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ARIZONA DEPARTMENT OF MINERAL RESOURCES

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INTRODUCTION

The "Stories of Arizona Copper Mines", published by this Department in 1957, covered the "Big Low-Grades and Bonanzas" developed up to that time. Since then, Duval Sulphur and Potash Company's "Esperanza Mine" came into production in March of 1959, and the American Smelting & Refining Company's "Mission Unit" in August, 1961.

This Department has therefore taken this means to record the story of these two new mines, which may serve as a continuation of the "Stories of Arizona Copper Mines".

Arizona Department of Mineral Resources

STORY OF DUVAL'S ESPERANZA MINE IN PIMA COUNTY, ARIZONA *

Until 1959, the name of the Duval Sulphur and Potash Company was associated with the production of sulphur in Fort Bend County, Texas, and of potash at Carlsbad, New Mexico, but in March, 1959 the Company became a large producer of low grade copper ore in Arizona, and since that time its Esperanza Mine, some 33 miles southwest of Tucson, has joined the ranks of the "Arizona Porphyries".

Test drilling at the Esperanza property began in May, 1955, and during the following two years 88 churn drill holes, 34 diamond drill holes and 2,100 feet of tunnels and raises were completed.

The old New Year's Eve mine made the first actual penetration into what is now Duval's Esperanza property. The original workings were reactivated briefly during the years of World War II. This recent effort failed to develop sufficient high grade ore for profitable small mine operation, even though traces of molybdenum mineralization were found.

By late summer of 1954, local mine interests had accumulated the 150 mining claims which cover the present ore body and adjacent areas.

Dr. Harrison A. Schmitt, consulting mining geologist, accompanied by the head of Duval's exploration team, first set foot on the Esperanza in the fall of 1954. Dr. Schmitt immediately recognized the potential of the property and contract discussions with the claim holders were begun at once.

Test hole No. 1 was started on May 8, 1955. Two years of intensive work in drilling, mapping, sampling and assaying were required before final appraisal and the decision to proceed could be reached.

Detailed metallurgical studies were conducted concurrently. Process development proceeded from the laboratory to a pilot plant. Basic flowsheet

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* The source of most of the material for this story was a brochure issued by the company in May of 1959.

drawings were prepared for the recovery of both copper and molybdenum.

A construction contract was awarded to Stearns-Roger Manufacturing Company on June 29, 1957 for the concentrator and related facilities. Pre-mining stripping operations began in November of 1957 by the Isbel Construction Company to remove 6 million tons of barren overburden to expose enough of the ore body so that routine bench mining could proceed. Both stripping and construction were completed by late February of 1959 and the first ore was fed into the process equipment.

Mining Practice

The ore body as outlined by the drilling program is roughly contained in a Sierrita Mountain foothill which is some 350 feet high and 4000 feet long. The ore body lies chiefly in three types of rocks: (1) a series composed largely of graywacke, arkose and conglomerate-breccia, (2) an intrusive andesite, and (3) a quartz monzonite porphyry. The known ore is an enriched blanket averaging about 130 feet in thickness covered by an average of 95 feet of overburden.

The mining practice is the standard bench operation typical of open pit mines. 9-inch blast holes are drilled along the bench face and loaded with ammonium nitrate explosive-with fuel oil mixture. After detonation, the shotdown face is loaded with 5 cubic yard electric shovels into 40-ton diesel trucks.

The nature of the deposit is such that waste rock must be continually removed to expose fresh ore for mining. The ratio of waste removed to ore mined, generally referred to as stripping ratio, will average about 1 to 1 over the life of the ore body. Thus, for the daily 12,000 tons of ore hauled to the concentrator, a like tonnage of waste goes to the dump. Bench heights are 35 feet with 0.5 to 1 slopes.

Careful assaying, mapping and mine planning are necessary to assure continuous daily production of ore, a low stripping ratio and a minimum loss of ore values to waste.

Milling Practice

Crushing

Mine run ore contains finely disseminated crystals of the black copper sulphide mineral called chalcocite along with lesser percentages of the so-called oxide minerals of copper. The ore itself varies in grade from 0.65 to 0.85 percent copper. Also present in addition to the copper minerals is a significant quantity of the molybdenum sulphide mineral called molybdenite. Molybdenum metal concentration is expected to average 0.022% throughout the ore body.

The first concentration problem is size reduction to unlock the mineral crystals from the mother rock and to reduce such crystals to dimensions suitable for flotation.

The mining method produces broken rock up to 4 feet in size. Primary crushing of this material is done by the 48 inches gyratory crusher which is housed in its seven-story building.

The primary crusher reduces the ore to a maximum size of 7 inches. Further size reduction is carried out in two stages by similar gyratory crushing machines of smaller sizes. Dry crushing ultimately reduces the particle size to less than 3/4 inch. This material is transferred by belt conveyors to the 20,000-ton storage bunker at the head of the concentrator. Throughout the crushing system dust collectors are used at all crushing and transfer points to prevent loss of fines and eliminate a serious house-keeping problem. Electronic instrumentation has been used throughout the system to provide maximum capacity overload.

Grinding

Further size reduction to less than 1/100 of an inch is accomplished in large wet grinding mills. Crushed ore from the 20,000-ton storage bunker is fed to two of the world's largest rod mills at the rate of 250 tons per hour each. Sufficient water is added with the feed to give the resulting pulp fluidity and the desired pulp density or percent solids.

The rod mill discharge is split to two ball mills wherein further and final size reduction is accomplished. The ball mill discharge is pumped with a slurry pump to the primary cyclone separators. These devices make a size classification and send the ore of desired fine size forward to flotation and return any oversize back to the ball mills.

These grinding mills have outside diameters of thirteen feet three inches. The rod mills are sixteen feet long and each is charged with 130 tons of steel rods. The ball mills each carry 150 tons of steel balls. These tonnages of grinding media are maintained by periodic additions equal to the weight of metal which is worn away in the grinding of the ore. The re-charging averages some eight tons of steel per day and is one of the major costs in the milling operation.

Here again in the grinding section the use of recording and control instrumentation is evident. These sensitive instruments keep a constant vigil on each phase of the section to assure maximum efficiency and reliability.

Flotation

Having accomplished the desired size reduction, next begins the important task of separating the valuable minerals from the mother rock.

The primary cyclone discharge enters the distributor-conditioners where the flotation reagents are added. These reagents, ignoring the gangue rock, selectively seek out the valuable minerals and are adsorbed on their surfaces. Once adsorbed they effectively resurface the mineral and alter the surface characteristics to one having a water repellent, air-loving nature.

From the conditioner-distributor the reagentized slurry enters the long trough-like flotation cells. The cells provide agitation such that the mineral particles are gently suspended in the water carrying medium. Air is introduced into each cell below the agitator resulting in a multitude of small bubbles rising through the suspended slurry. The reagentized minerals are attracted to the bubbles and floated to the surface of the cell. Additional reagents are added to provide a stable froth on the cell surface wherein the floated mineral collects and overflows the cell lip. Additional flotation steps are required to further concentrate the flotation product to the desired concentration - usually from 25 percent to 35 percent copper. The mother rock, unaffected by the action of flotation, moves from cell to cell down the series and ultimately discharges out the bottom of the last cell in the row.

Molybdenum Recovery

Both of the principal products, copper and molybdenum, plus a small amount of silver, are concentrated in the flotation product. The problem of separating molybdenum is one of destroying the reagents used initially to make the copper molybdenum minerals float and then reconditioning for specific molybdenum flotation.

This is accomplished by first filtering the reagent contaminated mill water from the combined concentrate and repulping with fresh water. The resulting slurry is fed to a giant pressure cooker wherein the reagents coating the minerals are distilled away. To the then sterile pulp is added a collecting reagent selective for molybdenum and flotation is again conducted. The froth product from this step is the molybdenum sulphide, while the tailing is the final copper product.

The molybdenum sulphide concentrate is then fed to the ten-hearth roaster where it is oxidized to the oxide form for sale to the metals trade.

Copper Concentrate Shipment

The final copper concentrate, the unfloated mineral from the molybdenum flotation section, is filtered and conveyed by belt conveyor to the storage house adjacent to the mill building.

Each day the accumulated tonnage is weighed into trucks for transport to the railhead some eleven miles away from the plant. At the siding the trucks dump into open gondolas for shipment to the custom smelter.

This concentrate, sold as such to the smelter, contains between 25 and 35 percent copper and three to four ounces of recoverable silver per ton.

Tailing Disposal

The mother rock waste leaving the plant presents the dual problem of ultimate disposal and water reclamation.

The magnitude of the disposal problem can be appreciated when one considers that nearly the entire 12,000 tons per day of finely ground plant feed must be disposed of every day for the life of the property. Obvious too, is the fact that if the water used to transport this waste away from the immediate vicinity could be salvaged for reuse, a tremendous saving in both money and a precious natural resourse would result.

An adroit solution to these problems has evolved through the years. In essence, it takes advantage of a gravity flow tailing line to provide feed to the tailing cyclones. The cyclones discharge their relatively coarse underflow on the top of the growing dam, and there compact. The relatively fine, clayey overflow discharges inside the dam. The fines settle out making a water tight seal against the dam and the clear water forms in a back lake for reuse in the milling process.

Instrumentation

Various types of industrial instrumentation have been used throughout the entire processing facility. Wherever possible the tasks of operating personnel have been replaced by electronic-pneumatic recording and control devices. In addition to providing process records for metallurgical study, these controlling instruments sense process upsets imperceptible to human beings and constantly react to maintain desired equilibrium. In this manner the duties of the operating personnel have been largely reduced to that of an attendant. Each section of the plant has a central station where both power and process controls have been assembled in consoles and graphic panels. The scope of each operator is expanded without sacrifice of either efficiency or reliability.

One example of applied instrumentation is in the operation of the water system:

Water System

A water supply for the Esperanza property was developed on the western edge of the Santa Cruz River Valley about 6 miles east of the mill site. Three 16 inch wells, located about 1,500 feet apart, were sunk to depths ranging from 650 feet to 900 feet. Water is pumped from these from a depth of 350 feet to a gathering tank, thence through a 16 inch steel pipe line for 30,000 feet to the mill system. The total lift from water table to the mill storage tanks is about 1,150 feet. Level control devices at the plant sense the process need for more or less fresh water. An automatic control signal is sent by radio to the water field where unattended pumps correct for the need.

Another example of the use of automatic control is in the molybdenum recovery section. Here a combination of flow, density, level, pressure and temperature measurements are integrated to maintain the desired metallurgical condition in the pressure cooker. The attendant operator functions only when process upsets and mechanical failures are beyond the range of the control devices. In such an event both light and sound alarms function to alert the operator.

TYPICAL METALLURGICAL DATA *

Tons milled per operating day	12,000
Operating time, % of possible	95.0
Copper Recovery:	
% of sulphide copper	92.0
% of acid-soluble copper	60.0
% of total copper	83.0
Molybdenum Recovery:	
Primary recovery from ore	80.0
Secondary recovery from Cu-Mo concentrates ...	90.0
Overall recovery	72.0
Grade copper concentrate:	
% Cu	25.0
% Fe	25.0
% Insol.	14.0
Grade Molybdenum Trioxide Calcine:	
% Mo	58.6
% M_oO_3	88.0
% Cu	0.25
% Fe	2.5
% Insol.	8.0
% S	0.25

* Reported in "Mining Engineering", November, 1961 by C. H. Curtis, Asst. Resident Manager, Duval Sulphur & Potash Co., Tucson, Arizona.

OPERATING STATISTICS *

Power Consumption	KWH/Ton
Crushing	1.4
Wet Grinding	12.8
Flotation	4.2
Water	0.9
Molybdenum Recovery	0.9
Total	20.2

Reagent Consumption	Lbs./Ton Ore
Lime	3.5
Potassium ethyl xanthate	0.025
Potassium amyl xanthate	0.005
Methyl amyl alcohol	0.10
Stove oil	0.03
Sodium ferrocyanide	0.05

* Reported in "Mining Engineering", November, 1961 by C. H. Curtis, Asst. Resident Manager, Duval Sulphur & Potash Co., Tucson, Arizona.

Employment

Mining is done under contract by Isbell Construction Company of Reno, Nevada. About 100 men are employed by Isbell on ore and waste.

About 235 men are employed at the present time by Duval Sulphur and Potash Company. Of these about 80 men work in the mill, and 155 men in the shops, warehouse and offices.

The Company spent about $20 million for exploration, development, stripping, and plant construction. The mine was named Esperanza, which is Spanish for Hope, by the Company's late President, Mr. George F. Zoffman.

The president of the Company is Mr. W. P. Morris, and the Company's office is in the Mellie Esperson Building at Houston, Texas. The Resident Manager is Mr. George E. Atwood, the Administrative Assistant is Mr. Ben G. Messer. There are excellent colored photos of the Company's Arizona property in the 1959 Report to Stockholders.

Production of the Esperanza Mine since inception in March of 1959 was as follows:

	Tons Copper Ore Mined	Pounds Copper Recovered
1959	3,104,530	34,106,798
1960	4,245,762	50,735,060

THE STORY OF ASARCO'S MISSION UNIT *

The new Mission Unit of American Smelting and Refining Company, which commenced operations on August 1, 1961, is now producing at its rated capacity of 45,000 tons of copper a year. This open-pit copper mine is located 15 miles southwest of Tucson, Arizona.

The Mission property was first optioned by Asarco in 1953 and exploration work undertaken. Pre-mine stripping and construction of a concentrating mill were commenced in August of 1959. This work was completed in less than two years at a cost of approximately $34,000,000, representing a substantial saving in time and money over original estimates.

During the stripping period, a total of 45,215,000 tons of waste over-burden was removed and 1,178,000 tons of ore were produced and stockpiled. The mill was designed to treat an average of 15,000 tons of ore per day, or 5,400,000 tons per year, from which approximately 165,000 tons of copper concentrates containing 45,000 tons of copper will be recovered.

These concentrates will be smelted at Asarco's Hayden, Arizona, and El Paso, Texas, plants. The resultant blister copper will be refined at its Baltimore and Perth Amboy refineries.

Geology

The Mission Unit of American Smelting and Refining Company lies in Pima County, Arizona, about fifteen miles southwest of Tucson. The area to be mined by open pit methods will cover about 250 acres, the maximum pit dimensions being approximately 2500 x 5000 feet.

The deposit lies within an extensive zone of porphyry copper type alternation-mineralization in sedimentary rocks which have been folded, faulted and intruded by monzonite porphyry. Disseminated pyrite and chalcopyrite pervade all rocks within the zone, but ore-grade copper mineralization occurs principally along certain of the sedimentary horizons, forming gentle to moderately steep-dipping tabular bodies ranging from a few feet to over 200 feet in thickness.

In the mineralized area, bedrock is overlain by approximately 200 feet of gravel wash. All but the lower 20 to 30 feet of this gravel is loosely consolidated and amenable to low-cost mining methods. In contrast, the lower portion is tightly cemented forming a hard tough layer immediately over the mineralized bed-rock.

From the standpoint of structure as well as mineralization, the ore body may be divided into three parts: east, central and west. On the east, where the grade is somewhat higher than the average, the ore-bearing beds are bounded in part by a series of northerly striking faults on which considerable movement has taken place, resulting in a horst-graben or vertically displaced structure. These faults are pre-mineral in age and have served to some extent to localize stronger copper mineralization. They also represent sharp ore-waste contacts, as, for example,

* The source of the information in this story is a brochure published by the American Smelting and Refining Company in November, 1961.

the east fault which forms the near-vertical ore limit on the east. In the north central part of the deposit, barren limestone lies at relatively shallow depths and ore grade mineralization is confined for the most part to a thin, irregular layer just above the limestone. On the west, the structure is less complex and ore mineralization is much more continuous along the bedding, but the grade is generally lower than the average for the deposit.

Although there is little variation in the ore minerals (essentially chalcopyrite with minor bornite in the primary zone, and chalcocite with some oxide copper in a thin, discontinuous secondary zone), the gangue is variable in mineralogical composition, depending on where it is found in the several sedimentary formations. Tactite (composed mainly of garnet) and hornfels (composed of various lime-silicates) comprise two of the three major ore types. The third type, argillite or siltstone is generally lower in copper content than the first two.

Development

In September, 1954, drilling was begun in part of the area. Three years later, drilling was begun in the remainder of the area. In all, 346 holes were drilled; their total length being about 200,000 feet. In February of 1958, work was started on a shaft, drifts, crosscuts and raises in the ore zone. Approximately 2300 feet of underground work was done to check interpretation of diamond drilling and obtain bulk samples for pilot mill tests. Pilot plant testing of samples were carried out at the University of Arizona to obtain metallurgical data for mill design.

Mining

It was necessary to remove about 200 feet of gravel. Several possible methods for removing this gravel overburden were studied. These included shovels and trucks, belt conveyors with drag lines, German-type excavating wheels and scrapers. The first was finally considered best because it offered maximum flexibility for placing waste in disposal areas and promised full life use of all major equipment.

The pit was designed with 50-foot benches in gravel and 40-foot benches in rock with main haulage road grades of 7%. The working slope of the pit averages 23 degrees. The ultimate slope will be 37 degrees or 1.33 to 1 in alluvial material and 45 degrees in rock, plus allowance for haul roads. Pit plans were laid out to keep at least 3000 lineal feet of ore exposed on working benches which makes the daily production rate five tons per foot of ore bench. Pre-mine stripping was planned in excess of 46,000,000 tons.

Principal Mine Equipment

5 - Electric shovels - 9 yard. 1-10-yard.
29 - Ore trucks - 55 ton.
3 - Rotary drills - 2-12¼ inch; 1-9 inch.
Main blasting agent, ammonium nitrate.

Milling

The Company's engineers planned a mill for treatment of 15,000 net tons of ore of average hardness per day, after allowing for down-time. The annual rate of 5,400,000 tons is based on 360 days at normal capacity.

Western Knapp Engineering Company was awarded the contract for construction of the crushing and milling facilities.

The primary crusher is a 54-inch gyratory with a grizzly for each of two truck dumping points. Further crushing is done in two stages with two 7-foot Symons standard cone crushers and two 7-foot shorthead Symons crushers. The final stage is in open circuit, but the plant is designed so that this can be closed merely by adding two screens.

The grinding circuit consists of four rod mills followed by eight ball mills. Because the ore varies greatly in hardness it was impossible to design grinding circuits to meet extremes at the rated tonnage so the over-all design was based on average hardness.

The rougher flotation time of ten minutes gives a good metallurgical recovery of the copper values of the ore, which are mostly in the form of chalcopyrite. Water is returned from the tailing pond and from two 275-foot tailing thickeners to keep the use of fresh water to a minimum.

Principal Milling Equipment

1 Primary crusher - 54" gyratory
Intermediate ore storage pile - live capacity, 20,000 tons
2 Secondary crushers - 7' standard Symons cone
2 Tertiary crushers - 7' short head Symons cone
Fine ore bins - live storage capacity, 15,700 tons
4 Rod mills - $10\frac{1}{2}$' x 15'
8 Ball mills - $10\frac{1}{2}$' x 15'
320 Flotation cells - Fagergren
2 Regrind ball mills 7'7" x 13'
2 Disc filters - 8'10" diameter
2 Tailings thickeners - 275' diameter
Mill water tank - 600,000 gallons capacity
2 Middlings thickeners - 125' diameter
1 Concentrate thickener - 90' diameter

Water Supply

Water is supplied from wells located near the Santa Cruz River about three miles east of the mill. The estimated consumption after return water from the tailings area is available, is 2,500 gallons per minute. Maximum requirements prior to that time are approximately 3,500 gallons per minute. Three wells 20 inches in diameter were drilled and each equipped with a 1600 gpm submersible pump. A 100,000 gal. gathering tank at wells, and 17,000 feet 18" pipe line discharges into a 600,000 gal. receiving tank at the mill.

Power Supply

Electric power for the operation is supplied by the Tucson Gas, Electric Light and Power Company over a 138,000 volt transmission line constructed from their Tucson facilities, stepped down to 4,160 volts at the mill substation.

Transportation

A six mile branch of the Southern Pacific Railroad was constructed to the property from its Tucson-Nogales line to handle shipment of concentrates and incoming freight.

Conclusion

From the first clearing of the desert's scrubby brush to the first flow of production required less than two years, bettering the estimated time by more than six months.

The Chairman and President of Asarco is J. D. MacKenzie with general offices at 120 Broadway, New York 5, N. Y. The manager of Asarco's Southwestern Mining Department is T. A. Snedden, with offices at 813 Valley National Building, Tucson, Arizona.

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