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 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 operations 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 sampling.

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 Seeley 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 8000 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 7000 feet. It ranges in width from about 200 feet at the center to over 2000 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

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

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 p ermeable to the ore solutions, downward flowing waters that had picked up copper in the oxidized 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 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.

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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.

Concentration

Because the prpposed 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 R. R. A subsidiary of the Ray Consolidated Copper Co., called the Ray and Gila Valley R. R. 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 Co., 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 8000 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 f ine 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, 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 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.

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 benefited, 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 daily tonnage of the latter was reduced to 5000 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.

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 account for the production of a half-million to a million pounds of copper monthly.

Improvements such as the open-pit development, additions to the concentrator, and power development, cost the Company over five million dollars in the last three years. 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. 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 $15,600,000 in churn-drilling, shaft-sinking, driving underground workings, 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 problemswere 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. It took years to exhaust this oxidized ore and produce the clean fresh ore on which the project's success depended.

The Kennecott Copper Corporation's reports do not segregate the Ray Mines' financial operations from the combined operations of the company's huge holdings, but statements of the Arizona Division, published by the Arizona State Board of Equalization, give the following record of the earnings since 1939 of the Ray Mine, before depreciation and depletion:

1939	$ 1,126,340
1940	2,101,903
1941	3,360,758
1942	3,318,697
1943	2,241,742
1944	1,487,021
1945	1,499,513
1946	1,301,005
1947	1,934,234
1948	1,629,410
1949	Loss 435,100
1950	2,657,455
Total Earnings	$ 22,222,978

The total production of copper, gold and silver since the beginning of operations by the Ray Consolidated Copper Co., in 1911, through the year 1951, were as follows:

Net Pounds Copper	1,989,139,635
Net Ounces Gold	23,521
Net Ounces Silver	1,330,006
Total Tons Ore Mined	81,428,176

Prior to 1939 the Ray Mine had paid an estimated 28 million dollars in dividends. Assuming that 17 million dollars were distributed out of the 22 millions in earnings listed above, a total of 45 million dollars would be the dividend from the Ray Mine in 40 years of operation. This would be seven 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 300 million dollars) which has been created out of this tiny section of Arizona, it is truly a fabulous tale.

Arizona Department of Mineral Resources

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