THE STORY OF THE BAGDAD MINE

The Bagdad Mine is the smallest of the low-grade copper mines in Arizona, but today, with about 20,000,000 tons of 0.9 percent copper ore in reserve, and with reserves expanding, Bagdad is making plans to more than double its present facilities. Bagdad had gone through almost 40 years of mining by various methods with indifferent success, until, under the direction and management of E. R. Dickie, it adopted modern open-pit mining and up-do-date concentration methods, and became a successful producer. Recent articles in the Mining World for September, 1951 and March, 1952, have been the source of this story of the successful conversion of low-grade copper rock to copper metal now so sorely needed for this country's defense effort.

Location and 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 camp is on Copper Creek, a few miles upstream from its junction with Burro Creek, at an altitute of about 3,200 feet.

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, a tailing-disposal line, and a road from Bagdad nearly to Hillside.

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 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 orebin, and conveyor system to carry crushed ore from the 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.

Geology and Mineralization*

A conspicuous 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 mineralized 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 east 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

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* Arizona Bureau of Mines Bulletin # 145, by Butler and Wilson.

copper in the ozidized 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 percent.

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 Bagdad Canyon. Ore, waste and low-grade are broken by 7" churn drills, loaded by electric shovels. Trucks carry sulphide ore to the pit crusher-plant, from where it is carried by a long belt to the mill proper. Trucks carry low-grade oxide ore to extend the downstream side of the new tailing dam; there it will be acid-leached at some future date. Trucks carry barren waste (mostly Gila conglomerate overburden) to a waste disposal area about 3/4 of a mile northeast of the pit.

The Bagdad pit is a testing ground for haulage equipment. Three makes (five models) of rubber-tired haulage units are running an endurance test against one another, with a close cost-accounting record being made on each unit. Since truck pitting began, Bagdad has cut its mining cost by 40 percent, more than doubled production.

Crushing and Concentration

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 percent. This close pH control also involved additional controls of density and initial ore feed. The company's metallurgist, 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

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 3/8 in. 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 1/2" - oversize of bottom screen to a cone crusher set at 3/8". Product of 1st cone crusher over a 3/8" screen with oversize back to grizzly. Product of 2nd cone crusher and undersize of both screens to any of four 1950-ton orebins. 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. Any surplus water (over and above daily requirements) is pumped into Marooney dam.

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. Co. copper smelter at El Paso. The thickened cleaner concentrate is sometimes treated before filtering, to recover 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 9,000 tons daily, and to install a plant for concentrate wasting, acid production, calcine leaching, precipitation, and electrolysis. It promises to make Bagdad one of the major copper producers of the United States.