumps. Similarly in the new reduction works the casual observer is apt to forget the months of hard and highly technical work done in the laboratories, the test mill, and the Douglas smelter to determine the flowsheet and metallurgy best adapted to the Morenci ores.

This work has been done creditably by the engineering and operating staffs at Morenci and with the full co-operation of the staffs of the other Western Branches of Phelps Dodge. In Arizona general supervision of the Morenci project has been in the hands of P. G. Beckett, Vice- president, with the more detailed direction under H. M. Lavender, General Manager, who has concentrated on this work since its start.

To all in this loyal organization, grateful acknowledgement is due."

THE BAGDAD MINE STORY

It was in 1944 that J. C. Lincoln, president of the Lincoln Electric Company, acquired control of Bagdad Copper Corporation and appointed E. R. Dickie as general manager. In the twelve years that have passed since then, the Corporation has expended over twelve million dollars in developing the property including over seven million dollars for removing waste. In 1954, the Corporation was able to pay its first dividend to its stockholders, amounting to $135,239.40, and in 1955, a dividend of $279,780.50 was paid. However, with the higher stripping expense of 2¼ million dollars, and lower grade of ore mined in 1956, the directors did not feel justified in paying a dividend for that year.

During this twelve-year period, Bagdad has mined about 14 million tons of ore from which approximately 205,500,000 pounds of copper have been recovered. In other words, only a little over 14 pounds of copper (together with small amounts of silver and molybdenum) were recovered per ton of ore treated. Despite this profitless operation, Bagdad has paid the state a production tax on its output throughout its producing history. It has enriched the state with the production of over 205 million pounds of indestructible copper, and in so doing has furnished remunerative employment to hundreds of Arizona's citizens.

Location and History

Articles in the Mining World for September, 1951 and March, 1952 have been the source of the information on Bagdad's history. The Bagdad Mine is in the Eureka district, western Yavapai County, 27 miles by road from Hillside, a station on the Santa Fe Railway. Bagdad Mine is on Copper Creek, a few miles upstream from its junction with Burro Creek, at an altitude of about 3,200 feet, and Camp is 2½ Mi. SE of Mine; Elevation 3,700.

The Bagdad claims were discovered in 1886, but it was 1906 before they were worked with small success by the Giroux Syndicate. Then, a new company, The Bagdad Copper Company, took a whirl at it.

In 1919, the Arizona-Bagdad Copper Company took over the claims, churn-drilled them, proved a section of the orebody, much as it is known today, and did underground work which resulted in small production. In 1925 and 1926, Arizona Bagdad conducted an interesting experiment in which the ore was leached in place. Workmen dug a trench around a square block, 300 feet on each side. After six months of water feed to the trench at a rate of 15,000 gallons daily, a "leaching solution" was fed at a rate of 15,000 gallons daily. Lack of money and water, and the excess of lime in the ore-body defeated the project. Also, the uncertain destination of the "leaching solution" made the effort too much like "pouring money down a rat-hole."

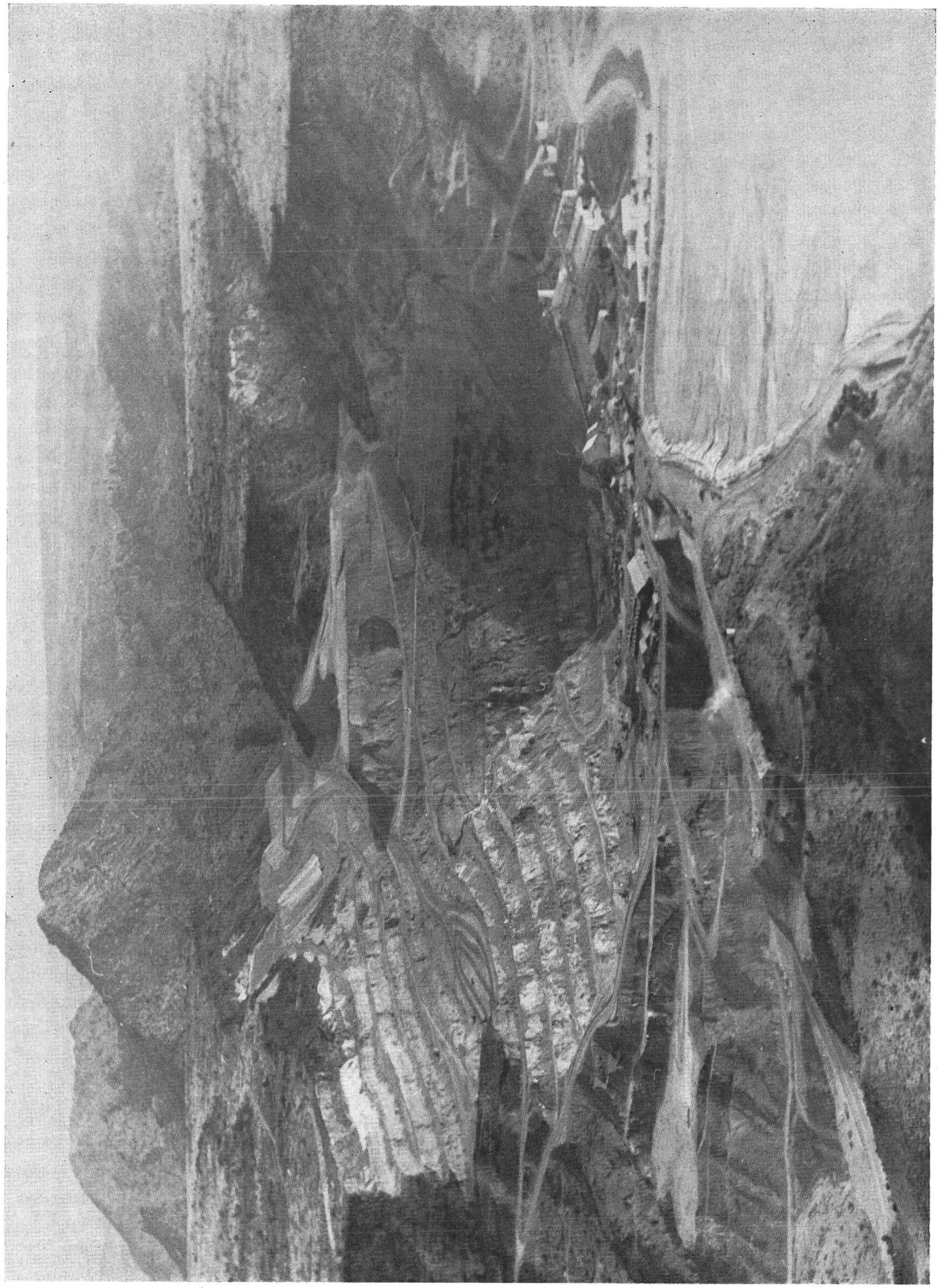
In 1927, Bagdad Copper Corporation succeeded the Arizona-Bagdad Copper Company, and, in a 50-ton pilot plant, tested a system of recovering copper by selective flotation, roasting, leaching and electrolysis. In 1929, just prior to Wall Street's Black Friday, after sinking 130 churn-drill holes and closely proving a larger part of the ore body, the company made plans to spend $7,000,000 to block-cave and mill 3,000 tons of ore per day.

Greatly scaling down its plans after the stock-market crash, the company completed a 200 ton mill in 1930 and brought mine production up to 150 tons daily.

In 1935, with the depression still raging, the operation was concentrated first on selective mining of high-grade molybdenite, then on a high-grade copper ore. In 1936, a block-caving project was planned and started; in 1940, it made an operational profit of $1,054, which, of course, was still not enough.

From 1941 to 1944, with the help of a $2,500,000 R. F. C. loan, the company installed a 2,500-ton flotation mill, renovated the mine for large block-caving production, built a 70-mile, 69,000 volt transmission line to bring in power from Parker Dam, and built a housing project, and a tailing-disposal line. In 1944, J. C. Lincoln, President of Lincoln Electric Company, acquired stock control of Bagdad Copper Corporation, and appointed E. R. Dickie as general manager.

By early 1945, block caving had proved only partly successful. Labor was in short supply. The ore-body was relatively thin for block-caving and so required a high ratio of development work per ton of ore. Then it was that Manager Dickie made the decision which made Bagdad a mine. On April 29, 1945, miners blasted 150,000 tons of surface ore into the open glory-hole of a caving block. Next, a contractor did minor



View of Bagdad open pit and plant, January 20, 1957.

STORY OF SAN MANUEL*

The San Manuel Copper Corporation holdings are located in southeast Pinal County, Arizona, about 45 miles northeast of Tucson. The concentrator, smelter, administration building, and other plant facilities are located some seven miles southeast of the mine area at the new town of San Manuel.

HISTORY

The district was prospected prior to the Civil War, but there was little or no production until 1881. Until the advent of the San Manuel mine, the chief producers were the Mammoth and Mohawk mines, located a mile farther north. Gold, lead, zinc, and some vanadium and molybdenum were the main recoverable metals at these properties.

In the San Manuel group there are claims located in 1906 that have been held continuously to the present time, and at least two exploratory churn drill holes were drilled in or near the ore zone in 1917. The copper content indicated by these holes was not sufficient to encourage further exploration at that time.

In 1942, tnrough the efforts of the owners, James M. Douglas, R. B. Griffin, Victor Erickson, and Henry W. Nichols, all of Superior, Arizona the Reconstruction Finance Corporation and War Production Board authorized the United States Geological Survey to investigate the property. The Survey confirmed the owners' original conception of the probable existence of important copper mineralization, and by its recommendation the Bureau of Mines was authorized to put down a limited number of churn drill holes. This test drilling started in November, 1943, and was continued by the Bureau until February, 1945, when seventeen holes had been drilled for a total of 15, 844 feet.

Magma Copper Company obtained an option from the owners in 1944 to buy the property. On September 17, 1944, Magma exercised its purchase option, and purchased additional adjoining claims held by the Apex Load Vanadium Mining Coporation and the Quarelli family, and located additional claims. In December of that same year, Magma commenced exploration by churn drilling.

The San Manuel Copper Corporation was incorporated in August, 1945, and all of the property acquired by Magma Copper Company in the district was deeded to San Manuel.

Exploratory churn drilling was essentially completed in early 1948. A total of 205,536 feet of drilling was done to prove an ore reserve of 367,624,000 tons of sulphide ore, averaging 0.785% copper. There is an additional 111,876,000 tons of oxidized ore averaging 0.717% copper, or a total reserve of 479,500,000 tons averaging 0.769% copper.

Underground exploration and development was started in March, 1948, and has progressed continuously. Up to the present time there have been five shafts sunk and over 20 miles of drifting completed to prepare the first lift for production.

On July 10, 1952, Reconstruction Finance Corporation authorized a loan of $94,000,000 to San Manuel for mine development and plant construction.

In the early part of 1953, Utah Construction Company and The Stearns-Roger Manufacturing Company (a Joint Venture) was awarded a contract for the design and construction of the entire surface plant, including the concentrator, smelter, railroads, and auxiliaries. Principal subcontractors were San Xavier Rock and Sand Company, which furnished the concrete, Newbery Electric Corporation, which installed the electric control and transmission system and Custodis Construction Company, which erected the stack.

The concentrator was completed in September, 1955, and trial runs on stockpiled ore and mine development ore were started. By the end of 1955, Plant construction was completed except for minor cleanup work and smelting of copper concentrate was started January 8, 1956. January 23, 1956, the Mine was in production with the first stope undercut completed.

To provide adequate permanent housing facilities for the construction period, as well as the future productive life of the mine, an agreement was made with the Del E. Webb Construction Company and M. O. W. Homes, Inc., under which they were to finance and build a town suitable for the accommodation of San Manuel's employees.

Active construction was started in mid-1953, and by late 1954 the town of San Manuel was

* The information in this story was obtained from the brochure published by the San Manuel Copper Corporation.

View of Lavender Pit, Bisbee, Phelps Dodge Copper Corp.

pounds of explosives per hole and shot simultaneously to break about 2,100 tons of rock for each hole.

The broken muck is loaded into 25-ton diesel trucks by five and six-yard electric shovels with six-cubic yard dippers.

At the loading dock, the muck is dumped into 43-cubic yard side-dump railroad cars and transported to a dump by 1,250-horsepower diesel electric locomotives.

In 17 trips to the dump in one eight-hour shift, the locomotive, pulling a 10-car train, will transport 12,000 tons of rock for a distance of 1.25 miles.

Since the ore body was located in the heart of a populated area, it was necessary to remove many businesses and residences, abandon the railroad into Bisbee, relocate U. S. Highway 80 and all utilities.

The construction work included a large crushing plant, concentrator and allied facilities, plus 75 new residences.

An additional 600 jobs have been created.

The Lavender Pit is expected to produce about 76,000,000 pounds of copper annually for a period of 12 years.

Processing The Copper From The Lavender Pit

(From Arizona Days and Ways, Aug. 8, 1954)

A man presses a dynamite exploder and the earth trembles. A cloud of dust drifts away in the wind and there, among tons of fractured rock, is the set of copper kitchen ware you will give your wife next Christmas. There, too, is the precious copper for wire to carry the messages of the world; copper to make the motor in your car run; copper for ammunition, copper for the thousands of intricate instruments of the atomic age.

The man at the blast control launches the fascinating series of steps that win copper from ore, but it all started countless geologic ages ago when nature laid down a low-grade copper ore deposit in a mountainside.

Today, the mountainside has been gouged into a pit embracing 155 acres. Dynamite and giant shovels will eat into the rock until the pit has reached a point 1,005 feet below the highest original ground level.

This is the great Lavender Pit Project of the Phelps Dodge Corporation, named for the late Harrison M. Lavender, whose vision and engineering skill on a Bisbee mountainside made possible a $25 million project — and all without benefit of Federal financial aid.

Almost four years have passed since the first homes and other buildings were relocated to make way for the new Phelps Dodge project. During the preparatory period, 46 million tons of waste rock were removed to expose benches of copper ore. During the life of the pit, 2⅓ tons of worthless rock must be removed to reach each ton of ore.

That ton of ore will yield less than 16 pounds of copper by the most advanced technological treatment known in the mining world. Only a short time ago, the low-grade ore such as is found in the Lavender Pit would have been considered commercially worthless.

From the first dynamite blast in the pit to the copper refining, the ore passes through a busy new life on the way to becoming a useful product.

Scooped up in the dippers of 6-cubic-yard shovels, the ore is then trucked, crushed, concentrated and smelted. The chain of operation in the new Phelps Dodge pit mine must run smoothly and efficiently to keep the costs low — for this is low-grade ore.

The ore, with its tiny amount of copper-bearing mineral, is dumped from 25-ton trucks into a large gyratory crusher capable of crushing 3-foot cubes of solid rock, located on the wall of the pit. The product is coarse, broken "muck" which falls from the giant crusher to a conveyor belt. Crossing U. S. Highway 80 for a distance of 975 feet, the belt lifts the roughly crushed ore from the bottom of the pit to a storage bin high on an adjacent mountainside, from which it may be withdrawn as needed for the concentrating operation.

The concentrating operation is one of getting rid of as much waste material as possible without losing too much of the valuable metals in the ore. The valuable minerals are so minutely distributed through the ore that they must be ground extremely fine in order to make the separation in the concentrator. To do this requires more dry crushing in the concentrator, followed by grinding and re-grinding with water in the ball mills until a pulp of mixed ore and water, fine enough so that most of it will pass through a silk handkerchief, is produced. It is now ready for chemical treatment and more mechanical pushing around.

Additives and re-agents transform the pulp into a soapy froth in flotation cells which act

unit consists of a 4-cell and an 8-cell flotation machine in series. Underflow from the middlings thickeners is pumped back to the two cleaner machines and the overflow goes to the reservoir mentioned previously.

Re-agents used in the mill circuit include lime, Z-11, Aerofloat 238, pine oil, and Dow froth.

The tailings disposal system operating between the large de-watering thickener at the foot of the concentrator building and the tailings ponds consists of two 16 in. transite pipe lines set at an 0.8% grade and with concrete drop boxes 8 ft. high placed at strategic points. The main line, 8,100 feet long leads to a large disposal area behind an earth-fill dam 45 ft. high, and the auxiliary line some 1,000 ft. long terminates behind a smaller earth-fill dam 25 ft. high. At the dam site the pipes are fitted with special valves and rubbed distributor pipes. Reclaimed water is pumped back to the large reservoir at the mill.

Water for the camp and plant use is obtained from three wells 500 ft. deep sunk in the valley about 9 miles southeast of the concentrator.

At the townsite there are available 107 modern two-bedroom houses and 68 three-bedroom units, two bunk-houses to accommodate 80 single men, mess hall, 8 apartment buildings.

The Silver Bell Mine is one of the new examples of a hitherto unprofitable orebody being converted to the production of a metal badly needed in both war and peace, by the investment of millions of dollars, and the employment of brains and labor. The low copper content made it a hazardous, marginal operation requiring the application of the latest improvements in equipment and technology, as well as the highest qualities of management.

bined properties produced 5,500,000 pounds of copper between 1927 and 1930 with a total value of $900,000. Total production from the entire Silver Bell District was estimated at $15,746,000.

The railroad connecting the mine with the smelter at Sasco remained in operation until the 1930's, when it was abandoned and the tracks torn up. The smelter was demolished in the late 1920's.

Reactivation of Silver Bell was considered during World War II, but plans were abandoned when the government lowered its sights on the amount of copper needed for the war effort. The principal reason given for refusal of government support was that it would take too long to get the mine into production.

In 1948 the company began extensive geologic exploration and churn drilling at Silver Bell and in December, 1951, development of two pits, the Oxide and the El Tiro, was started. Since then and up to January 1, 1957 there have been removed from the Oxide pit some 21,000,000 tons of waste and 6,400,000 of ore assaying about .9 copper. From the El Tiro pit, four miles distant by road, some 15,000,000 tons of waste have been stripped and 1,000,000 tons of ore have been mined.

Geology and Mining

The geology of the area and the ore-bodies are described and illustrated in July, 1954 issue of the Engineering and Mining Journal.

The two porphyry ore bodies developed for exploration consist of rudely tabular accumulations of chalcocite from 100 to 200 ft. in thickness. Lying beneath about 100 feet of leached capping, they were formed by two-to three-fold enrichment of copper contained in the primary mineralization.

The Oxide is oval shaped measuring roughly 2,100 ft. by 1,500 ft. Entry is by spiral roadway. Six 40-ft. benches have been established so far, the top bench being known as the 2,908, and the lowest as the 2,780. The present pit floor will ultimately go 160 ft. below the 2,780 horizon.

The major fault traversing the pit in about the center in a northeasterly direction is very noticeable. Of the two types of prophyry occurring in the pit, the dacite is hard and the monzonite is fairly soft, influencing drilling speeds and techniques to some extent.

Blast holes are drilled with churn-drills using 9-in. bits. Broken ore and waste are loaded into 37-ton and 22-ton trucks, by a 5½ yd. electric shovel. Haulage distances to the concentrator average 0.4 mi., and waste haulage about 0.8 mi. Current ore-waste ratio is 1:1. Constant road maintenance has cut equipment repair costs to a minimum. Communication between pit and offices of contractor and company is maintained by a radio-phone short wave FM system.

Concentrator

Silver Bell's modern concentrator was designed for economical up-keep and low operating costs. Feeders, crushers, vibrating screens, and belts serving them are interlocked both automatic and manual. All plant buildings are equipped with crane installations to speed repairs and handle materials with minimum labor.

Crushing to ¼ in. ball mill feed is accomplished in three stages. A 48-in. gyratory crushes to 6 in., a 7-ft. standard secondary cone crusher, set to 1¼ in., and two 7 ft. tertiary cone crushers with vibrating screens fitted with screens containing ½ in. square openings. Two large Roto-Clone units represent the dust collecting system at the crushing plant.

Grinding to about 65% minus 200-mesh is done in four 10½ x 12-ft. ball mills, using 3- and 2-in. balls, operating in closed circuit with 95-in. Akins screw classifier. The pulp overflowing from the classifiers at 24% solids goes to a central distributor serving four units of rough flotation machines, each made up of two 4-cell and two 8-cell machines in series. Rougher tailings flow direct to a 275-ft. dewatering thickener, with the overflow going to a 1-million-gal. reservoir, and the underflow via a transite pipe line system to the tailings ponds. The rougher concentrates are pumped to a 26-ft. Hydroseparator. Underflow from this unit is the feed for the regrind section consisting of two 7 x 12-ft. ball mills operating in closed circuit with four Dorr-Clones, and the overflow according to need can either be sent direct to the two 6-cell cleaner machines, or to two 100-ft. middlings thickeners.

Concentrates produced by the cleaner machines are re-cleaned in a 6-cell machine, with the final concentrates receiving successive treatment in a 60-ft. thickener and 6-ft. disc filter installed at the shipping plant. Tailings from the final cleaner machine go to the middlings thickeners, as do the concentrates produced by the scavenger flotation unit handling the tailings from the two cleaner machines. The scavenger

much like an egg beater. This froth attracts to it the tiny copper-bearing particles and carries them over the lip of the cell. This is because chemistry has been busy in this process, and each particle is coated with a substance that makes the copper minerals adhere to the froth bubbles. The waste materials sink to the bottom of the cells and are discharged to large settling basins known as "thickeners" where most of the valuable water is recovered and the solids are conveyed through a pipe line to the tailings disposal area.

The concentrate produced by the froth from the flotation machines also goes to a thickener where much of the water it contains is recovered, and where the concentrate is drawn off as a heavy pulp to filters that further dry it. From the filters, it drops into railroad cars all ready for the trip to the smelter.

The concentrate product travels by railroad to the Phelps Dodge smelter at Douglas, 25 miles from the pit and mill. In the smelting process, which transforms the concentrates into a large amount of slag and a small amount of almost pure copper, large quantities of heat are required.

Here the concentrate, after being mixed with lime and silica, is first passed through roasters at red heat to remove excess sulphur. One thousand tons per day of the roaster product are fed into a reverberatory furnace, the second smelting step required in the process of becoming pure copper.

The copper, combined chemically with iron and sulphur in a substance known as "matte", sinks to the bottom of the furnace where it is drained off. The top layer of the white-hot molten mixture is slag which is drained off, too, and disposed of so colorfully as waste on the slag dump.

From the reverberatory furnaces, the molten matte is transported in huge ladles and poured into a "converter" for more metallurgical treatment, including blowing with air. The product from the converter is "blister" copper which is ladled from the converters to the anode furnace.

Green oak logs at this point are used to stir the molten copper. The excess oxygen in the copper unites with the carbon in the log, forming carbon dioxide gas which passes off. Without the log treatment, excess oxygen would remain in the blister copper as an impurity.

The final product, from the anode furnaces, contains 99.5 per cent copper with minute amounts of gold and silver. The molten copper at this point is poured into revolving molds and then cooled in a water bath.

Each bar of anode copper is about 3 feet square, about 2 inches thick and weighs approximately 700 pounds. The bars are loaded neatly on railroad flat cars for shipment to the refinery at El Paso, Tex. The business of the refinery is to purify these bars by electro-metallurgical treatment to the highest possible degree and to cast into shapes suitable for fabrication. Here too, the small amounts of gold and silver metals are recovered.

From the refinery, the copper goes to various plants throughout the country for fabrication into useful products.

Production Record to January 1, 1957

In 1954 the open-pit mine produced 1,671,753 tons of ore from which were recovered 17,056,589 pounds of copper.

In 1955 the mine produced 4,433,218 tons of ore, from which were recovered 59,862,955 pounds of copper. The tons per day rate was 14-15,000 compared with 12,000 tons projected. The ratio of waste and leach material to ore was 1.81.

In 1956, the mine produced 5,069,049 tons of ore from which were recovered 80,305,962 pounds of copper. The tons per day rate was 15,700 compared with 12,000 tons projected. The ratio of waste and leach material to ore was 1.29.

At the presently scheduled rate of mining, and on the basis of presently known minable ore, the estimated remaining life of the mine is about seven years. To the first of January, 1957, the mine has produced 11,174,020 tons of ore from which 157,225,506 pounds of copper have been recovered; or only 14.07 pounds of copper per ton of ore.

The successful exploitation of an orebody containing only 14 pounds of recoverable copper in 2,000 pounds of rock, is an achievement of which the Company's executives, engineers, miners and all of its employees can well be proud. It is an amazing spectacle to witness the many operations needed to be performed to recover the metal from a mass of apparently worthless rock. The State has acquired rather than been depleted of taxable wealth, and thousands of its citizens have benefitted tremendously from the high wages they have received.

STORY OF SILVER BELL

A. S. & R. CO.'S NEW ARIZONA COPPER PROJECT

Full-scale production was started in May, 1954 by the American Smelting and Refining Company at its Silver Bell Unit, 40 miles northwest of Tucson, Arizona.

The Company is mining approximately 7,500 tons of ore daily, with a monthly output of 1,500 tons of refined copper. The ore body is estimated to contain approximately 0.9 percent copper, and at the proposed rate of production will have a life of 12 to 13 years.

The Silver Bell open-pit development was made possible through an agreement with the U. S. Government, which guaranteed the company a market for 177,000,000 pounds of copper out of the first 197,000,000 pounds produced at a floor price of 24.5 cents, plus escalation for higher costs. The entire project was company financed with government assistance limited to rapid amortization of a portion of the investment for tax purposes and the price guarantee for the specified tonnage. This guarantee has terminated without the government purchasing any Silver Bell copper.

Originally, the total cost of the development was estimated at $17,000,000 and the A. S. & R. Co.'s 1954 Annual Report states that the cost of the project was slightly less than the 17 million dollars. Construction work was completed in March (1954), and production reached the planned rate of 1,500 tons of copper per month by mid-year. At the end of 1953, American Smelting reported $14,708,000 had been expended in stripping the ore body and in construction of the mill and townsite. Stripping of the ore body started in December of 1951.

The mine is working two shifts daily and the mill three shifts. Concentrates are trucked a distance of 20 miles to Plata, a siding on the Southern Pacific, then shipped by rail to the El Paso Smelter.

American Smelting and Refining Company has 140 men on its payroll. Mining is handled under contract by a crew of 80 men employed by the Isbell Construction Company. However, the Company's 1956 annual report states that the Silver Bell Unit is acquiring new equipment for the change from the contractor's operation of the open pit to full company operation.

HISTORY*

Mining in the area dates back to 1865 when the Mammoth mine of the Silver Bell Mining Co., also known as the Boot Mine, was opened. Oxide copper ores containing minor silver-lead values mined from replacement deposits in garnetized limestone were treated in local smelters.

During 1909 the disseminated copper possibilities in igneous rocks were recognized and a three-year campaign of churn-drill exploration followed, leading to the partial delineation of two copper sulphide deposits known today as the Oxide and El Tiro. Low copper content of the ore discouraged exploitation of the deposits at that time, but selective mining of orebodies in the sedimentary rocks continued intermittently until 1930.

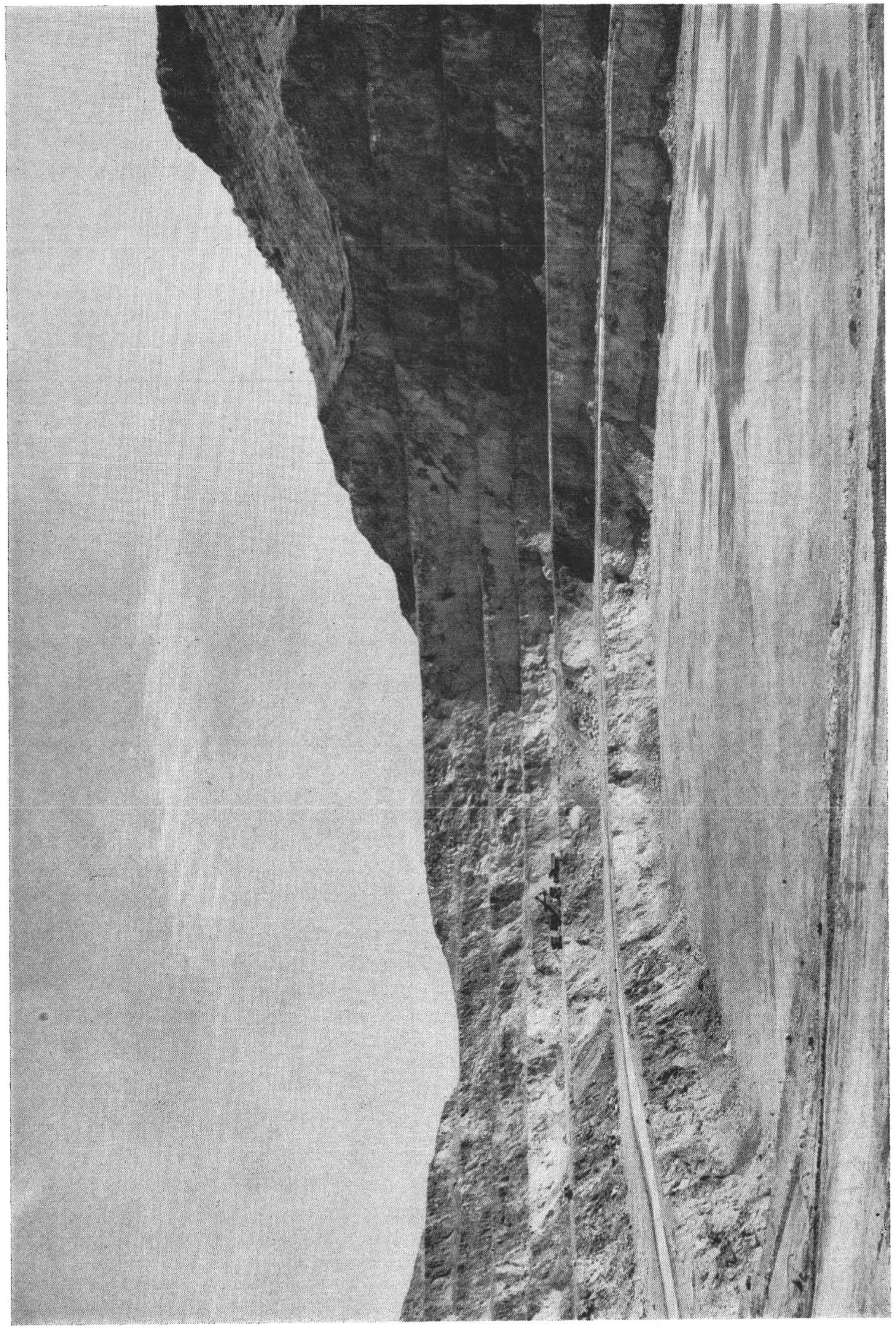
American Smelting and Refining Company first became interested in the Silver Bell district in 1915, through acquisition of the holdings of the Imperial Copper Company. In 1928 the adjoining properties of El Tiro Corporation were acquired.

The Imperial Copper Company, incorporated in 1903, bought the old Silver Bell mine, built the Arizona Southern Railway line from the Southern Pacific to the mine, erected a smelter at Sasco, through a subsidiary, the Southern Arizona Smelting Company, and built a concentrator at the mine. Mining was stopped in 1913 through the loss of a 450-foot shaft by fire and through inability to furnish sufficient tonnage of high-grade ore to make the property pay with copper below 12.5 cents a pound.

The El Tiro Copper Company entered the district in 1907 as a successor to the Cleveland-Arizona Copper Company, and was in turn succeeded by El Tiro Leasing Company and El Tiro Corporation. Its properties were acquired under bond and lease by American Smelting and Refining Company in June 1928.

Production records compiled by the Arizona Bureau of Mines show that the Imperial mine, between 1904 and 1926, produced 64,000,000 pounds of copper, plus some gold and silver, for a total value of $12,125,000. El Tiro, between 1906 and 1927, produced 14,000,000 pounds of copper, 1,000,000 pounds of lead and $20,000 in silver for a total value of $2,150,000. The com-

* Source: Pay Dirt Dec. 21, 1951, May 21, 1954. E. & M. J. July, 1954.



View of Silver Bell Mine, American Smelting & Refining Company.

At this time, mining has progressed to the 3070 level. This level is roughly the top of the sulfide ore zone. A drop cut has recently been started below this level to the 3030 level.

Milling Operation

The purpose of the milling operation is to seperate the wanted copper minerals from the unwanted "gangue" or waste rock. The first step in this separation is to reduce the ore to a size where the individual mineral and rock grains are substantially free of attachment to each other. This action is first accomplished by crushing equipment which reduces the ore to almost all minus 1-inch in maximum size.

Next, water is added and the ore is treated in rod and ball mills where the tumbling action of steel rods and steel balls grind the ore to a size where a large portion of the individual grains of rock and minerals are as fine as face powder.

The resulting suspension of ground rock and water is known as "pulp". The pulp is then agitated and aerated in a series of flotation machines. Certain chemicals are added which have an affinity for the copper minerals and create a water repellent coating on the mineral surfaces. The tiny coated mineral particles attach themselves to air bubbles created in the flotation machines and rise to the top of the machine in the form of a froth. The froth overflows the lip of the flotation machine.

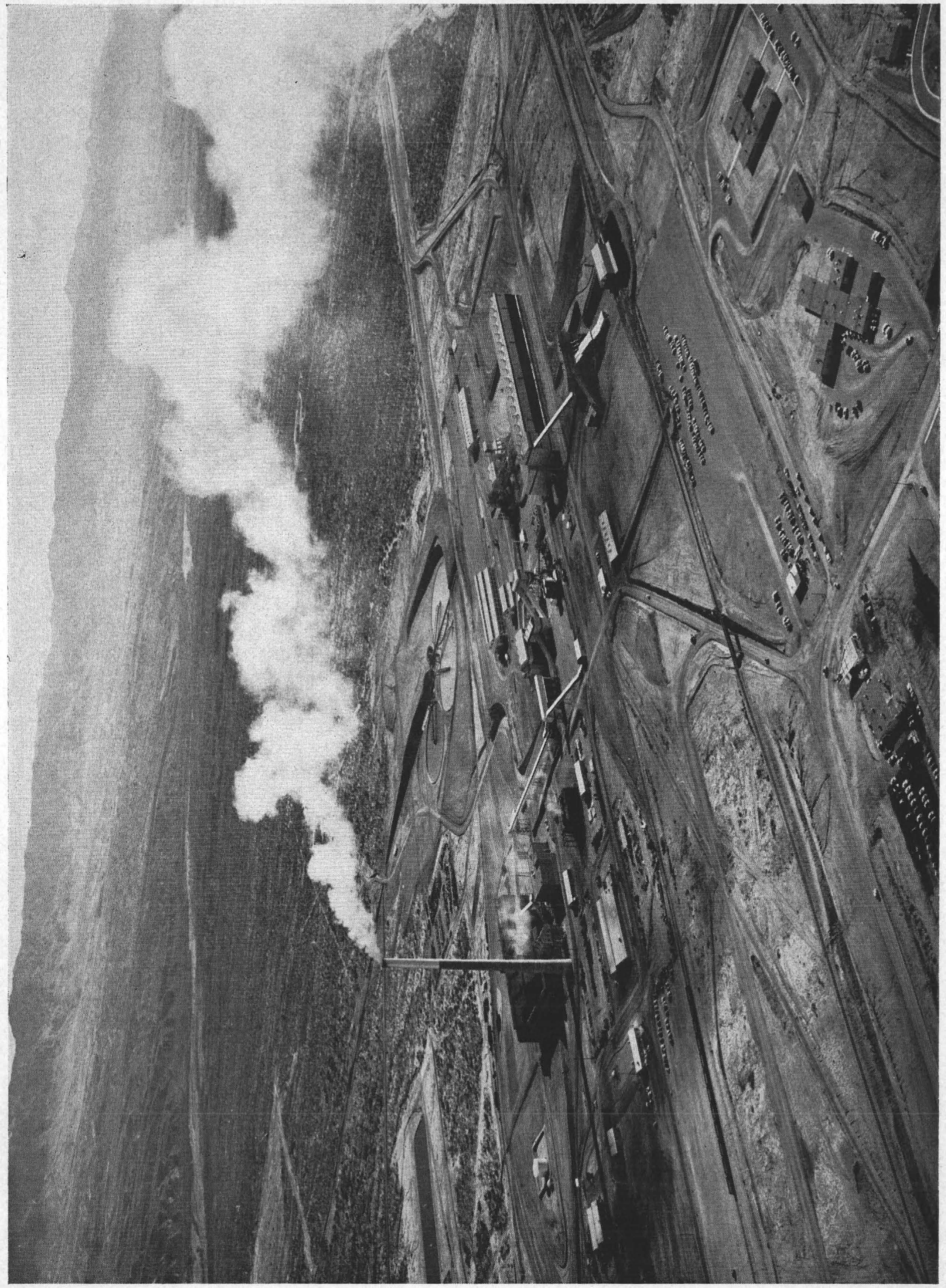
The rejected material, consisting of unwanted rock, is not affected by the chemicals and flows out of the lower portion of the flotation machines. This material is pumped to the tailings disposal area where it is allowed to settle into storage basins covering several acres. The clear water resulting from this settling operation is decanted and returned to the mill water circuit.

The froth overflowing from the flotation machine is twice subjected to reflotation in order to increase the concentration of copper minerals. The final froth is called "concentrate".

The concentrate is a thin suspension of copper minerals in water and is partially dewatered by thickening in a large circular tank. The partially dewatered concentrate is then treated in vacuum type filters where the water content is reduced to about 12% by weight. The filter cake or dewatered concentrate, containing 20 to 25 percent copper, is now ready for shipment to the smelter.

Conclusion

It took seven years of hard work to convert an area of sagebrush, cactus and alluvial wash to a potential source of valuable copper metal. If it had not been for the application of the latest geophysical know-how, the existence of such a copper orebody might never have been discovered. The Pima Mining Company is engaged in adding to Arizona's wealth instead of depleting it.



View of San Manuel reduction plant, San Manuel Copper Corporation.

completed to its present status of 1,000 homes, shopping facilities, and hospital.

Magma Copper Company acquired the town early in 1955.

SAN MANUEL OREBODY AND METHOD OF MINING

The San Manuel orebody is part of a mass of mineralized rock, chiefly a granitic appearing monzonite and a similar, though finer textured monzonite porphry. This large zone of mineralization is covered for the most part by conglomerate, a younger rock containing no copper. The orebody, or portion of the general mineralized mass containing appreciable copper sulphide minerals in addition to iron sulphides, covers an area over one mile long by one-half mile wide. The known depth of ore extends about 2,600 feet below the surface. The control as to size and shape of the orebody is an arbitrary cutoff based on copper content of the mineralized rock. Therefore, that portion considered economically feasible to mine appears in the more northerly portion as a tabular mass up to 400 feet thick with its long dimension bearing northeast and lying at an angle of 55° from horizontal to the southeast. This attitude persists down dip for about 2,400 feet where it flattens and then rolls upward to form a cross-sectional fishhook shape. Within this part of the orebody there is a pronounced thickening, and it is the upper one-third of this southeast portion, starting some 1,100 feet below the surface, that was selected for initial mining operations. Of this 1,100 foot thickness from the first mining level to the surface, there is an average of about 430 feet of ore and 670 feet of waste overburden.

The thickness of the overburden and shape and size of the orebody combine to make open pit mining impractical. For these reasons the underground block caving method of mining was selected. The monzonite in which the ore occurs is well fractured, caves readily and crushes to a size that is easy to transport.

The area to be mined has been divided into panels 210 feet wide, separated by 35-foot pillars. The blocks or stopes within each panel vary in length from 175 feet to 270 feet.

Block caving entails the undercutting or removal of a horizontal slice of ore of sufficient area (stope block) so that the unbroken ore above will not support itself, but will cave and slough into the undercut. As the broken ore is drawn off, thereby removing support from the ore above, caving progresses upward. As drawing continues, caving extends to the surface, the overburden or waste rock following the ore down. When the waste rock reaches the undercut horizon, drawing is stopped and the stope block is finished.

The underground track for the haulage system is 36 inch gauge with 70-pound rail through the panels. On the main lines between the mining area and the hoisting shaft, 90-pound rail is used to accommodate the heavy traffic and higher speeds. The ore cars in this haulage system have a capacity of about 12.5 tons, and each train is made up of 15 to 18 cars, pulled by a 23-ton, 250 HP trolley locomotive.

At the two ore hoisting shafts on the 1,475 haulage level the trains pass through a rotary tripple which dumps three cars at a time into a 1,500 ton pocket or underground storage bin adjacent to the shaft.

The bottom-dump ore-skips, which hold 18 tons of ore, are hoisted to the surface and discharged into a 5,000-ton surface storage bin for transportation to the Plant.

Oxidized ore for smelter silica flux requirements is being mined by a small open pit operation on the orebody outcrop. Limestone and high grade silica for metallurgical use is mined from quarry sites along the San Manuel Arizona Railroad about 17 miles north of the Plant. These products are hauled to the flux crushing plant by rail in 50-ton bottom-dump cars.

THE SAN MANUEL MILL

Ore transportation from the Mine to the Plant is by rail shuttle service in 100-ton capacity bottom-dump railroad cars. The 35 to 40-car train is pulled by a 1,600 HP, 125-ton diesel electric locomotive. The seven mile ore transportation track is standard gauge, 132-pound rail, and was constructed with liberal curves and no grades.

A 10,000-ton coarse ore receiving bin feeds two seven-foot standard Symons cone crushers at the rate of 1,000 tons per hour to each crusher. The crushed ore from the two primary crushers is conveyed and distributed to four secondary seven-foot Symons cone crushers, each preceded by mechanical screens to by-pass the undersize material.

The final product from the crushing plant, all

ments and volcanic material, known as "pyroclastics". These have likewise been altered and mineralized, but the ore values are more sparsely distributed, yielding a low grade disseminated ore minable only by low-cost (i.e. open pit) methods. This type of ore is found in most extensive development to the east and northeast of the main high grade ore body. It shows no well-defined structural form, but occurs in irregular masses.

The principal ore mineral at Pima is chalcopyrite. There are also small amounts of sphalerite and molybdenite, neither of which is recovered at present. Pyrite and magnetite (magnetitic iron ore) are accessory minerals. For a short distance below the bedrock surface, the copper sulfides have been oxidized to form the green copper silicate, chrysocolla, and the black copper oxide, tenorite.

Various types of igneous rocks have been recognized in the Pima Mine, but none shows any direct connection with the ore values. It is generally believed that the entire region is underlain at fairly shallow depths by a granite mass which may be the source of the ore solution. Granite has been penetrated by drill holes a short distance west of the Pima property but has not been found to date in any of the Pima holes.

General Mine Description

The mining operation is planned for production of 3,500 tons per day.

The pit development is laid out for a final over-all slope of 1.45/1 in the alluvium and 1/1 in the rock.

Present daily production is as follows:

Ore mining	3,500 tons
Rock stripping and oxidized ore	8,500 tons
Alluvial stripping	12,000 tons
TOTAL	24,000 tons

The mine is operated on a 2-shift basis and equipment maintenance and repair on a 3-shift basis. At this time the total mine force consists of 73 men and the maintenance force consists of 29 men. These figures include supervision.

Mining equipment selected to accomplish scheduled production is as follows:

	Production Capacity
Alluvial Stripping:	
6 — DW-21 Caterpillar Carryalls (rubbed-tired)	122 tons/hr/unit
2 — D-8Caterpillar Tractors (pushcarts)	
1 — D-8 Caterpillar Tractor (ripper-dozer)	
Rock Stripping and Ore Mining:	
3 — 54-B Bucyrus-Erie Diesel Shovels 2½ c.y. capacity	343.7 tons/hr/unit
7 — 802 Kenworth Rear Dump Trucks 24-ton capacity	77.5 tons/hr/unit
4 — 802-B Kenworth Tractor-Trailer 48-ton capacity	122.6 tons/hr/unit
1 — D-8 Caterpillar Tractor (dozer)	
1 — 40-R Bucyrus-Erie Rotary Blast Hole Drill	47 feet/hr/unit
General:	
1 — No. 12 Caterpillar Motor Grader	
1 — GMC Water Truck — 3,500 gallon capacity	
1 — GMC Flatbed Truck — 1½ ton capacity	
2 — GMC Pickups — ¾ ton capacity	

In addition to this equipment, a rockover skip system is being installed and will be in operation in the near future. The double drum hoist for this system is powered by four 500 HP wound rotor AC motors. These motors are semi-automatically controlled with grid resistors. Two 22-ton skips will be hoisted in balance and will transport ore and waste rock from the loading pocket (now on the 3070 bench) to the surface. The incline railway for the skip hoist has been placed on the north side of the pit on what is considered to be a final pit slope. The capacity of this system will be 14,000 tons per day. When this system is in operation, the 802 Kenworths will be used only in the pit hauling to the loading pocket, and the 802-B Kenworths will be used to haul on the surface from the skipway bin to the crusher and to the waste dumps.

THE STORY OF THE PIMA MINE*

One of the more outstanding events in the history of the mining industry — the discovery of a major copper deposit by geophysics — occurred at the Pima Mining Company's property, 17 miles southwest of Tucson, Arizona. Here is a typical setting of sagebrush and cactus, entirely devoid of surface mineral indications, this company has located and developed a promising copper orebody buried under 200 feet of alluvial wash.

History

The Pima ore body was the first base metal deposit of any magnitude in the western U. S. to be located by geophysical methods. Under the guidance of Herbert Hoover, Jr., who was then President of United Geophysical Corporation, Robert Thurmond and Walter Heinrichs — exploration engineers for UGC — made their first discovery in this area in 1950, using equipment primarily designed for use in exploration for buried mineral deposits. Subsequent preliminary drilling indicated a deposit of medium size and grade which could be worked by underground methods.

In January 1952 an underground development program was initiated and carried on until approximately the middle of 1954. During the latter phase of this program, it became apparent that the medium size high grade ore body could be more economically exploited if the halo zone of low grade material were incorporated as a part of the entire ore body. After extensive study, it was decided that the deposit could be more profitably worked as an open pit mine.

In the Fall of 1955, Cyprus Mines Corporation exercised an option and assumed management of Pima Mining Company. Union Oil Company retained a 25 percent interest and a 25 percent interest was sold to Utah Construction Company.

In November 1955, Utah Construction Company started removal of the overburden over the main ore body. In April 1956, Pima started its own stripping operation alongside the Contractor. Utah completed its stripping contract on 1 October 1956 after having stripped 6 million yards of alluvium and waste rock. (Pima had stripped an additional 3 million yards of waste material during the time Utah was working in the pit.)

Pima moved its offices to the mine site on June 1, 1956. All efforts were concentrated on completion of the mill, auxiliary buildings and the water supply system in order to get the mine into production. Plans were underway for a County Road due east of the mine which would shorten the haul of concentrates to the railroad spur on the Nogales Highway. Ore was being stockpiled for processing in the mill.

At 8:40 A.M. on December 15, 1956, the first load of rock was dumped into the crusher for a preliminary tryout. The mill turned over for the first time on December 21st — and on December 28th, the first concentrates were made.

Pima started its shipments of concentrates to the El Paso smelter on 4 January 1957. There are still problems to be ironed out and some construction to be completed; but after almost seven years of hard work, the Pima Mine is adding its potential to the copper resources of the Country.

Geology

The Pima deposit includes two distinct types of ores:

(1) A highly altered limestone, strongly mineralized and relatively high grade, and

(2) Low grade disseminated ore mineralization in volcano-sediments.

The high grade ore occurs in what was originally a dolomitic limestone which has been thoroughly altered by igneous action to a calcium silicate rock called "hornfels"; the latter was subsequently impregnated with the ore minerals.

The ore formation dips about 45 degrees to the south and trends east-west, curving from a northwesterly bearing on the west to a slightly northeasterly direction on the east. It is quite variable in thickness but probably averages about 200 feet. In the main part of the mine it has been developed over a lateral extent of 1,600 feet, extending into neighboring property on the west and being cut off by a fault to the east. Its lower limits have not been determined, but it has been intersected by drill holes at vertical depths of around 800 feet.

Enclosing the "hornfels" band is a thick series of detrital rocks, essentially a mixture of sedi-

* Source: "Mining World"; Pima Mining Company Staff Report to February, 1957.

less than one inch in diameter, is conveyed by belt conveyor to discharge on the 54-inch belt conveyor, carrying the crushed ore at the rate of 2,000 tons per hour up to the 45,000-ton capacity fine ore bin in the concentrator.

The ore is drawn from underneath the fine ore bins by belt conveyors onto a gathering conveyor which feeds each rod mill at the rate of 4,000 tons per day. A weightometer both registers and controls tonnage to the rod-mills. Water is first added at the rod mill feed to start the wet grinding.

The concentrator is divided into eight sections and each section consists of one 10-foot by 13-foot rod mill and two 10-foot by 10-foot ball mills; each ball mill operates in closed circuit with a 16-foot by 35-foot drag classifier in which the ore ground to the specified size overflows to the flotation section.

The wet grinding bay is serviced by a 175-ton crane, which is capable of taking out a fully charged rod or ball mill for repairs. A 10-ton crane serves for lighter, faster service.

The classifier overflow goes to distribution boxes where, with reagents added, it is distributed to 48-inch rougher flotation cells. There is a total of 480 of these mechanical flotation machines. The concentrate is floated from the surface, and the tailings are piped by gravity to the tailings thickeners where approximately 12,000 g.p.m. of reclaimed overflow water is returned to the mill. The thickened underflow is piped to the tailings pond.

The concentrate is pumped from the rougher flotation cells through cone classifiers in closed circuit with four 8-foot by 12-foot regrind ball mills. The reground concentrate is distributed to 144 48-inch cleaner flotation cells. The tailings from this regrind section are returned to the mill circuit, and the final copper concentrate, averaging about 2% copper, is pumped to the molybdenum thickener with the thickened concentrate going to the molybdenum plant.

Molybdenum is recovered from the concentrate through another series of flotation cells, after which the concentrate is pumped into a final thickener, then filtered, dried, and conveyed by belt conveyor to the concentrate bins.

THE SAN MANUEL SMELTER

The copper concentrate, amounting to approximately 750 tons per day, averages about 28% copper. The concentrate is drawn from the storage bins in the smelter building by conveyor belts and is fed to the 32-foot by 100-foot reverberatory furnace through hoppers located along each sidewall of the furnace. The concentrate is smelter in the furnace at a temperature of approximately 2700° F., using natural gas for fuel.

All gases from the reverberatory furnace and the converters pass through an electric precipitator prior to entering the 500-foot high stack. Practically all the small particles of solid matter are removed from the smoke. This dust has a high copper content and is returned to the reverberatory furnace.

When the charge is smelted the furnace wall is tapped for slag which is allowed to run into railroad car slag pots of 200-cubic foot capacity. The slag pots are then hauled to the slag dump. After the slag is skimmed off, the matte, which is chiefly copper, sulphur and iron, is tapped into 200-cubic foot ladles and poured into the 13-foot by 30-foot Pierce-Smith type converters. There are three converters in the smelter, and two 60-ton overhead cranes handle the ladles.

After the matte has been poured into the converters, a flux with a high silica content is added. This flux, with the iron, forms a slag which is skimmed off and returned to the reverberatory furnace. The molten copper is transferred by ladle into the holding furnace.

In the holding furnace the oxygen is burned off by the burning of wooden poles. The copper is poured into anode moulds located on a 34-foot diameter casting wheel. The finished anode slabs, weighing 700 pounds each, are cooled in water in a bosh tank. The anodes are then removed by overhead crane and stacked on the storage floor where they are later inspected and loaded on flat cars for shipment to the electrolytic refinery.

MISCELLANEOUS FACILITIES

The flux plant is between the smelter and concentrator buildings and includes receiving bins and crushers for handling limestone and silica flux. A lime kiln for calcining limestone and a slaker have been built to provide metallurgical lime for the concentrator.

Other Plant facilities include a machine shop with locomotive service and repair pit, carpenter and auto shops, warehouse, time office and change house.

The San Manuel Arizona Railroad Company

operates 30 miles of standard gauge railroad from the Plant to connect with the Southern Pacific at Hayden. Current timber and other operating supplies are being brought in. All of the anode copper is transported by rail.

REPORT OF FIRST YEAR'S OPERATIONS (1956)[*]

5,496,328 tons of sulphide ore assaying 0.77 per cent copper were produced and milled at the San Manuel Mine during the year. In addition 43,253 tons of oxide ore assaying 0.7 percent copper were mined from the surface pit for smelter flux. 17,523 tons of limestone and 11,179 tons of silica were quarried for smelter and concentrator requirements.

Net Metal Production (1956):

Copper	Silver	Gold
78,152,140 lbs.	136,074 ozs.	9,719 ozs.

Molybdenum Sulphide
591,970 lbs.

There are presently approximately 2,200 employees at San Manuel. To reach full production, which is planned for the middle of 1957, about 150 additional employees will be needed. Considerable development work has been done and must continue to be done to prepare the ore body for orderly and continuous long term mining operations. Such development work now planned for the second level will require substantial expenditures over the next six years and these deferred or prepaid development costs will be written off as the ore so developed is mined in future years.

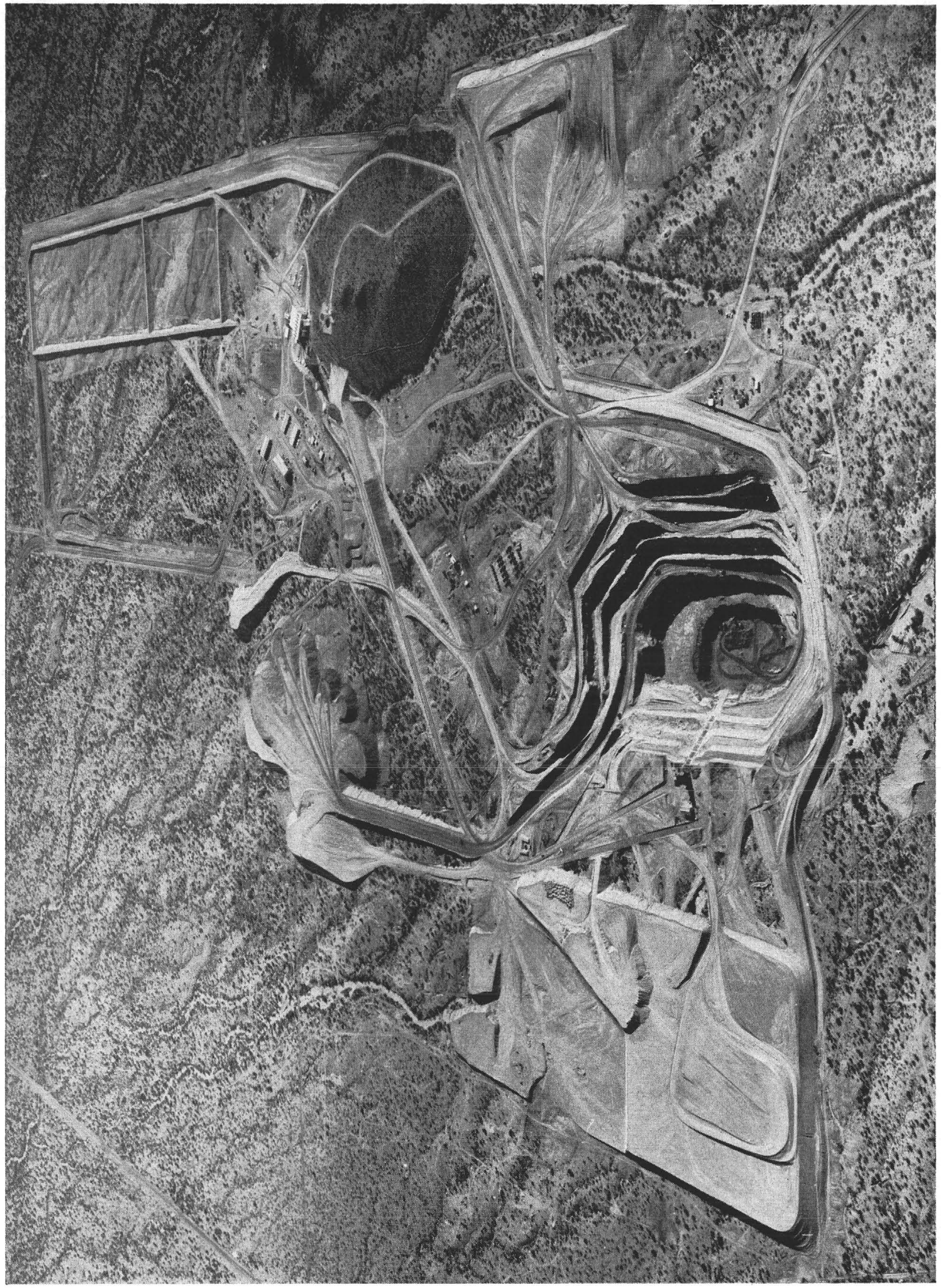
[*] From 1956 Annual Report.

San Manuel's total capital expenditures to the end of 1956, including railroad, but excluding the townsite, were $102,589,445, being $1,150,847 for property, $27,701,948 for deferred development and $73,736,650 for plant. Of this total, $88,587,000 were expended on the production "Project" which commenced January 1, 1952 and has now been substantially completed.

San Manuel, under its original $94,000,000 Government loan authorization obtained in 1952 to carry on its production "project", to date has borrowed $70,754,137. It also has borrowed from Magma Copper Company $27,595,000. The Government, by agreement with San Manuel, has extended to May 10, 1957 the date within which a final disbursement of loan funds may be made and has reduced to $6,000,000 the maximum amount which hereafter may be disbursed under the loan authorization.

The guiding genius of this tremendous undertaking has been Wesley P. Goss, the president of the Company, and in his 1956 annual report to the stockholders he gives special commendation to the operating staff for their "notable accomplishment in attaining a rate of mine production in excess of 580,000 tons of ore per month within nine months after undercutting the first stope and starting production in January, 1956. This is an achievement believed never before equalled in the history of underground mining."

The "Story of San Manuel" has been a prime example of the conversion of a mountain of worthless rock into indestructible copper metal.



Pima Open Pit showing incline skip method of hoisting ore, Pima Mining Company.

Porphyry Ore Bodies

There was a fairly large mineralized area within the stock of Sacramento Hill. These ore bodies were secondarily enriched by chalcocite and were partly in the porphyry mass of Sacramento Hill and partly in the contact breccia around it. The protore contains less than 0.50 percent copper. The stock of Sacramento Hill was highly silicified, sericitized, and pyritized, and the small amounts of chalcopyrite and bornite in the protore are responsible for the copper of the secondary enrichment.

Ore Guides

Granite-Porphyry dikes and sills are guides to ore: By following them on both sides ore may be encountered in the embayments.

Fracture zones, where they are rather steep and dip more or less normally to the bedding, are well worth following if they are at all mineralized.

Manganese oxides as outcrops or along fracture zones can be used as guides. Silica breccia and hematite, or both, are usually closer to ore than managanese.

Limonitic gossans and calcite-filled cracks in the limestone over oxidized slumped ore bodies are direct guides and point down to the possible ore.

Copper Queen Concentrator*

Because of the sulphide character and the low grade of the ore in Sacramento Hill, a concentrator was deemed necessary. Experiments preliminary to the design of such a plant were commenced as early as 1916 in a small test plant constructed for the purpose near the mine. Early in 1918 H. K. Burch was employed to supervise the design of a 3,000-ton mill to be constructed at a site about two miles south of the mine on the slope of Mule Mountains. Besides affording gravity flow of the ore through the concentrator, the site was exceptionally well situated with respect to disposal of tailing on the valley floor below.

Many obstacles delayed the completion of the mill until 1923. First, the Government declined to release steel necessary for construction; then in 1919 important changes in the design of the plant were made; in 1920 the strike of railway employees in the United States held up shipment of materials; and finally in 1921 the general curtailment in copper production caused a complete suspension of construction, which remained in force until January 1, 1923. However, on April 1, 1923 the first unit of the plant was put in operation, the nominal capacity having in the meantime been increased to 4,000 tons per day.

At the start the concentrator provided a combination of gravity and flotation treatment, flotation constituting an intermediate process between "roughing and finishing" concentrating tables. Although a number of Porphyry Copper mills had by this time discarded tables, the reason they were retained at the Queen mill was because it was not planned to obtain rich concentrate and a high ratio of concentration. Coarse concentrate was more readily handled at the smelter, and moreover there was the supposed need of iron-bearing minerals at the smelter to flux the large quantities of highgrade ores that were mined from the carbonate orebodies at Bisbee and smelted without concentration.

As the minerals of copper and iron in the sulphide concentrating ore were very intimately associated it would be necessary, if they were to be separated, to grind exceedingly fine, and fine grinding is a costly operation. Early operation, however, indicated that radical changes were desirable. Within a year, the gravity tables were discarded, leaving the flotation cells as the only concentrating devices in the plant. The next change was the introduction of finer grinding to permit the removal of more of the gangue constituents of the ore. From these changes came a saving of freight on the concentrate, a reduction in smelting costs, growing out of the treatment of a smaller tonnage, and a reduction of slag losses because of the removal of worthless slag-forming elements in the furnace charge.

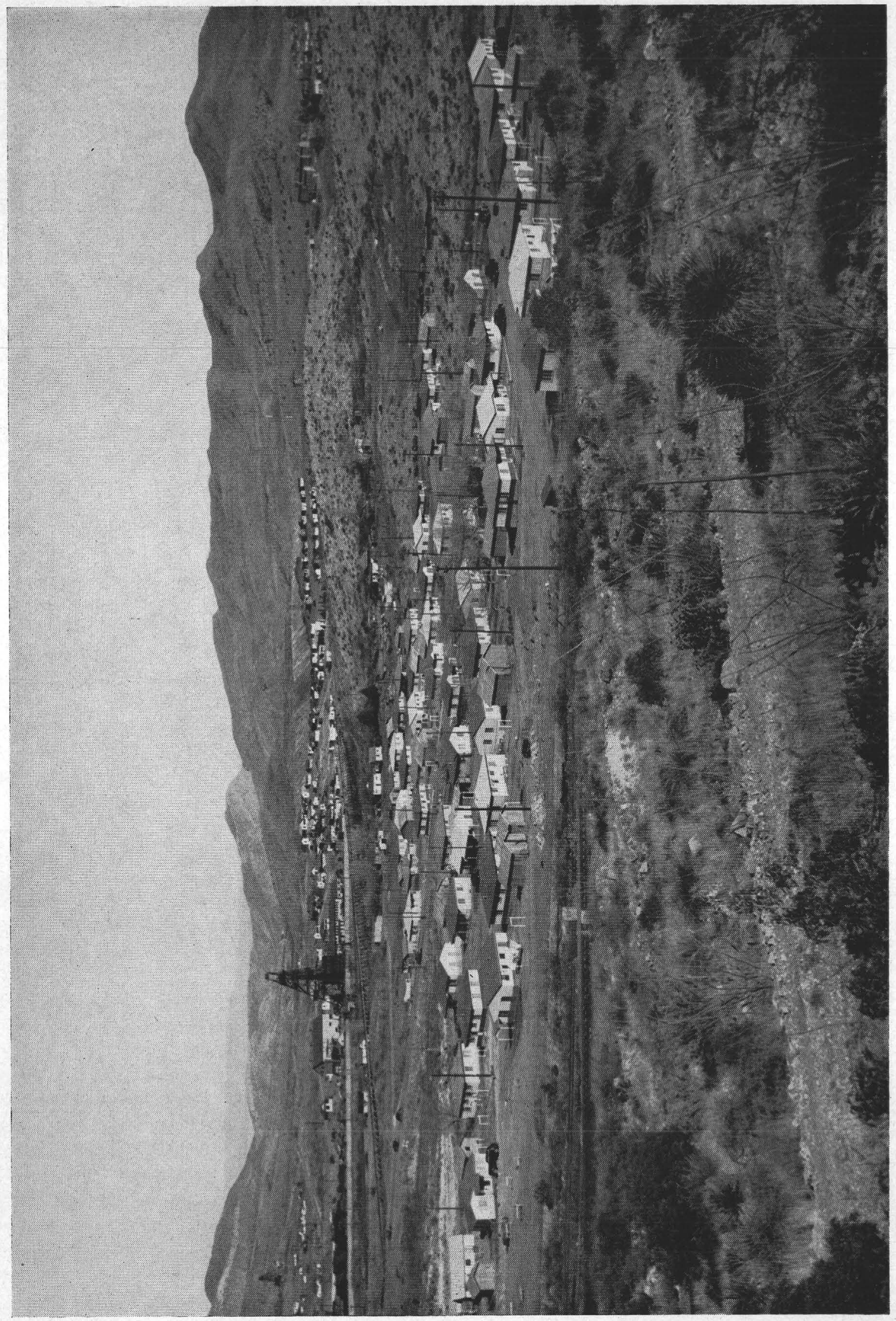
The ore mined from the Sacramento Pit increased in grade as the lower horizons of the deposit were reached. For example, the first five years of operation produced an average grade of 1.65% copper as compared with 2.04% for the last four years. The concentrate grade was increased from 7-8% copper to 13-15%. An excellent recovery was made from the start, averaging better than 88%.

Heap Leaching*

In one respect the Sacramento Hill project

* Parsons "Porphyry Coppers."

* Parsons "Porphyry Coppers."



Galena Townsite in the Bisbee District with Bakerville & Warren in the background, March, 1951.

THE STORY OF BISBEE AND THE COPPER QUEEN

From the time when the Bisbee (or Warren) District began to produce ore (about 1880) until the end of 1951, the district had mined almost 55 million tons of ore containing over 5½ billion pounds of copper, 50 million dollars worth of gold, 56½ million dollars worth of silver, over 300 million pounds of lead and over 360 million pounds of zinc, or a grand total of mineral wealth amounting to over one billion dollars. This would indicate an average value of 20 dollars per ton of ore, which puts the district in the bonanza class, as distinguished from the low-grade porphyry copper districts with their three to four dollar ore.

Since 1951, the Copper Queen underground mine has produced 2,852,574 tons of copper ore from which 297,319,674 pounds of copper have been recovered. This copper at the prevailing price of the metal, had a gross value of about $96,600,000. The value of gold and silver by-products, and of some lead and zinc produced in 1952 and 1953, would bring the gross value of Bisbee's production (not including the new production from the Lavender Pit, which amounted to 11,174,020 tons of ore and 157,225,506 pounds of copper) to about $100,000,000 for the five year period since 1951. The higher price of copper during this period brought the gross value of the new ore to about $35 per ton.

To be sure, the net profit to the operators in producing this mineral wealth is only a small fraction of the gross metal value of over 1.1 billion dollars. Such gross value was only attained after many processes outside the State of Arizona were performed and the final product transported to markets.

History*

The discovery of ore in the Bisbee district was made by an American Army Scout named Jack Dunn, in August 1877, when he located a claim called the Rucker, near the Mexican border. Dunn's location was named after J. A. Rucker, an army officer, to whom was given a share in the claim. The Copper Queen deposit was discovered by Hugh Jones in 1877, and a claim named the Mercey was located by George Warren, after whom the district is named, on Dec. 27, 1877. This claim was re-located as the Copper Queen by George Eddlemann and M. A. Herring on Dec. 15, 1878. The original locator, Jones, abandoned his discovery because he saw nothing more than "copper-stained rock." A little copper furnace was erected by Warner Buck on the Robb claim owned by B. D. Rea of Tucson, and some matte was produced unprofitably in 1878. The Copper Queen prospect was purchased by John Ballard and William Martin, of San Francisco. They were successful contractors, but entirely ignorant of mining; they had, however, the advice of two competent men, Ben Williams and Lewis Williams, the sons of John Williams of Globe. John Williams had been a Welch miner and was now a partner with Judge Dewitt Bisbee in the noted brokerage firm of Bisbee, Williams & Co. of San Francisco. Bisbee sponsored the new company of Ballard & Martin, and the town was named in his honor. Under the direction of the Williams Brothers, George Center built a smelting-furnace, a 36-inch water-jacketed cupola, in 1880. This little smelter treated an ore yielding 23 percent of copper, and for a time did well. The fuel was English coke, brought by way of San Francisco.

In 1881, James Douglas came to Bisbee and obtained an option on the Atlanta claim, which was next to the Copper Queen. In developing the Atlanta, Dr. Douglas was unsuccessful at first in finding ore, and after he had spent $70,000 in exploratory work it was proposed by his associates to discontinue operations, but on his advice they agreed to advance $15,000 more for development, with the understanding that if this renewed attempt failed to discover sufficient ore, they would abandon the venture. Sinking was resumed, and within a few feet the Atlanta workings penetrated a great orebody, which proved later to be the basis for a magnificent copper enterprise.

Meanwhile, Ballard and Martin had exhausted the ore in the Copper Queen, and in 1884 litigation was threatened between them and the owners of the Atlanta, whereupon the two mines were joined in the name of the Copper Queen Consolidated Mining Company. This was in 1885, and Douglas, who was acting for the firm of Phelps, Dodge & Company, became the moving spirit of this company. In 1890 he engaged Louis D. Ricketts as his assistant, and their association continued for 17 years.

* James H. McClintock, "Arizona", and Richard's "History of American Mining."

sion was undertaken, first by extending the underground workings in the limestone sections of the mines, and later by churn-drilling from the surface. Two orebodies separated by a mass of rock too lean for profitable exploitation, were proven. The so-called West, or Sacramento Hill orebody, was richer, on the average, and the overburden was thinner, ranging from 50 to 350 feet with an average of 250 feet. Steam shovel operations began in 1918.

Sacramento Hill was — before it succumbed largely to the steam shovels—a bold precipitious hump standing in the center of Mule Gulch. Its crest was dark brown from stains of iron; it contrasted sharply with the reddish schist on one side and the gray limestones on the other. The demolition of it was a most spectacular project.

In September, 1929, shovel operations were finally suspended after moving 15,000,000 cu. yd. (equivalent to about 30,000,000 tons) including ore and waste. As the ratio of waste to ore was 2.75 to 1, about 8,000,000 tons of ore was shoveled during the period 1923 to 1929. At least three million tons of ore remained to be won. A glory-hole method was developed that recovered this ore economically. In the meantime, mining of the East porphyry orebody was started. In spite of some misgivings on account of the wet and sticky character of the ore, a block-caving method adapted from Morenci practice was put into successful operation, and a substantial part of the ore going to the concentrator in 1930 and 1931 came from this section of the mine.

The old underground sections of the Copper Queen mine have been mined by the use of both square-setting and top-slicing methods, or modifications thereof. The high grade of the ores mined permitted these more expensive mining methods. The Denn Mine, which was taken over by the Phelps Dodge Corporation in March 8, 1947, also used the square-set and pillar system, the pillars being mined by the Mitchell slicing method developed at Bisbee. The Denn Mine had originally been owned by Lem Shattuck and Maurice Denn. In the early days, Lem Shattuck, like almost everyone in the district, picked up a number of claims, including one southwest of the "Copper Queen." When the boom hit Bisbee, he interested some Minnesota investors in helping him sink a shaft on his property. At the three-hundred-and-fifty foot level, the shaft dug into a body of high grade ore which continued all the way down to the eleven-hundred foot level and made the "Shattuck" renowned as the "biggest little mine" in the area. Then with Maurice Denn and others, he owned another group of claims to the northeast where no one expected to find ore; but Shattuck sank a shaft to the seventeen-hundred foot level and again ran into an enormous body of suphide ore.

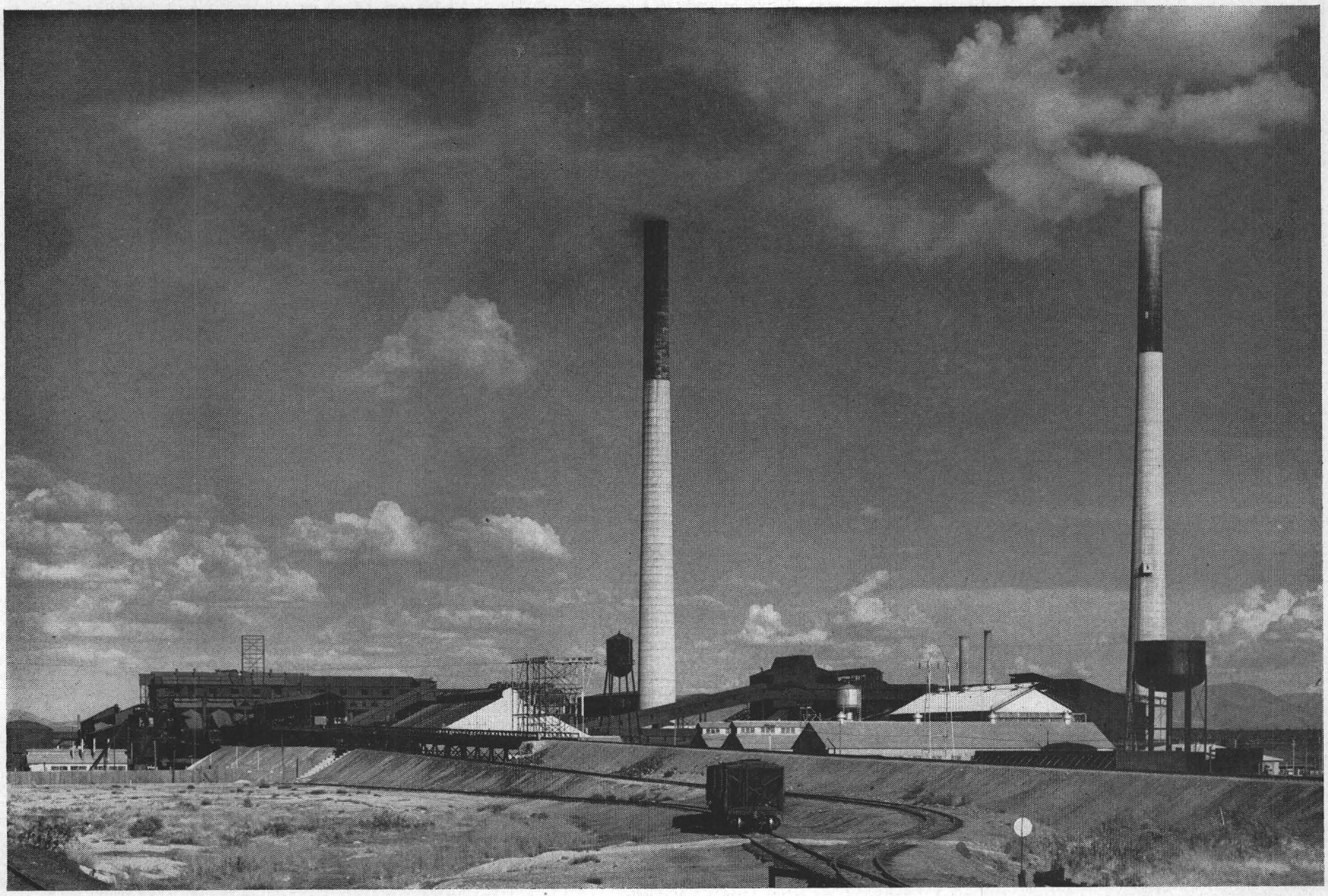
Ore Bodies*

The first discovery of copper ore in the district was in the old open cut on the hillside above the Bisbee Post Office. Except at the White Tailed Deer Mine, it was the only copper outcrop in the district. The ore here was malachite and azurite (copper carbonates), which for many years was the only kind of ore found or mined. As work progressed downward and southeastward, secondarily enriched sulphides and finally primary sulphides of mineable grade were found.

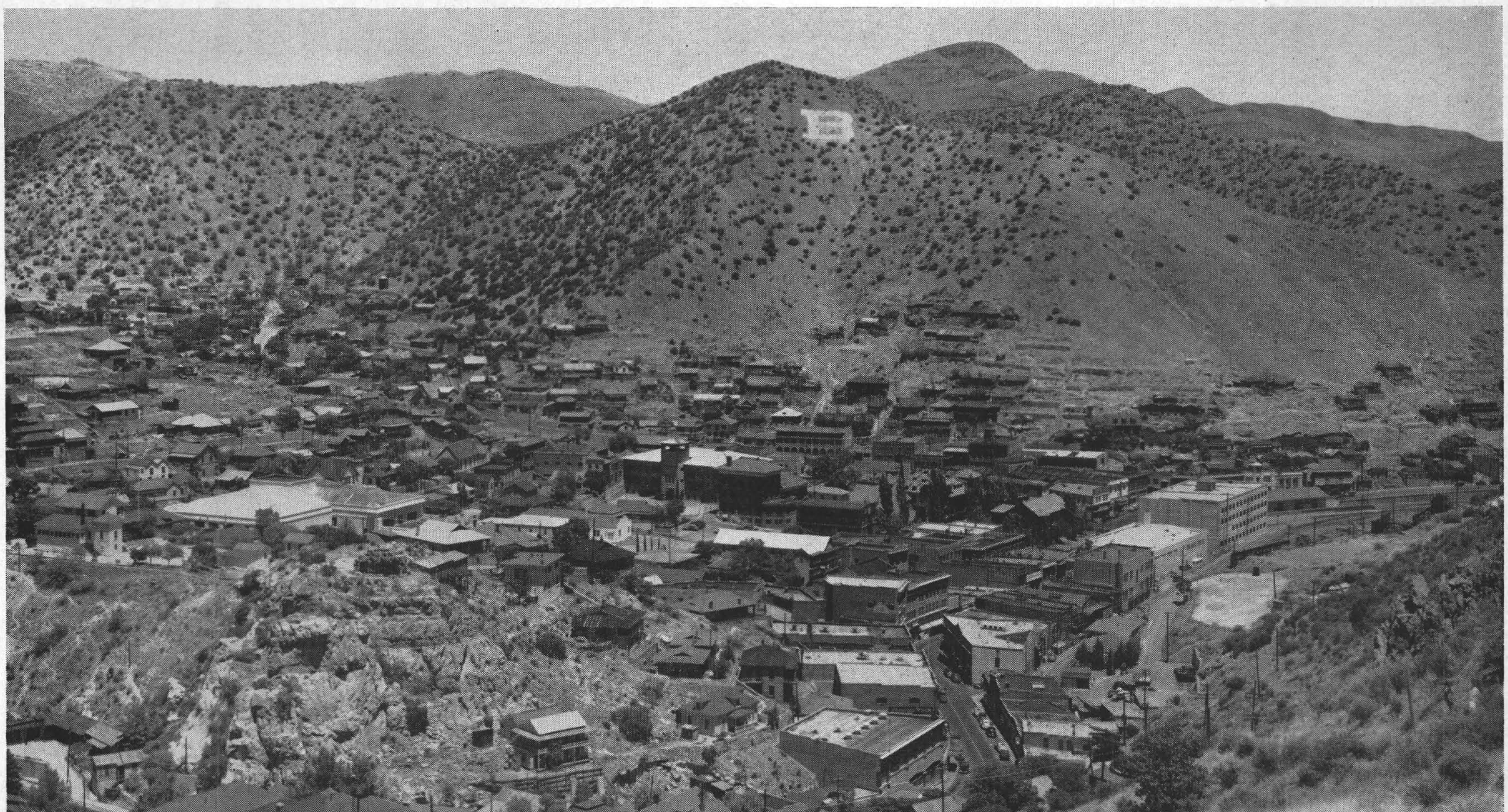
The ore bodies of the district are arranged in the semicircle around Sacramento Hill and also radiate outward from this center. A commonly accepted idea about the replacement ore bodies in the limestone is that they are tabuuar, wider than they are high. The idea originated at a time when mining was done mostly in the western portion of the camp. Here oxidation and erosion shank and cut down the height of some of the ore bodies of this area. In the extreme eastern ore area, height is generally greater than length or width. Oxidation progresses in intensity from southeast to northwest. In small portions of the Campbell area, however, oxidation has penetrated as deep as the 2,300 level.

Practically all of the ore bodies of the district had a central core of somewhat siliceous pyrite containing small amounts of copper around which sulphides of copper and iron occured. In the fine grained pyrite core, the pyrite is commonly shattered and becomes ore because of the deposition of small veinlets of copper sulphides in the breaks and cracks. Hematite is frequently associated with the ore along its contact with the limestone. Magnetite is intimately mixed with the pyrite and chalcopyrite in certain areas. In the process of replacement the grain structure, bedding, and the included unreplaced chert lenses of the limestone are frequently beautifully preserved in the resulting sulphide.

* From Cark Trischa's article in the Arizona Bureau of Mines Bulletin No. 145, pages 38-41.



General view Douglas smelter, taken in August, 1949.



Looking down on center of Bisbee, May, 1944.

The Copper Queen Company extended its territory by acquiring the Goddard properties and by purchasing outlying claims including the Neptune and Lowell groups. The Irish Mag and one or two other desirable claims, however, were involved in litigation because the owner, an Irishman named James Daley, was a fugitive from justice, and a Mexican wife became claimant to his belongings. Eventually the Supreme Court of the United States recognized her title, which soon afterward passed to Martin Costello of Tombstone. He was willing to sell for $500,000 and Douglas was willing to take a bond at that price provided he could explore the property by extending the underground workings of the Copper Queen mine, whereas Costello insisted that the work be done from the surface of the Irish Mag, so that he could have a shaft in case the deal fell through. When these negotiations failed, in 1901, the Irish Mag was purchased by a group from Michigan and Pennsylvania in the name of the Lake Superior & Western Development Company, which later became the Calumet & Arizona Mining Co., the leaders of which were the Hoatson Brothers, Thomas F. Cole, George E. Tener, Chester A. Corigdon, and Charles Briggs. This company subsequently acquired additional territory and eventually became one of the leading producers of copper in the Southwest. Litigation over apex rights would have ensued between this company and the Copper Queen if Douglas had not possessed the sagacity to arrange with his neighbors to waive any extralateral rights in favor of the common law, whereby each company waived any claim to ore in depth that was vertically outside its side and end lines. At the same time an agreement was made giving each company free access, for information, to its neighbor's underground workings. This not only ensured peace but also the opportunity to become informed concerning discoveries of ore, all of which redounded greatly to the prosperity of the district, and to the esteem in which Dr. Douglas was held by his fellow-engineers.

Only oxidized ores were worked by the Copper Queen until 1893, when converters were added to the smelting plant. As early as 1886 a film of matte floated on the bars of copper and the quality of the metal suffered so much that the direct method of smelting had to be abandoned, whereupon matte was made; and reduced in the converter. In 1908 the mine began to produce some lead, and in 1916 some zinc. Since those dates, the district has produced over 312 million pounds of lead and over 366 million pounds of zinc. Gold, amounting to over 1.9 million ounces and silver amounting to almost 81 million ounces, have also been produced by the district since operations began.

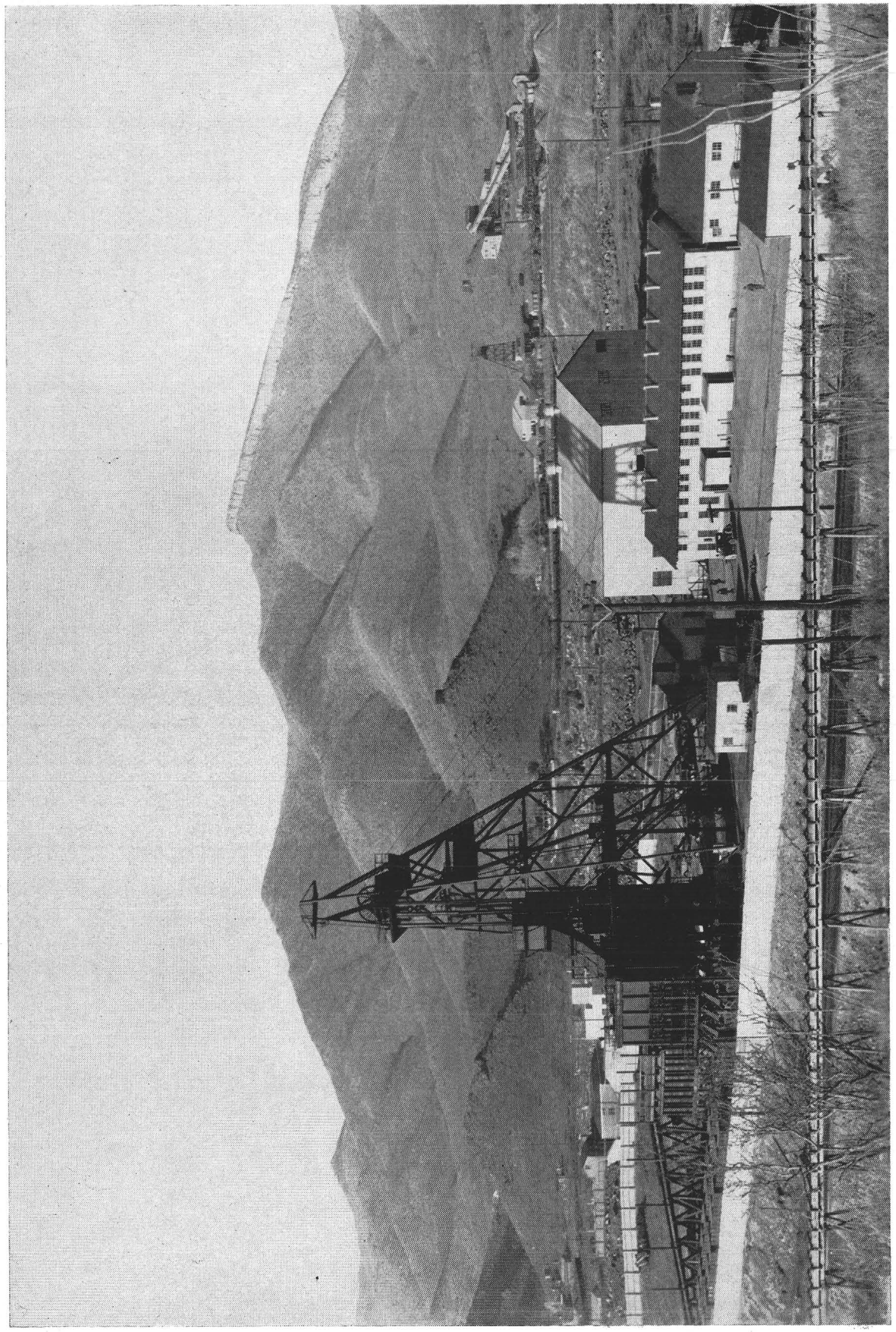
*The first smelter of any importance was erected at Fairbanks on the Southern Pacific Railway, 37 miles northwest of Bisbee; and for several years ore was packed thither on mules and burros. In 1888 a railway was built by the mining company from Bisbee to Fairbanks, but in 1900 plans were made for the new reduction works at Douglas, and the El Paso and Southwestern Company, controlled by the Phelps Dodge interests, constructed the necessary railroad. The Copper Queen smelter at Douglas went into operation in 1904, being supplied principally by the Copper Queen mines with rich carbonate ores of smelting grade until 1932.

The blowing-in of the smelter in 1904 was a milestone in the company's history. From a single water-jacketed cupola no higher than a man, its smelting plant had now grown into the most modern structure of its kind in the world. Containing five blast furnaces and four barrel-type acid-lined converters, the new works covered three hundred acres with a fifteen mile network of standard gauge railroad tracks connecting smelter, power houses, machine shops and foundry. It was built to handle a production of more than a hundred million pounds per year, but through the years it was constantly enlarged to meet even greater demands upon it. This camp became a thriving town—and in honor of the man who had done so much to develop copper mining in the southwest, it was named Douglas.

In 1917, the name Copper Queen Consolidated Mining Company was changed to the Phelps Dodge Corporation and the assets of Phelps, Dodge & Co., were transferred to the new corporation.

When the other porphyry mines began to cut an important figure in the copper-mining world, the attention of Dr. Douglas and his associates was naturally drawn to the large mass of granite or monzonite porphyry which had intruded into the limestone, in past geologic eras, and with which had been associated the copper-bearing solutions that were responsible for the formation of the rich limestone "replacement" orebodies. As early as 1909 exploration of the porphyry intru-

* Parsons' "The Porphyry Coppers."



Campbell shaft, Bisbee, 1943.

STORY OF THE UNITED VERDE AND THE UNITED VERDE EXTENSION

According to the Phelps Dodge Corporation's Annual Report for 1951 there were then only a few months more life in the United Verde Mine which, at the time it was owned by Senator Clark was probably the richest mine that was ever worked under individual ownership. From the date of its purchase by William A. Clark in 1888 to the end of 1935, the mine had yielded 20,346,000 tons of ore, from which 1,979,105,400 pounds of copper have been extracted, together with 971,735 ounces of gold and 34,358,390 ounces of silver. The gross value of this output, after transportation, refining and marketing, was slightly more than $350,000,000. This indicates an average grade of better than 17 dollar ore, and the United Verde Mine ranks among the "bonanza" mines of the State, as distinguished from the "low-grade porphyry" mines.

History*

The United Verde Mine, the chief mine of the Jerome or Verde Mining District, is at Jerome, in Yavapai County in north-central Arizona. Jerome is on the northeasterly slope of the Black Hills. The mean altitude is about 5,200 feet, and the smelter towns of Clarkdale and Clemenceau are in the valley about 2,000 feet lower. The Verde Tunnel and Smelter Railroad connects Jerome with Clarkdale, which is on a branch of the Santa Fe.

The first mining claim to be located in the Jerome District was that of Albert Sieber, a noted Scout, in 1877; he named it the Verde because of the green carbonate stain. However, Al Sieber located none of the original United Verde claims. The first claims in the original United Verde group were located on February 17, 1876, as follows: Venture No. 1 North by John O'Dougherty, John P. Kelly and Josiah Riley; Venture No. 1 South by Edward O'Dougherty, John D. Boyd and A. B. O'Dougherty. By 1880 the district had acquired fame enough so that the Phelps Dodge Company sent Dr. Douglas to examine it. He reported that there was a little copper ore, but the long 175-mile wagon haul to the Santa Fe Railroad discouraged him from recommending exploitation. During these early days the United Verde Mine was worked on a small scale and shipments of high-grade gold-silver ore were made from the surface workings.

In the summer of 1882, Fred Thomas, a San Francisco engineer, obtained an option on the Wade Hampton and nine other claims and two millsites which comprised the original United Verde grant. The Wade Hampton had been located in 1877 by M. A. Ruffner and Angus McKennon. With the help of George Treadwell (who later developed the Great Treadwell Gold Mine in Alaska), Thomas organized the United Verde Copper Company. Its secretary was Eugene Jerome, for whom the growing town was named. The Governor of the Territory, F. A. Tritle, maintained an active interest in the company until Clark took over in 1889. Thomas built a fifty-ton furnace and turned out nearly $800,000 worth of copper in the first year, and paid $62,000 in dividends.Then the price of copper dropped and the mine had to shut down. Even 20 or 30 percent ore was of no value in such a remote camp when copper sold for less than 10 cents a pound.

Dr. Douglas visited the United Verde a second time in 1887, after the first little smelter had been in production and the railroad was then only 45 miles away. He was sufficiently impressed with it to enter into negotiations for an option. The terms he offered were opposed by Charles Lennig, the principal creditor of the United Verde, and in January 1888, the deal went on the rocks. In the same month W. A. Clark took his option.

In 1888, W. A. Clark came down from Butte with his smelter man Joe Giroux. Clark took a lease on the United Verde and bought it the following year. The development work he carried on soon proved that the 10 to 20 percent copper glance ore was two hundred feet wide and six or eight hundred feet long.

In 1894 Clark built a twenty-seven mile narrow-gage railway to connect with the new Santa Fe running south from Ash Forks to Prescott. With a new smelter and roast heaps like those at Rio Tinto to burn the sulphur out of the ore, the United Verde was soon one of the great copper mines. As the grade of ore dropped with increasing depth of the mine, new equipment and larger tonnage kept up the yield of copper and the profits. In the thirty years before he

* Rickard's "A History of American Mining."
Paper by Louis E. Reber Jr. in Arizona Bureau of Mines, Bull. No. 145.
Joralemon's "Romantic Copper."
H. V. Young, longtime employee of the old United Verde Copper Company and Phelps Dodge Corporation.

is unique among the Porphyries, and that is the process of heap-leaching. Heap-leaching itself consists essentially of: (1) piling run-of-mine ore on a gently sloping hillside to form a bed; (2) "irrigating" this heap with slightly acidulated water; (3) collecting the water (which, in percolating through the heap, has acquired a burden of copper in the form of a solution of copper sulphate) in a pond at the foot of the bed; (4) passing the pregnant solution over scrap iron to precipitate the copper; and (5) collecting and drying the mudlike precipitate of "cement copper" to be fluxed and melted to produce comparatively pure metal. A distinctive feature of the process is that the foregoing sequence of operations is repeated for a particular section of a heap with long intervals intervening during which the sulphide minerals oxidize by contact with atmospheric oxygen. The consequence is that a period of years is required to effect a satisfactory extraction, a features that militates against wider utilization of the method.

Ever since early in 1900, experimentation and research have been devoted to the heap-leaching of Bisbee waste dump and low-grade ore piles in the district, and a considerable amount of low-cost copper has been produced by the process.

Zinc-Lead Deposits

Records of the earlier mines of the Bisbee district show that zinc and lead occured throughout the district in areas mined for copper. The zinc and lead production of Bisbee since 1939 has come largely from the Eastern part of the district, particularly the Campbell and Junction areas. Near the borders of the Campbell copper orebody, sphalerite[1] and galena[2] become increasingly abundant.

The deposits vary greatly as to size, shape and mode of occurence, but in general they may be classified as follows:

Deposits peripheral to barren siliceous-pyritic bodies.
Deposits intimately associated with, or peripheral to, rather massive pyrite-copper ore bodies.
Deposits associated with porphyry.

The Phelps Dodge Corporation annual report for 1951 has this to say regarding the lead-zinc ores at Bisbee:

"During the year, the change-over from
Deposits along structural breaks.
lead-zinc ores to the mining of copper ores as the major source of production was brought to completion. This changeover was started in the previous year as a result of the exhaustion of lead-zinc ores of importance. The tonnages mined in 1951 totaled 490, 184 tons of copper ore and 40,426 tons of lead-zinc ore."

Conclusion

For 42 years, until 1932, the Copper Queen Company relied on smelting ores from its carbonate mines to produce its copper, but since 1927, the Porphyry ores—milling and leaching—have contributed the preponderant proportions of the output. The absorption of the Calumet & Arizona Company by Phelps Dodge in 1931 gave the Corporation enormous proved bodies of ore of direct smelting grade, and there is the ever present possibility of finding still further bonanzas in the famous old district.

1 Sphalerite – Zinc Sulphide – 67.1% Zn and 32.9% S.
2 Galena – Lead Sulphide – 86.6% Pb and 13.4% S.

STORY OF THE MAGMA MINE

Since the Magma Copper Company began operations in 1910 to the end of 1956, the Magma mine has produced a total of over 11,000,000 tons of all classes of ore, from which 1,200,000 pounds of copper have been recovered. The ore mined averaged better than 5.6 percent copper and contained 2.1 ounces of silver and .032 ounces of gold per ton. A total of 70 million pounds of zinc have been recovered from 806,440 tons of copper-zinc ore, included in the total tonnage mentioned above.

History of the District and Early Development[*]

The Magma mine is situated in the Pioneer (Superior) mining district, Pinal County, Arizona, approximately 70 miles southeast of Phoenix and 21 miles west of Miami. Superior is served by a 30-mile standard-gage railroad which connects with a branch of the Southern Pacific R. R. at Magma, Arizona. The elevation of the mine is about 3,500 feet.

The discovery in 1875 of the Silver King mine, one of the famous old Arizona silver producers, first attracted attention to the Superior District. The Silver Queen, which later became the Magma, was located in the same year about three miles south of the Silver King. In the early days the Queen mine was worked for silver, which was, however, associated with considerable chalcocite. The Magma Copper Co. was organized in 1910 by William Boyce Thompson and associates. This company has maintained nearly continuous operations to the present time. It built a railroad and a concentrator in 1914 and completed its smelter in 1924. The mine, which has reached the 4800-foot level is now the deepest in Arizona. The constant high tenor of its ore has made the Magma one of the low-cost producers of the United States, despite depth, temperature and heavy ground.

Previous to 1910, the underground work at the Magma mine consisted of a shaft sunk to the 400 foot level, where small isolated bodies of high-grade ore were developed and stoped. From 1910 to 1914 the shaft was sunk to a depth of 800 feet, and active exploration started on several levels. The first important bodies of ore were discovered on the 600 and 800 foot levels during this period.

An electric power line was completed by 1914 connecting the Magma mine with the power line from Roosevelt Dam, by way of the Inspiration Mine. Early the same year a 2-compartment winze was sunk from the 800 to the 1,000 foot level where a high-grade bornite ore body was discovered. In 1915 a narrow-gage railroad was constructed to serve Superior and was changed over to the present standard-game road in 1923. Before the smelter was completed in 1924, the concentrates had been transported to Hayden for smelting.

The concentrator, first built in 1914, was kept up-to-date through the years, with research and remodelling, and since 1948 the Magma Company has had a real gem of a mill capable of handling up to 1,500 tons of ore per day, and is sectioned to treat copper ore and copper-zinc ore separately.

After about 1902 the Lake Superior and Arizona Mining Company drove the Carlton and Holt tunnels and sank a 1400-foot incline in ground between the Magma vein and Queen Creek. Copper ore, containing some silver and gold, was produced in 1907 and during World War I. Since 1920, the ground has been owned by the Magma Copper Co. In 1932 T. D. Herron and C. Laster leased the mine and opened large bodies of gold ore. Their production during 1932 to 1937 inclusive, as stated in the annual reports of the Magma Copper Company, amounted to 56,649 tons of ore which yielded 372,420 pounds of copper, 53,162 ounces of silver, and 31,598 ounces of gold.

Since the beginning of operations in 1910, the Magma Copper Co., has done the following work, according to its 1956 Annual Report:

Drifting and Cross-Cutting	Raising	Sinking	Total
343,438 ft.	143,302 ft.	30,646 ft.	517,386 ft.

The Company has also done 193,371 feet of churn drilling and 73,795 feet of diamond drilling.

Geology, Ore Deposits and Mineralization[*]

At the Magma Mine the rocks are essentially the same as at Ray. The oldest formation, the Pinal schist, has been penetrated by the 3,600 foot level of the Magma mine. There it is unconformably overlain by conglomerate, quart-

[*] Arizona Bureau of Mines Bull. No. 145, by M. N. Short and Eldred D. Wilson. U. S. B. M. Information Cir. No. 6168 & 7300 by Fred Snow and Ed J. Caldwell.

[*] Arizona Bureau of Mines Bull. No. 145, by M. N. Short and Eldred D. Wilson. U. S. B. M. Information Circular No. 6168, by Fred Snow.

A crushing plant at the north end of the smelter, adjacent to the filter plant, is used to handle direct-smelting ore, silica ore and lime-rock, which are hauled from the mine by the Magma Arizona Railroad in 50-ton cars. Cleanings from the converter aisle of the smelter are also crushed here.

There are four parallel bedding bins, each with a capacity of 2,300 tons. They are fed by conveyor belts, equipped with automatic trippers. Conveyor belts deliver the bedded material to a storage bin from which the west charge is transported to the furnace in cars. Roasting was discontinued in September, 1949.

The reverberatory furnace is 100 feet in length and 22 feet in inside width, with over-all height of 13 feet 11 inches. The bottom 4 feet is filled with crushed silica. The side walls are built of silica brick 27 inches thick for the first 5 feet 10 inches, 22½ inches thick for the next five feet, and 18 inches thick for the remainder of the height. The furnace is shut down every 2 years, of whenever the entire arch has become too thin.

The charge per shift is usually 160 tons of ore and concentrate 10 to 15 tons of silicious fettling material. The matte, which has a grade of 32 to 34 percent copper, runs through a semi-circular cast-iron launder into matte ladles of 12 tons capacity. A 40-ton crane carries the ladles to the converters. The slag runs into a launder built of crushed silica, then into a semi-circular cast-iron launder to the moter-dump 17-ton cinder cars on tracks below. They are hauled by a trolley locomotive to the slag dump south of the smelter.

The converting plant consists of two 12-foot Great Falls converters lined with 15-inch magnesite brick. Silicious converter flux is fed to the converter from a hopper above it. The converter slag is poured back into the head end of the reverberatory furnace. The finished copper is transferred by a 12-ton ladle from the converter to the casting-machine; which casts the copper into bars which are loaded into railroad cars for shipment back east to a refinery. The bullion bars contains 99% copper, and about 27 ounces of silver and .65 ounces of gold per ton.

Conclusion

Although the Magma mine is included among the few bonanza mines of the State, along with the United Verde, the U. V. X. and the Copper Queen, the profitable operation of the property has demanded the highest quality of management and engineering skill. General Manager Wesley Goss has received loyal and efficient co-operation from his entire organization.

The ventilation problem has involved the expenditure of over a million dollars, and has taxed the brains of the company's engineers. Being the deepest mine in the State, safe mining methods and practices had to be employed. Fire hazards had to be guarded against, and the expenditures for such measures were by no means small.

With twelve hundred men on its payroll, the Company had to provide suitable living conditions for its employees. The town of Superior, with an estimated population of 5,000, is almost entirely dependent upon the Magma mine for its economic existence. The taxes which the Company pay support an excellent school system. Labor relations have always been amicable and still are. The Company's annual reports to its stockholders are most informative. Its financial statements and reports of property development are quite complete. Among other things, the 1956 Annual Report had this to say:

"The stockholders of the Company at a special meeting held October 15, 1956, acting upon the recommendation of the Board of Directors, increased the authorized capital stock of the Company from $12,000,000 consisting of 1,200,000 shares of the par value of $10 each, to $30,000,000 consisting of 3,000,000 shares of the same par value.

On December 3, 1956 the Company paid from its current earnings a five per cent stock dividend, being one share for every twenty shares held on November 2, 1956. The issuance of 57,367 shares in payment of the dividend increased the shares outstanding from 1,147,337 to 1,204,704 shares. Under the San Manuel loan agreement with the Government no cash dividends may be paid without the Government's consent. No cash dividend in any case could be contemplated in 1957 as the Company must continue to conserve its cash for the planned capital expenditures, needed working capital, and provision for debt retirement."

nection with the ventilation system; No. 6 on the eastern end of the property and No. 7 on the western end, both to the 2,550-foot level. The No. 8 has been sunk to below the 4,800-foot level.

All permanent workings are driven in the country rock. Haulage drifts, usually are driven in the footwall of the vein. Experience has shown that a pillar at least 60 feet thick between the footwall drift and the vein is desirable.

Most of the ore mined above the 800-foot level was stoped by the rill or "inclined cut and fill" method. Later the timbered rill and a combination rill stope and pillar system have been employed. Haulage is by trolley and storage battery locomotive on an 18-inch gage track.

The mine is in high temperature rock, and the company has installed the best mechanical ventilating system they could devise. Also every precaution against fire is employed. In addition, a squad of men is trained in standard mine-rescue practices and is available at all times. Mine safety work is in charge of a safety engineer who has organized workmen's committees who make regular safety inspections of all working places.

Milling[*]

The first mill was constructed in 1914 and had a rated capacity of 150 tons. It was designed for gravity and flotation concentration using Wilfley tables and the old style deep-bottomed Callow cells. The first Marcy mill to be put to commercial use was installed at this time for coarse grinding. A Chalmers & Williams tube mill was used for fine grinding. The flotation concentrates from an Akins classifier, dropped into a storage bin. A freight wagon was used to haul the concentrates to a platform scale near the narrow-gage railroad. High-grade ore sorted from a picking belt in the mill also was hauled to the scale. Here the ore and concentrates were loaded on the narrow-gage cars and hauled to Magma, where transfer was made to the standard-gage cars of the Arizona Eastern R. R. for transportation to the smelter at Hayden.

A second section, capacity 50 tons, was built in 1915 for treating lead-zinc ore. It ran for about three months on this kind of ore and then was changed over to treat copper ore.

In 1921 and 1922, a third section was added and the capacity brought up to 600 tons.

After the smelter construction was completed in 1924, the system for pumping the concentrates from the mill to the smelter filter plant was installed.

* U. S. B. M. Information Circulars 6319 and 7300.

In August, 1928, a 4-foot Symons cone crusher was installed replacing two 24 inch Symons horizontal disk crushers. The crushing time for 700 to 800 tons of ore was reduced from 10 to 12 hours to 8 hours or less; and the jaw opening of the Blake crusher was increased from 2 to 3½ inches.

The milling ore during the first fifteen years of operation averaged about 7% copper, .037 oz. gold and 3.48 oz. silver.

The fresh water supply was obtained from the mine and stored in a 600,000 gallon old tailings pond.

In 1936, the deep Callow cells were replaced by Agitair flotation machines. In 1937, a fourth section of the mill was installed to treat copper-zinc ore. This section has a capacity of 450 to 500 tons and contains two No. 66 Marcy mills which operate in closed circuit with two 60-inch Akins classifiers. The copper-zinc ore was later switched to the No. 1 Section.

The electric power supplied to the mill is either generated at the smelter by waste heat and direct fired boilers, or is obtained from the Salt River Valley Water Users' Association.

As already stated, a new concentrator was placed in operation in 1948, and is the last word in mill design, with all up-to-date features.

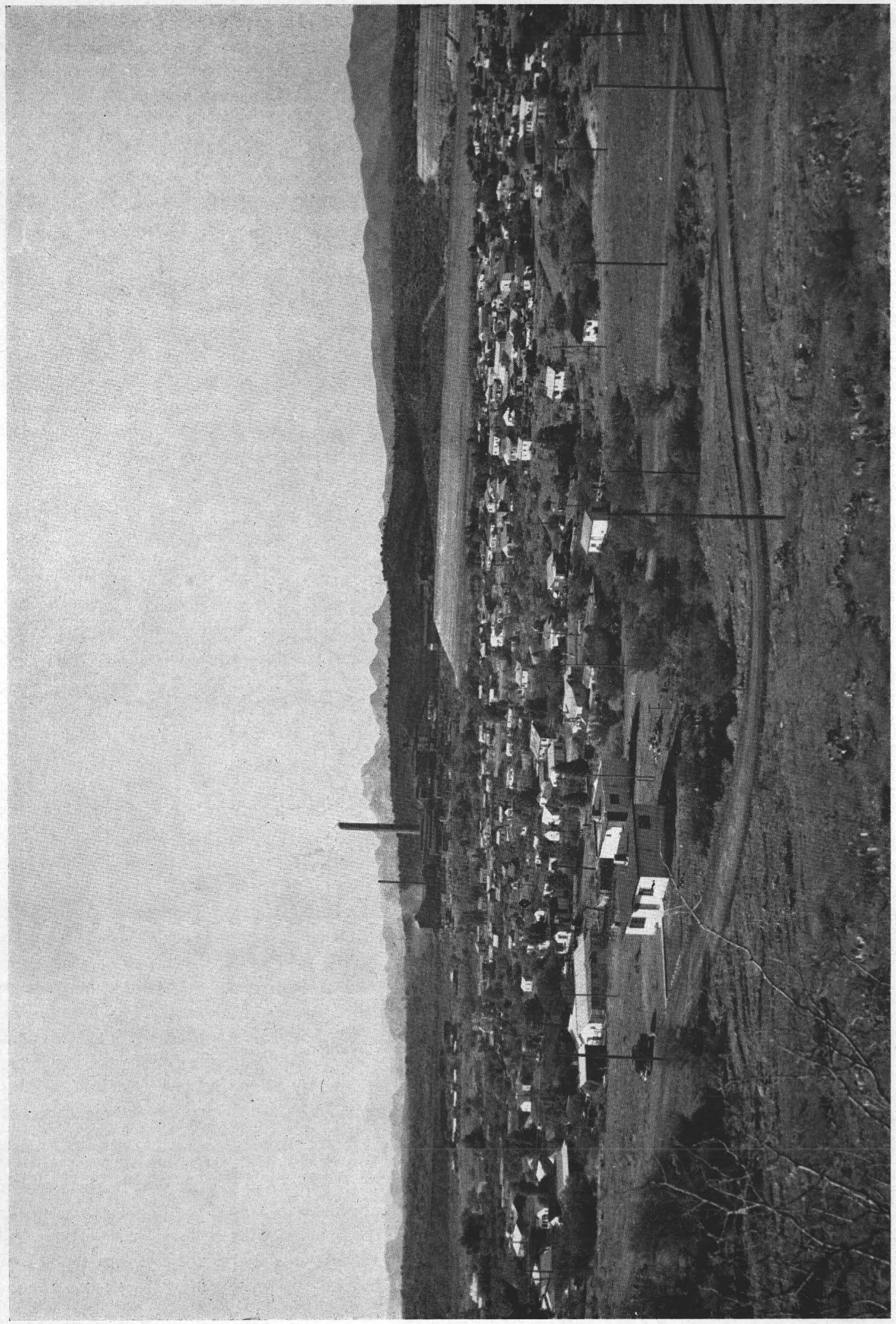
The average recovery of copper from 5% copper ore is about 97%, with a 26% or 28% copper concentrate. The copper-zinc ore averages about 1.2% copper and 8.4% zinc and a 50% zinc concentrate is filtered and shipped to Bartlesville, Okla. However, the Company has not mined its copper-zinc ores since 1952.

Smelting[*]

The construction of the smelter was begun in February, 1923 and completed in April, 1924. The original capacity was 500 tons of dry charge in 24 hours. By the addition of a sixth roaster in 1930 the capacity was increased to 600-650 tons a day.

The construction of a natural-gas pipe-line to Superior was completed January 1936, and thereafter the reverberatory furnace, roasters, direct-fired boilers, and assay furnaces were fired with gas. Fuel oil is kept in storage in case the gas supply fails.

* U. S. B. M. Information Circular No. 7300.



View of smelter and townsite, Magma Copper Company.

zite and limestone. The older rocks are intruded by large masses of diabase. The limestone and underlying formations are invaded by dikes and sills of quartz manzonite porphyry. Exploration of the Magma vein for a length of 8,700 feet and a depth of 4,800 feet has revealed three groups of ore shoots. Most of the production has come from the main or middle ore body. The west ore body was west of the Main fault below the 2,500 foot level. It consisted of copper ore now largely mined out. The east ore bodies lie between the main crosscuts and No. 6 shaft and consist largely of zinc-copper ore.

Considering the size of the Magma ore bodies, the outcrop of its veing is inconspicuous. Above the main ore body the bleached faulted porphyry dike is stained by copper and iron and locally contains small masses of residual chalcocite. The main ore body has its apex between the 400 and 500-foot levels and extends to the lowest workings of the mine. The ore shoot is of replacement type and is richest where its walls are of diabase. Commercial ore is confined to the fault zone itself.

The sinking of the No. 5 shaft between the Main and Concentrator faults disclosed an ore body in the Magma vein that extended from 100 feet above the 2,250-foot level to approximately 100 feet below the 2,500-foot level. It was fifteen feet in width and averaged 7 percent copper, principally as bornite, and is known as West Ore Body.

Several small ore shoots have been found in the Magma vein east of the main crosscuts between the 1,600 and 3,200-foot levels. Their ore is principally sphalerite, but copper minerals are locally abundant.

On most levels, bornite[1] is the principal mineral, although in places chalcopyrite[2] predominates. Pyrite[3] is abundant with the chalcopyrite, but less so where bornite is the dominant mineral. Above the 1200-foot level, the western branch of the main ore shoot contains no copper minerals but consists of sphalerite[4] and galena[5]. Below that level it changes abruptly into a bornite-rich ore with little or no zinc and lead. Tennantite[6] is important from the 1,200 to the 3,600-foot level, where enargite[7] takes its place in the western part of the ore body. Deep level chalcocite[8] accounts for about 5 percent of the copper in the lower levels of the main ore body. There it invariably occurs intergrown with bornite.

1 Bornite — Copper — Iron — Sulphide 63.3% Copper.
2 Chalcopyrite — Copper — Iron Sulphide 34.6% Copper.
3 Pyrite — Iron Sulphide 46.7% Iron.
4 Sphalerite — Zinc Sulphide — 67.1% Zinc.
5 Galena — Lead Sulphide — 86.6% Lead.
6 Tennantite — Arsenical Copper Sulphide — 57.5% Copper.
7 Enargite — Arsenical Copper Sulphide — 48.4% Copper.
8 Chalcocite — Copper Sulphide — 79.8% Copper.

Mining[*]

As stated before, the No. 1 shaft had been sunk to the 400-foot level before Magma Copper Company took it over. The small isolated bodies of high-grade ore were probably mined by the square-set method, but as the workings were inaccessible at the time Magma took over the property, the method used is not known.

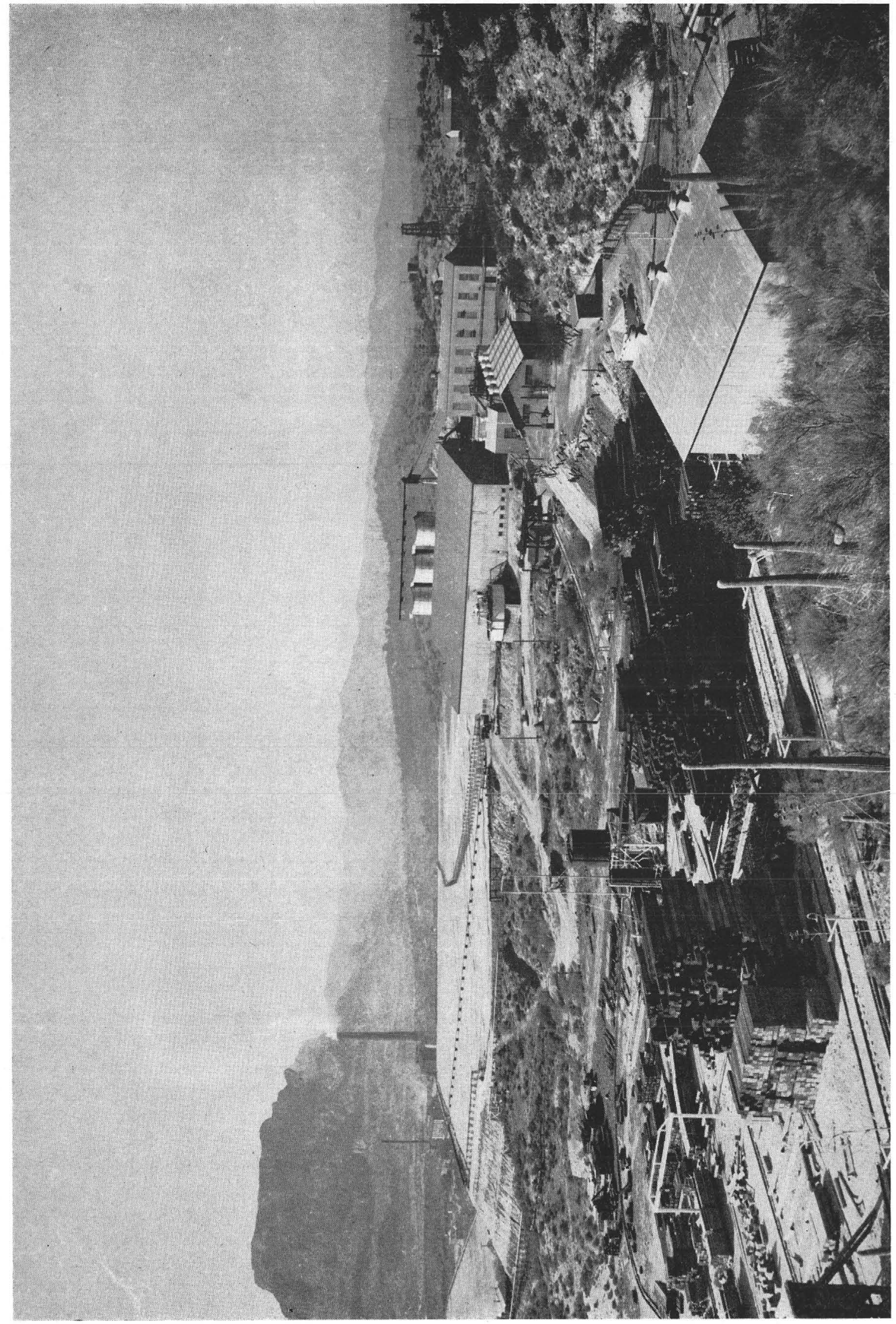
Early in 1914 a 2-compartment winze was sunk from the 800 to the 1,000 foot level where a high-grade bornite ore body was discovered. This winze was later enlarged to three compartments and became a part of No. 2 shaft.

By the end of 1916 No. 2 shaft had been sunk from the 200-foot, the main adit level at that time, to below the 1,600-foot level. A double drum electric hoist was installed underground on the 200 level. In 1917 a second working shaft to the lower levels became necessary. As the 2-compartment No. 1 shaft was in bad condition near the 100 level due to the early stoping operations, it was decided to sink a new 3-compartment shaft (No. 3). By the end of 1919, both No. 2 and No. 3 shafts had been sunk to below the 2,000-foot levels; also the 500 adit had been connected to all shafts, and was used for the main outlet of the mine. At present, the portal of this adit is connected with the various parts of the surface plant by means of a standard-gage railroad system.

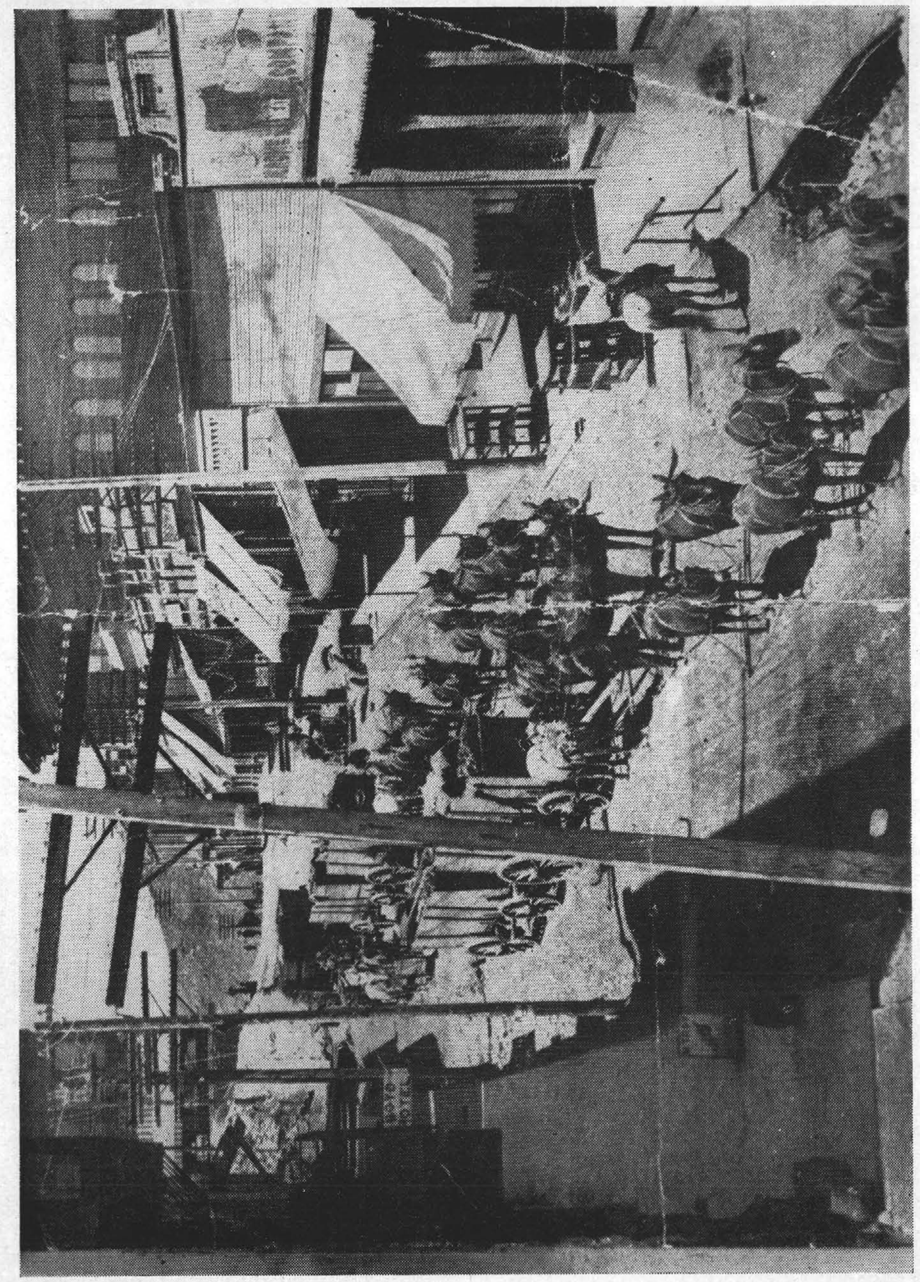
In 1919 No. 4 shaft was started from the surface to be used as the main outlet for the ventilation system. In 1921-22 No. 2 shaft was sunk below the 2,250-foot level. Development work was pushed on the 1,800 and 2,000-foot levels, and a large body of ore blocked out, sufficient to warrent the building of a smelter and increasing the capacity of the concentrator to 750 tons per day. These improvements were completed early in 1924.

For the economical operation of the western part of the mine, No. 5 shaft was begun in 1926 and completed to below the 2,960 level late in 1928. It connects with a short adit on the 500 level. It has since been sunk to the 4,800-foot level. No. 6, 7, & 8 shafts have been sunk in con-

* U. S. B. M. Information Circulars 6168 and 6319.



View of mine plant and concentrator, Magma Copper Company.



View of Jerome about 1900.

died, Senator Clark made $60,000,000 out of the mine that Thomas had bought with so much difficulty for $50,000.

The smelter which Clark built was unfortunately placed over the mine workings and became endangered by the settling of the ground; moreover, the site was inadequate for the desired expansion of the plant. In 1912, the building of a new smelter was started in the valley, at Clarkdale. It was completed in 1915. At this time the Santa Fe built a branch of standard gage to this point. 1919 marked the beginning of open-pit operation. In 1931 the United Verde purchased the Verde Central and in 1935 the Phelps Dodge Corporation purchased the United Verde.

The development of the United Verde Extension Mine, beginning in 1899, makes a story in itself, and it has been very interestingly told by T. A. Richard in his "History of American Mining." The data for this story was obtained from Ira Joralemon's "Romantic Copper." Joralemon was given credit by Rickard for having recommended the venture to Mr. James Douglas (the son of James Douglas of Copper Queen fame), and Major A. J. Pickrell.

*Just below the "Big Hole" (United Verde Mine) is a great fault. The rock east of this Jerome fault had slid down toward the Verde Canyon for half a mile. As a result, the limestone and lava that were laid down on an ancient erosion surface long after the orebody was formed are high up on top of the mountain west of the fault and of the United Verde, and far down toward the canyon east of them. Under these comparatively recent rocks east of the fault, the older schist that contains the ore is buried six hundred feet deep. The fault cut off the greatly enriched top of the United Verde orebody, together with the enclosing rock, and slid it two thousand feet down an equal amount to the east. Erosion then exposed the roots of the ore west of the fault. The former top of the orebody, now east of the fault, remained safely covered and hidden by the limestone and lava. The dip of the fault was to the east, under claims owned by George Hull, a Jerome Pioneer. In 1899, he formed the United Verde Extension Mining Co., and induced a New York broker, named Louis Whicher, to sell a lot of stock and to sink a shaft through the lava on the Little Daisy claim.

* Joralemon's "Romantic Copper."

In the next twelve years Whicher and his associates raised and spent nearly half a million dollars on the Verde Extension. Only a few streaks of ore resulted from the investment and the Little Daisy was finally shut down.

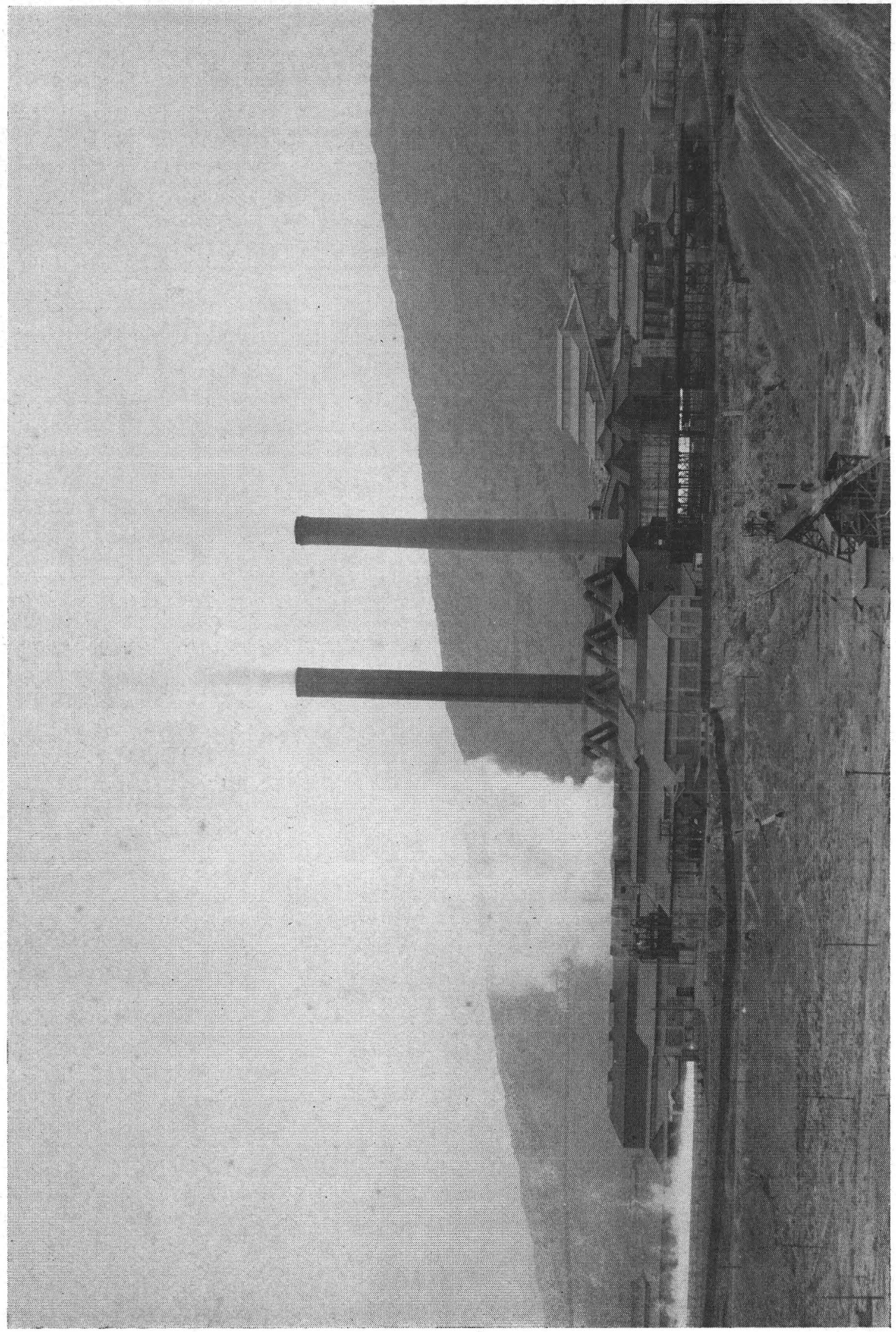
Among Verde Extension's stockholders was a fine old southern gentleman, Major Andrew Jackson Pickrell, who still had faith in the property, and persuaded his friend James S. Douglas to become interested in it. The latter, with his friend Geo. Tiner of Pittsburgh, sent an engineer to examine the Verde Extension. It was recommended as a good gamble, and Douglas and Tiner started development. $200,000 went into the ground with no results. They decided to risk another hundred thousand. Two years after they started work, a crosscut on the 1,200 foot level found five feet of 45 percent copper glance, and they started to sink again.

In 1916, after a four-year campaign of development, the fourteen hundred level electrified the mining world by cutting 300 feet of 15 percent ore. It was the faulted top of the Great United Verde orebody and its richest spot. A vertical side-line agreement with the old company prevented a complicated apex suit that might have ruined the Verde Extension. Under Clark's very nose, Jim Douglas and his friends took out over 42 million dollars in dividends. The ore-body was finally exhausted in 1938.

Rickard paid the following glowing tribute to James S. Douglas for the part he played in this successful venture:

*"Many of the richest mines in the world have been the cause of great financial loss to the public because they were over-valued on the stock exchange and their shares were bought at inflated prices. The "Bonanzas" have been as much a source of regret as the "borrascas"; the genuine enterprises, by being grossly exaggerated, have done as much harm to the pockets of innocent folks as the calculated frauds. The U. V. X. has been free from anything of the kind; not much stock was sold at the high quotations, because the principal holders retained their stock even when, in 1916, it went up to $52 per share. Mr. Douglas, I may add, sold none of his stock until 1928, when he sold some, most of which he bought back later. The whole business has been clean from start to finish; it has justified the claim of Agricola that "mining is a calling of peculiar dignity."

* Rickard's "History of American Mining", p. 379.



General view of Clarkdale smelter in 1938.

As initially constructed, the mill consisted of two units consisting of 8'x12' ball mills and mechanical flotation machines. Hunt flotation machines were also used experimentally. Auxiliary thickeners, classifiers and pumps were employed in each unit of the plant, and the capacity of the plant varied from 1,000 to 1,600 tons per day, depending upon the degree of grinding required.

The ore treated usually contained about three percent copper, and consisted chiefly of the schist ore, and at times the massive. Lime was used in the mill to neutralize deleterious soluble ore salts and for pyrite depression. Although an extraction of over 91 percent of the copper was obtained, constant experimenting and research were carried on by a competent metallurgical staff.

The concentrate, after filtering, and containing about 15 percent copper, 5 percent silica and 30 percent iron, was conveyed to the roaster-charging conveyor system of the smelter. The latter, built at Clarkdale in 1915, had a capacity of 5,000 tons of ore a day. It consisted of a crushing plant and sampler; a calcining plant of 21½ foot Wedge furnaces with dust chambers and a Cottrell precipitating plant, six 100 foot reverberatory furnaces; four 48x320 inch blast furnaces; seven stands with eight shells of Great Falls converters; and necessary pumps and compressors. The smelter has been described by L. A. Parsons in Mining & Scientific Press Oct. 16, 1920 and June 25, 1921.

Conclusion

Mining operations were terminated at the United Verde Branch on March 23, 1953. The United Verde Mine had produced over two and three quarter billion pounds of copper, which with gold and silver values, was worth about 475 millions of dollars. The U. V. X. Mine has produced over three-quarters of a billion pounds of copper, which, with gold and silver values, was worth over 125 millions of dollars. Of course, most of this grand total of six hundred million dollars was turned back to the state and nation in the form of wages, purchase of supplies, and taxes. However, probably one hundred and twenty-five million dollars was the profit returned to the investors, or a little over 3½ cents per pound of copper produced. For the seventy years of production, this was a return of less than two million dollars per year. With a probable capital expenditure of twenty million dollars for plant and development, the average return for the investment was less than ten percent, which can be considered only a fair return on what at many times must have been a hazardous proposition.

April, 1957

Aerial view of Jerome in 1935.

Ore Mineralization**

***"The United Verde ore zone, as developed in the United Verde Mine, consisted of a very irregular pipelike body of massive sulphide and rock. In plan the mineralized zone ranged from more than 500,000 square feet to less than 300,000 square feet, with an average of near 400,000 square feet. The massive sulphide itself had an average cross section of approximately 250,000 square feet. Pyrite, quartz, carbonate minerals, and some sphalerite (locally insignificant quantity) formed the sulphide gangue. Black chlorite rock (black schist), with some quartz porphyry, is the predominant rock gangue. The mineralization is very clearly of the replacement type. Although other sulphides were present, the copper content of the ore as a rule depended on the abundance of chalcopyrite with about one-seventh of the volume of the mineralized zone as commercial copper ore."

The ore zone in the U. V. X. Mine probably represents a segment from over 2,000 feet above the top of that exposed in the United Verde Mine. Probably a large part of the chalcocite ore was a fairly good grade before enrichment. As in the highest levels in the United Verde, there was probably a smaller-than-average area of mineralization, with a higher-than-average proportion of chalcopyrite. The intensity and extent of the secondary enrichment in the U. V. X. Mine formed an almost unique deposit of chalcocite that placed the mine in the front ranks of high-grade copper mines.

Mining, Milling* and Smelting

Several methods of underground stoping have been employed in the United Verde mine: horizontal cut-and-fill, incline cut-and-fill; square-set and fill, shrinkage and fill, and glory hole. In 1918, open-pit operation was started, and was completed in 1940. Since then, underground mining was employed chiefly in removing the pillars left in the mine.

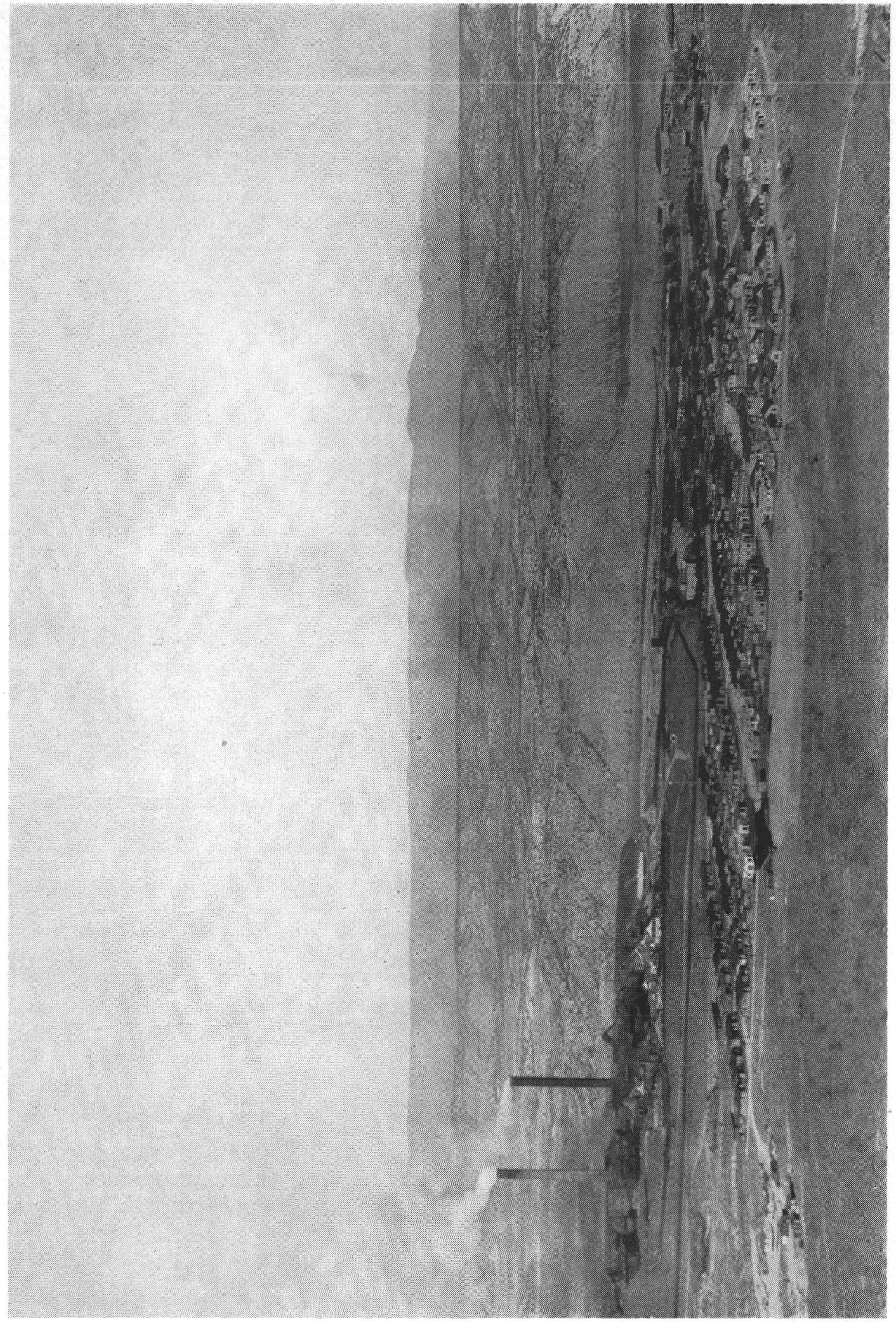
The system of ventilation was complete and modern and has been fully described by Tally in his paper on mine fires. Owing to several expensive mine fires it was found necessary to devote much attention to this subject. One fire, on the 400-foot level, burned for over twenty years. Mining in the fire zone was conducted under the plenum system, by which air under pressure is introduced into the workings. As far as possible the fires were isolated by bulkheads. In order to reach the burning sulphides, steam shovels were introduced in 1918 to remove 15,977,807 cubic yards of overburden, which permitted the mining down to the 600-foot level of some 9,708,923 tons of ore said to average 3.47 percent copper, 2.07 ounces silver and .07 ounces gold.

Most of the copper-bearing mine water was formed during the progress of natural surface drainage through the oxidized zone and through old filled stopes above the 500-foot level. Before and during early Pit operations these waters were the source of profitable copper precipitate. All ore hoisted through the No. 5 shaft was dumped into storage bins above the 1,000-foot level. Trains of 40-ton ore cars were hauled an average distance of 8,900 feet through the Hopewell tunnel to a crushing plant which was originally at the tunnel's mouth but later moved to Clarkdale near the new smelter.

A concentrator, designed by H. Kenyon Burch and United Verde's chief engineer, J. E. Lanning, was constructed near the crushing plant, and began operations in 1927, handling 1,000 tons of ore per day. The general location of the concentrating plant was such that tailings could be delivered by gravity through a pipeline to a very desirable location for tailinggs disposal. The plant was also located favorably with respect to all services such as railroad, water, power and the like. The Verde Tunnel & Smelter Railroad, owned by the corporation, hauled the ore from the Hopewell Tunnel, a distance of six miles to the crushing plant. The water supply had its source in springs, artesian wells, and a tunnel under the Verde River. Power was available from the smelter power plant, the generators therein being operated on waste-heat steam from reverberatory furnaces. The smelter power system, however, is interconnected with the Arizona Power Co.

The primary breaking was done by 48"x36" jaw crushers, followed by 48" vertical disk crushers and 56"x24" rolls crushing to minus ¼" size. The maximum size piece of ore received at the crushing plant was about 17 inches. The product of the Jaw crushers was minus 4-inch size, and of the disk crushers minus 1-inch size. Conveyors and elevators were used throughout the plant for transporting the ore to each machine.

** L. E. Reber's Article in Arizona Bureau of Mines Bull. 145.
*** Paul Yates.
* Milling method described by Kuzell & Barker in U. S. B. M. Information Cir. 6343.



General view of Clarkdale smelter and townsite taken several years ago.