STORY OF THE MAGMA MINE

Since the Magma Copper Company began operations in 1910 to the end of 1951, the Magma mine has produced a total of 8,823,770 tons of all classes of ore, from which 946 million pounds of copper have been recovered. The ore mined averaged better than 5½ percent copper and contained 2.2 ounces of silver and .033 ounces of gold per ton. A total of 61,132,027 pounds of zinc have been recovered from 736,275 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-gage road in 1923. Before the smelter was completed in 1924, the

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* Arizona Bureau of Mines Bull. #145, by M. N. Short and Eldred D. Wilson

U. S. B. M. Information Circular #6168 & 7300 by Fred Snow and Ed J. Caldwell

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 1500 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 silverand gold, was produced in 1907 and during World War 1. 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 1951 Annual Report:

Drifting	Cross-Cutting	Raising	Sinking	Total
200,002 ft.	94,491 ft.	114,906 ft.	29,425 ft.	438,824 ft.

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 3600 foot level of the Magma mine. There it is unconformably overlain by conglomerate, quartzite 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 monzonite porphyry. Exploration of the Magma vein for a length of 8,700 feet and a depth of 4800 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 2250 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 vein 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 hasits 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

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U. S. B. M. Information Circular #6168, by Fred Snow.

2250-foot level to approximately 100 feet below the 2500-foot level. It was fifteen feet in width and averaged 7 per-cent 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 1600 and 3200-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 1200 to the 3600-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.

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 1600-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.

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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

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

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 2250-foot level. Development work was pushed on the 1800 and 2000-foot levels, and a large body of ore blocked out, sufficient to warrant 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 2960 level late in 1928. It connects with a short adit on the 500 level. It has since been sunk to the 4800-foot level. Nos. 6, 7, & 8 shafts have been sunk in connection with the ventilation system; No. 6 on the eastern end of the property and No. 7 on the western end, both to the 2550 foot level. The No.8 has been sunk to below the 4800 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 locomotives 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 oldstyle 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 wasmade 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.

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

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

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 or 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 isobtained 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 and 17% copper concentrate are produced. The zinc concentrate is filtered and shipped to Bartlesville, Okla.

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 in 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.

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 limerock, which are hauled from the mine by the Magma Arizona Railroad in 50-ton cars. Cleanings from the convertor aisle of the smelter are also crushed here.

There are four parallel bedding bins, each with a capacity of 2300 tons. They are fed by conveyor belts, equipped with automatic trippers. Conveyor belts deliver the bedded material to a storage bin from which the wet charge is transported to the furnace in cars. Roasting was discontinued in Sept. 1949.

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* U.S.B.M. Information Circular #7300.

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 5 feet, and 18 inches thick for the remainder of the height. The furnace is shut down every 2 years, or 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 motor-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-toot 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 contain 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 United Verde and Copper Queen, the profitable operation of the property has demanded the highest quality of management and engineering skill. The ventilation problem alone has involved the expenditure of over 1,000,000 dollars, and taxed the brains of the company's engineers. Being the deepest mine in the state, safe and efficient 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 over eleven 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 4300 is almost entirely dependent upon the Magma mine for its economic existence. The taxes which the Company pays support an excellent school system. Labor relations have always been amicable and still are. The Company's annual reports to its stockholders are the most informative of all corporation reports. Its financial statements and reports of property development are quite complete. Among other things the 1951 Annual Report had this to say:

> "No dividend was paid in 1951, it being necessary to continue the cash-conserving policy in order to make repayments of the borrowed funds and to finance San Manuel.
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> The average net operating cost of producing copper in 1951 was 17.84 cents perpound. This cost includes all operating costs, profit or loss of the Railroad Company, Arizona taxes, Federal Social Security taxes, and amortization of prepaid development, and after deducting gold, silver and zinc credits, but excluding

depreciation, depletion, and federal income and excess profits taxes. The comparable cost for 1950 was 14.61 cents per pound. This increase of operating cost resulted from the lower grade of both the copper and zinc ores mined, and from large increases in labor and supply costs.

The company received for all copper produced in 1951 an average price of 24.15 cents per pound, as compared with 21.05 cents per pound in 1950.

Production for 1951 and for comparative purposes, for the two preceding years, was as follows:

Year	Copper (lbs)	Silver (oz)	Gold (oz)	Zinc Concts. (tons)
1949	41,003,355	371,402	11,533	--
1950	48,285,474	517,518	14,257	5,390
1951	36,934,477	491,223	10,962	12,628 "

Magma has been fortunate in having first-rate managers who have received loyal and efficient cooperation from their entire organization. In the 37 years of production, the Company has paid $21,240,313.13 in dividends to its stockholders, of whom a goodly percentage are Arizona citizens. This is equivalent to 2¼ cents per pound of copper produced, and indicates the narrow margin the mine has worked on through the ups and downs of the copper industry. It is now engaged in developing the big San Manuel Mine near Mammoth, Arizona. The San Manuel ore-body is estimated to contain at least 500 million tons of ore with a content of 0.8% copper. Plans call for mining at the rate of 30,000 tons daily, with an annual output of approximately 140 million pounds of blister copper. The Magma mine itself, however, is by no means reaching the point of exhaustion. Every year it is developing new ore of promising grade.

Arizona Department of Mineral Resources

July, 1952