COPPER MINING IN ARIZONA

Before going into the economics and the practical aspects of copper mining, perhaps we should try to describe what copper looks like before it is mined and converted into the red metal which you see every day in copper wire, copper pennies, copper utensils, etc., etc.

First of all, copper very rarely occurs in its native metallic state. By far most of the copper produced in Arizona is found combined with sulphur, or iron and sulphur, and is a grayish black mineral appearing in little specks or veinlets in the rock of the earth's crust. The copper ore mined in the large mines of Arizona looks for all the world like ordinary rock that you would pick up on a hike in the mountains. Sometimes you can hardly see the copper mineral with the naked eye. In addition to the black specks of copper sulphide which are the chief source of Arizona copper, there are brassy-yellow specks of copper-iron-sulphide, and also green and blue carbonates of copper, which account for the green and blue copper stains you see on the surface of good mining properties. They are the result of the oxidation of the sulphides by surface waters containing carbonic acid.

Of course there are really scores of varieties of copper minerals, but copper sulphide has been the chief mineral, and the basis of the copper mining industry of Arizona. At various times, the carbonates and silicates of copper have accounted for a goodly production of copper. Lately,with improvements in the technology of leaching, the recovery of oxidized copper has been increasing.

In the last three years, 1956-1958 inclusive, Arizona has been producing copper at the rate of over 500,000 tons of copper per year, or nearly one-half the total U. S. production. And when you consider that over ninety percent of this production was from the large low-grade copper mines of Morenci, Inspiration, Miami, Ajo, San Manuel, Silver Bell, Bagdad, Bisbee, Pima and Ray, you will appreciate that here is an industry that is not depleting the natural resources of the state, but is actually creating wealth from the millions of tons of worthless rock in mountains of scenic value only.

The developed ore in none of these mines now averages more than sixteen to eighteen pounds of copper to the ton; that is, in every two thousand pounds of rock there are less than eighteen pounds of copper. Enormous plants had to be built to extract this metal from its containing rock.

Over three hundred millions of dollars had to be spent on these low-grade mines before they began to produce copper and return a profit to the investor. It took vision and courage, as well as capital to convert these large copper deposits into profitable enterprises. It was a fortunate thing for the state and nation that this copper was developed, for without it, one wonders whether this republic could have survived the last two World Wars. Now the use of copper in the electrical and electronics industries is increasing every year.

The Magma Copper Company in the past few years has developed a stupendous ore-body at the San Manuel Mine in Mammoth District of Pinal County, and this is a prime example of the conversion of worthless rock to copper metal. Over one hundred million dollars had to be spent and many years of work and planning done

before a dollar's worth of copper was taken out of this mine. There are less than fourteen pounds of recoverable copper in each ton of ore, and it needs no more than ordinary sense to appreciate the utter worthlessness of this rock as it existed in the ground. Brains and capital had to be combined to create wealth out of this property.

Before the big, copper producing properties were developed, they were 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, remained in business long after the twenty years were past. In some cases additional drilling on the fringes of developed ore-bodies showed many years supply of what would have originally been classed as waste, but with new processes, became ore.

The block caving of large bodies of copper ore was developed in Arizona by Louis S. Cates when he was manager of the Ray Mine, and it proved to be a relatively cheap method of mining ore. However, in recent years, with the war and all, experienced miners have been rather scarce, due to the younger men not being attracted to this relatively hazardous occupation. It has therefore resulted in more and more open-pit mining, which requires less men and more machines. Here the use of forty and fifty-ton trucks has simplified the transportation problem, and many of the large open-pit mines of the state have made successful use of them. In many cases, they have spelled the difference between profit and loss, for the low copper content of the ore leaves a very small margin to work on.

After the ore is mined, a large plant is needed to crush and free the metal from its enclosing rock. It is then concentrated by the use of especially developed processes which discard the worthless portion of the rock and collect the copper into a high-grade concentrate. The early method of concentration was to crush and grind the ore by the use of gyratory or jaw 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 copper 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. 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. Even when the tables were followed by endless corrugated rubber belts, known as vanner belts, some slimed copper was lost, The result was usually a recovery of less than 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. 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, making a 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 same 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 less than seventy percent to as much as eighty-five or 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 one and one-half to two percent was the yardstick for ore classification the measure has been gradually reduced to less than one percent. Some mines today treat ore containing only 12 pounds of recoverable copper per ton.

Other metallurgical or mechanical improvements used in improving copper concentration have been the substitution of cone crushers, rod mills and ball mills for the more inefficient gyratories, rolls and chilean mills. They have resulted in finer grinding and the freeing of additional copper for flotation. Substitution of other chemical reagents for oil hasalso been a factor in the improvement of the flotation process. Lime has been used to coat pyrite particles with a film which inhibits their floatability, thus raising the grade of concentrate.

Where the principal copper mineral has been oxidized copper instead of sulphide, such as in the overburden of the New Cornelia mine at Ajo, the copper has been recovered by leaching with sulphuric acid, and then precipitated electrolytically. The sulphide ore underneath was given the regular flotation and smelting treatment. Both processes have been eminently successful, and have made New Cornelia one of the most successful mines in the state.

Where the oxide and sulphide copper minerals have been more or less equally divided in the ore, such as at Inspiration, the ore has been treated by leaching both the oxide and the sulphide by the use of ferric sulphate and sulphuric acid, followed by electrolytic precipitation. Inspiration has practiced this operation very successfully for over thirty years, but recently, on account of the predominance of sulphide copper in the ore, especially, chalcopyrite which is insoluble in ferric sulphate, the company has adopted what they call a "dual process". They first leach the ore with sulphuric acid, precipitate the copper solution electrolytically. The leached tailings are concentrated by flotation and then smelted. This has resulted in better copper recovery than usually obtained by the average copper mine which recovers a very small part of the oxidized copper usually present in the ore.

The Ray mine of the Kennecott Copper Corporation has developed a special process for additional recovery of the oxidized portion of its ore in conjunction with the recovery of the sulphide portion. It is called the Leach Precipitation Flotation process (or L.P.F.). The process involves the production of sponge iron and sulphuric acid from the pyrite which up to recently

had been rejected in the mill tailings. The acid is used in dissolving the oxidized copper in the ore, and the sponge iron is used to precipitate the dissolved copper; the resultant precipitated copper is floated in the mill circuit.

The smelting of the concentrate follows the flotation process. Here the smelting is done in two steps: reverberatory furnace smelting of the concentrate to further separate the heavy copper mineral from the lighter minerals that are still attached to it, and producing a "matte" consisting chiefly of copper, iron and sulphur, and a "slag" which is tapped off the upper portion of the molten mass and taken to the slag dump in trains of dumpable ladles; the second step is conversion of the molten matte to blister copper by burning off the sulphur and adding a flux to combine with the iron into what is known as converter slag, which is returned to the reverberatory furnace for re-treatment. Although the blister copper is more than 99% pure, it still has to be refined electrolytically, which separates the precious metals, leaving practically pure copper for manufacturing rods, wire, sheets and other copper products.

Gold and silver are heavy metals which have been attached to the copper throughout all the processes, until it is electrolytically separated.

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 big copper producers of Arizona have taken Federal lands on which no taxes were being paid, and have put them on the tax rolls, thus contributing to the state tax revenue.

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 among the highest paid wage earners in the State, and he spends practically all of his earnings within the State. The railroads get the major portion 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 the 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 big low-grade copper mines in Arizona are located at Morenci, Ajo, San Manuel, Ray, Inspiration, Miami, Bisbee, Silver Bell, Bagdad, Pima and Esperanza. The last two are located about 20 miles south of Tucson.

Higher grade copper mines are the Copper Queen at Bisbee, and the Magma at Superior. Worked-out high-grade copper mines were the United Verde and United Verde Extention at Jerome.

There are eight copper smelters: two at Hayden, one at Douglas, one at Morenci, one at Ajo, one at Miami, one at San Manuel, and one at Superior.

Arizona has no electrolytic copper refineries which recover gold and silver by refining. Inspiration has a small electrolytic copper refinery, but it does not recover gold or silver in the process. Arizona's blister copper is refined at El Paso, Texas and at refineries on the East Coast, Maryland, New Jersey and New York. Other refineries are located at Tacoma, Washington, Great Falls, Montana and Garfield, Utah.