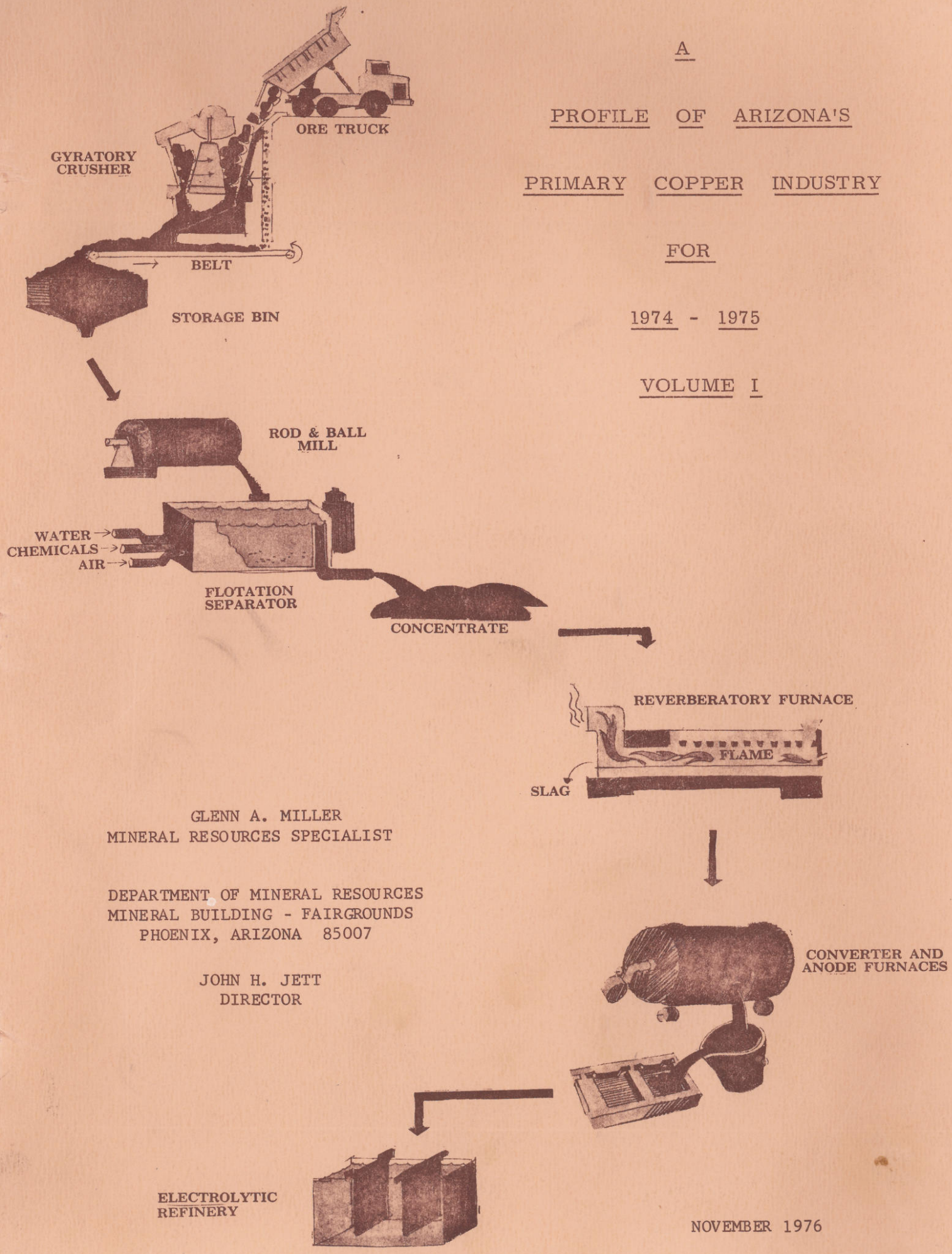
A

PROFILE OF ARIZONA'S PRIMARY COPPER INDUSTRY FOR 1974 - 1975

VOLUME I



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ABSTRACT

Arizona was the leading copper producing state through 1974-1975. In 1974, Arizona's primary copper output accounted for 54 percent of the nation's total copper production. Arizona's 1975 copper output was 56.6 percent of the total U.S. production. To maintain its distinction as the nation's largest producer of copper, the industry, in 1974, mined 178.9 million tons of copper ore which contained 1.8 billion pounds of recoverable copper. In 1975, Arizona's copper companies mined 164.5 million tons of copper ore which contained 1.6 billion pounds of recoverable copper.

Arizona's primary copper industry is comprised of 13 firms. These firms conduct copper recovery operations at one or more locations within the state. Two of the companies, Inspiration Consolidated Copper Company and Newmont Mining Corporation, have fully integrated operations (mining through fabrication) located at their Arizona properties. Three of the companies, ASARCO Inc., Kennecott Copper Corporation and Phelps Dodge Corporation, have processing facilities through the smelting phase within the state. Four of the companies, Anamax, Cities Service Company, Cyprus Mines Corporation and Duval Corporation, mine and concentrate their ores on site. The concentrates are then shipped to smelters and refineries for toll processing. These facilities may or may not be located in Arizona. Two of the companies, McAlester Fuel Company and Ranchers Exploration and Development Corporation, produce copper only by hydrometallurgical processes, i.e., electrowinning and cementation. The copper produced by cementation is smelted and refined at plants owned by other companies. One company, Hecla Mining Company, was in the development stage through 1975 and reported no production. All but two companies, Duval Sierrita Corporation and Newmont Mining Corporation, conduct some type of leaching and recovery operations at their mine sites.

Demand for copper was high and supplies were tight through mid-1974. As the recession deepened, demand for copper took a sharp downturn. Consequently, stockpiles at the producer point, within the copper pipeline, increased. Production cutbacks were initiated in the latter part of 1974.

A hoped-for upturn in demand for copper did not materialize in 1975. Further production cutbacks were initiated. Nonetheless, as in 1974, producers were unable to stem the increase in stock buildup.

In June, 1973, price controls were placed on the domestic copper industry. The price of copper was frozen at 60¢ per pound until the close of 1973 when the domestic industry was allowed to increase its price by 8.5¢ per pound. This price held until May, 1974, when the price controls were removed. At that time, U.S. producers' price rose to 80¢ per pound. Prices peaked at 85¢ per pound in mid-September, 1974. The year ended with copper at 72¢ per pound. Early in 1975 prices dropped to 63¢ per pound and remained at that level throughout 1975, except for a brief period mid-year when two U.S. producers lowered their prices to 60¢ per pound.

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I. INTRODUCTION

The Arizona Department of Mineral Resources was established in July, 1939, and since that time has compiled and reported statistical data on Arizona's primary copper industry. This data was published annually in The Copper Industry Statistics for (year) Compared With Other Years, Arizona, The United States And the World, (The Copper Report). Over the intervening years, editorial policies changed, the format of the report changed, but typically there were two sections in the report — a narrative section and a section containing the year's final statistical data. A considerable time lag exists between the closing of a calendar year and the availability of the statistical data for that year. This lag, plus the time required for writing and publishing the report, causes any narrative section on the industries' activities to be out of date by the publication's release date. To reduce this problem, a new publication policy is being adopted.

Under the new policy, this report and future Copper Reports will be issued in two volumes. Volume I will present a profile of Arizona's primary copper industry and brief statistical data. This volume will be published in late spring. Volume II will contain the final statistical tables and will be published in the latter part of the year.

The present report is a transitional volume and profiles the copper industry for 1974-1975. It includes brief statistical information for 1975. (Final statistical tables for 1974 were published by the Department in February, 1976). Volume II will contain the final statistical data for 1975.

Purpose of this Report

The purpose of this report is to present a brief non-technical discussion of Arizona's copper-producing companies.

Scope and Limitations

Only the companies' Arizona facilities which mine, concentrate, smelt, refine and fabricate Arizona's copper ores are presented in the report. The exception is the reference to Phelps Dodge's Hidalgo smelter. These parameters were chosen knowing, full well, that only one aspect of a highly sophisticated, complex industry would be covered. Limiting factors include: (1) the short amount of space allotted for the discussion of each company's separate operations. A major report could be written on each operation. (2) writing in late 1976 about activities which took place in 1974-1975. Some of this information is out-dated (3) reliance on secondary sources for all information published in this report. No personal visits were made to any of the companies discussed in this report.

Methodology

The information presented in this report was collected from many sources: companies' annual reports; Securities and Exchange Commission's Form 10-K; stock prospectus; professional journals; other published sources and personal communication.

A Preview to the Presentation

This report is structured to accomodate a varied audience. Originally, it was to contain only a profile of Arizona's copper producers in terms of their Arizona operations. This limited the range of the readership to those persons already familiar with the copper mining industry. Several new sections were incorporated into the report design to shift its focus toward those who are not familiar with the industry.

The subject matter is divided into three major sections. A glossary of mining terms is provided to alleviate difficulties related to a specialized vocabulary. A logical order of presentation is followed, however, each section of the report may be read independently.

The Background section contains brief, elementary discussions of topics that will help place Arizona's copper industry in the context of the copper-producing industry as a whole.

The second section of the report contains a review of economic and marketing factors which affected Arizona's copper production for 1974-1975. It discusses the general reasons for the copper industry's major actions during this period. Many of these actions are expanded upon on an individual basis in Section III.

Section III presents detailed descriptions of Arizona's copper producers, their operations and activities for 1974-1975. This is the section which satisfies the report title and consequently is the longest and most involved portion of the text.

II. BACKGROUND INFORMATION

This section contains general information on the copper producing industry, the end-users of copper and the pricing structure for copper.

Copper has atomic number 29; atomic weight 63.54; a melting point of 1981°F (1083° centigrade); a specific gravity of 8.93 to 8.95; a chemical valence of 1 or 2 and an electrical resistivity of 1.682 microhms/cm at 20°F. Its chemical symbol is Cu. Its name is derived from the Latin word Cuprum which in turn comes from the Greek — Cyprus or Kypros.

The Copper Producing Industry

The copper production industry is divided into two major segments - the primary industry and the secondary industry. (see Figure 1.)

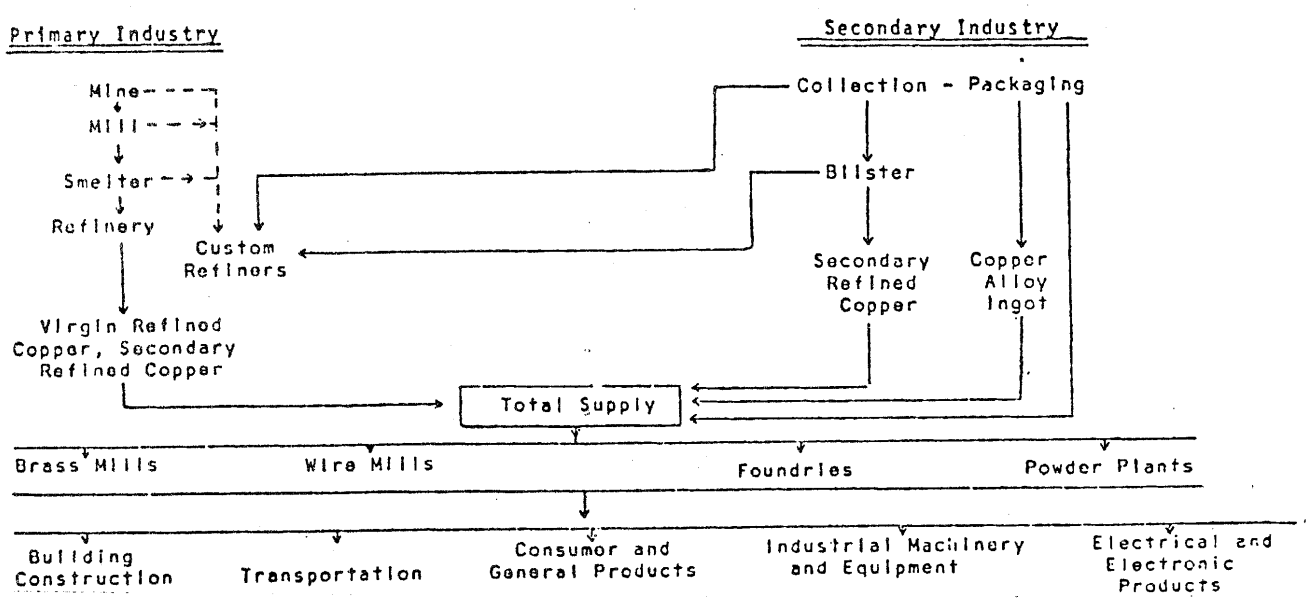

Figure 1. Primary and Secondary Industry — Flow of the Output Generated by Semifabricators
Source: Charles River Associates, Inc.

The domestic, primary copper industry supplies over half of the total copper consumed in the United States. Arizona's primary copper industry for 1974 and 1975 provided 54 percent and 57 percent, respectively, of the total U.S. production. The domestic, secondary copper industry provides approximately one quarter of the copper needed by the U.S. Imports account for the remaining quarter.

Primary Industry The primary industry produces copper from primary sources, i.e., it recovers metallic copper from copper ores. Several operations are required to produce a marketable product. These include (1) mining (2) concentrating (3) smelting and (4) refining. (see Figure 2.)

Each operational phase, after mining, is designed to increase the copper content of the resultant material from that phase. The copper content of Arizona's ore averaged 0.6 percent in 1974 and 1975, whereas the copper content of the finished marketable product was 99.99 percent.

Copper is one of the few metals that enjoys its greatest use in the commerically pure form rather than in an alloyed form. The mined ore is concentrated into a 20 to 30 percent copper product referred to as "concentrates." Concentrates are then shipped to a smelter to be further processed. The end product of smelting is blister copper which has an upgraded metal content of 98 to 99.5 percent copper. Because of the impurities, such as gold, silver, arsenic, antimony, bismuth, lead, selenium, tellurium and iron, (McMahon, 1965, p. 115) blister copper cannot be used for most applications. The amount of these impurities varies greatly, depending on the original character of the ore and the degree to which the impurities are eliminated during the smelting and converting processes. The removal of the impurities from blister copper and the subsequent recovery of these economically important metals is accomplished by electrolytic refining.

The common sequence of refining operations is: (1) fire refining of converter copper (blister copper) to produce purer and more homogeneous anodes (2) electrolytic refining of the anodes to recover precious metals and to remove impurities and (3) a second, fire refining to adjust the physical properties of the electrolytic copper for casting into shapes for use in industry (McMahon, 1965, p. 115). Refined shapes include: (1) wire bar (2) cake (3) billet (4) ingot and ingot bar (5) cathode and (6) copper powder.

The recovery of precious metals in the electrolytic refining process is of extreme economic importance to Arizona's mineral industry. The recovery of gold as a refinery byproduct amounted to approximately 91 thousand troy ounces in 1974 and approximately 82 thousand troy ounces in 1975. These figures are much more

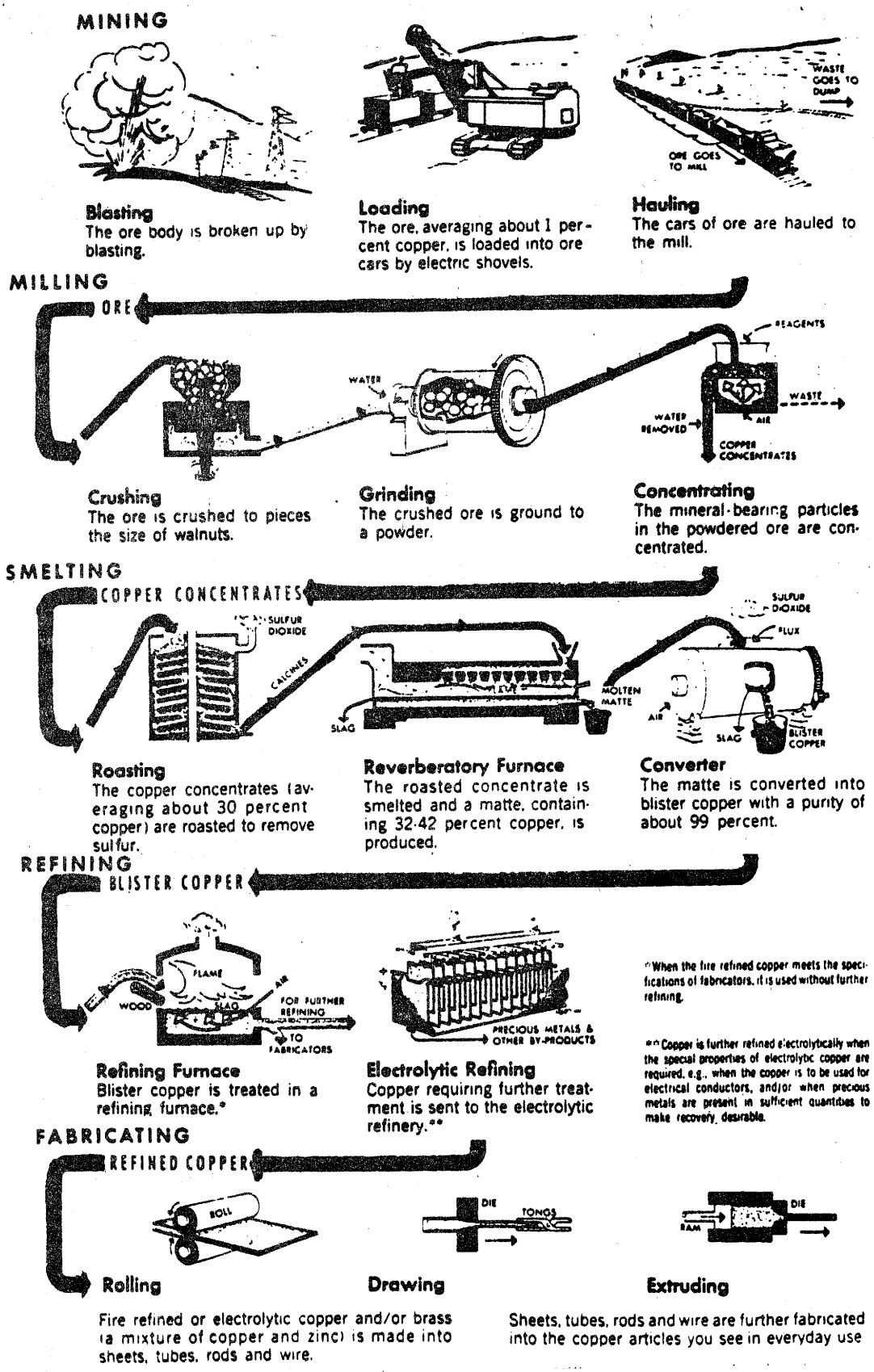

Figure 2. Basic Steps — Copper Ore to Finished Product
Source: Kennecott Copper Corporation

significant when it is realized that more than 99 percent of the recovered gold is a byproduct of Arizona's primary copper industry. As a result of this output, Arizona is the fourth largest producer of gold in the U.S. Arizona ranked second in the production of silver in the U.S. for 1974 and 1975. Again, the silver is primarily recovered as a byproduct from copper refining.

Many of the industry's large firms are vertically integrated and control their mining, smelting, refining, fabricating and marketing facilities. Some companies only mine and concentrate their ores and then ship the product to custom plants for smelting and refining (McMahon, 1965, p. 253).

The foregoing discussion applies primarily to sulfide ores. Ores or copper-bearing materials, which for reasons of grade, composition or other considerations are not amenable to concentration and pyrometallurgical (fire) extraction, are recovered by another process, i.e., leaching or hydrometallurgy.

In leaching, the copper is taken into solution from the copper-bearing material by dissolution with an aqueous solvent, generally dilute sulfuric acid. The host material is left virtually unaffected. Metallic copper is recovered from the copper-bearing (pregnant) solution by one of two methods: (1) chemical precipitation (cementation) or (2) electrolytic deposition (electrowinning).

In the cementation process, copper is precipitated out of the pregnant solution onto scrap iron, generally shredded detinned cans, or in some cases, sponge iron. The end product is called cement copper. The main disadvantage of this process is that the cement copper is only between 50 and 90 percent copper; it still requires smelting and refining to be marketed as high-grade copper.

Prior to electrowinning, a liquid, ion-exchange process is used to increase the copper concentration of the solution from which the copper is then recovered by electrolytic deposition. The advantage of electrowinning is that the end product, high-grade copper cathodes, can be marketed directly. The smelting and refining stages are bypassed.

Secondary Industry The secondary copper industry is comprised of numerous enterprises which employ many of the recovery and refining processes used in the primary industry. There are, however, processes unique to the secondary industry. (Spendlove, 1961, p. 1)

The industry recovers copper from copper scrap, copper-alloy scrap and other copper-bearing scrap materials, or from copper-bearing chemicals and compounds. (McMahon, 1965, p. 75) Scrap is classified according to two principal classes; old scrap and new scrap.

Old scrap is copper or copper-alloy products that have been used and then discarded because they are obsolete, worn out, or damaged. It is the only class of scrap which is considered a supplement to primary production for any given year. New scrap, which is scrap generated in fabricating and manufacturing semi-finished and finished products, does not supplement primary production. This scrap represents a circulating quantity of copper previously counted in the supply of primary copper. It is returned to the fabricating process without reaching the product stage (McMahon, 1965, p. 75)

End Users

Little of the copper output from primary or secondary sources is marketed directly as consumer goods. The few items that are marketed include pots, pans and decorative products. The prime market sources are generated by semifabricators which produce a variety of products for industrial users. (see Figure 1.) Copper is primarily a producers' goods, with demands for refined copper and other copper outputs being directly generated by fabricators. Refined copper is purchased by wire mills, brass mills, foundries and powder mills for the production of semi-fabricated goods. Some fabricated products include rod, wire, sheet, castings and tube. These products are marketed to industries which use them in the manufacture of consumer items or services. Wire and brass mills process the largest amount of refined copper into semi-fabricated products. In 1974 and 1975, respectively, wire mills accounted for about 67.2 and 69.0 percent of the refined copper consumed in the United States. Brass mills accounted for about 30.5 and 28.5 percent, respectively, for the same years.

Demands for semi-fabricated copper products are typically generated by five, principal economic sectors. These are (1) electrical and electronic products (2) transportation (3) construction (4) consumer and general products and (5) industrial machinery and equipment. (see Table I)

TABLE I

Ultimate end use markets of copper (primary and secondary)

Electrical 1/	52%
Construction	18%
Industrial machinery	13%
Transportation	9%
Ordnance	3%
Miscellaneous	5%

1/ Includes copper sold to other sectors that is ultimately used as an electrical or electronic product.
Source: U.S. Bureau of Mines

Pricing Structure

This section presents a very brief description of the copper pricing structure. Pricing is a complex system, and a full description of it is beyond the scope of this report.

In the United States, there are three main sources for price quotations. They are the U.S. producers price, the Engineering and Mining Journal quoted price and custom smelter prices. Of less importance are the New York Commodity Exchange price (COMEX) and the American Metal Market price. U.S. copper prices are expressed in cents per pound and are quoted for the ordinary forms of wirebars and ingots. Cathodes are priced to sell slightly below wirebar and small differentials exist for other refinery shapes.

The producers' price and the custom smelter price are set quotations which respond to supply-demand relationships. The Engineering and Mining Journal price is a weighted average historical price, calculated for a day, week, month or year, based on the sales reported by producers and their agencies (McMahon, 1965, p. 260). COMEX prices are rarely, if ever, used as a pricing medium; however, they do provide a facility for hedging as far ahead as twelve months. The American Metal Market price is the net price at New York refineries, derived from the producers quotation less an average delivery cost.

Copper scrap prices are quoted for numerous grades and specifications. "Most scrap either is purchased directly by consumers, refined by the large primary refineries and marketed by them as refined copper, or is smelted and marketed as brass and bronze ingots by secondary producers. Quotations for such ingots bear no fixed relationship to the price of copper quoted by the large producers, as the content of alloying metals and supply-demand factors have a marked influence on ingot prices." (McMahon, 1965, p. 261)

International trade in copper is essentially based on three pricing systems: (1) the quotations published by the London Metal Exchange (LME) price (2) the export quotations published by Engineering and Mining Journal (E&MJ price) and (3) the quotations by Union Miniere du Haut Katanga (Katanga quotation) (McMahon, 1965, p. 261).

III. A BRIEF REVIEW OF THE ECONOMIC AND MARKETING FACTORS THAT AFFECTED ARIZONA'S COPPER INDUSTRY IN 1974 AND 1975

This section discusses not only the economic and marketing factors for 1974 and 1975, but for 1973 as well. The events of 1974-1975 can better be understood by reviewing the industry's response to the increased consumption and speculative purchasing which occurred in 1973.

Copper utilization serves as a measure of a country's industrial development — the consumption of copper being relatively proportional to the level of industrialization. As a basic and important industrial commodity, the demand for copper responds to changes in the general level of business activity. The demand for copper can be broken down into two distinct areas, industrial use and speculative purchases.

Industrial demands are influenced mostly by the level of economic activity. Speculative demands are highly influenced by the monetary climate in the sense that copper, like most commodities, has participated in the flights from paper into tangibles during currency crisis periods. Large scale speculative buying appeared on the copper market for the first time in 1973. Both types of demand react to specific copper industry developments such as strikes, equipment problems and other factors which could prompt sudden change in market conditions and price (Conway and Trenthan, 1975). The time frame covered by this report, 1974-1975, illustrates the difficulties faced by an industry recovering from a period of industrial demand coupled with intensive speculative purchasing.

Domestic copper consumption in 1973 rose by over 6 percent from the 1972 level. U.S. mine production increased over the 1972 level, but output of refined metals, although it increased somewhat, did not keep pace with demand. Power shortages, pollution, control related technical problems and breakdowns at various plants were significant factors contributing to the failure of refined metal output to match demand.

Deliveries of refined copper far outdistanced industry production for the first two quarters of 1973; in the final two quarters, production was slightly below deliveries. (see Figure 3.) This failure of production to keep pace with deliveries resulted in an inventory downturn. Consequently, stocks of refined copper in the hands of U.S. producers, LME, COMEX and U.S. fabricators was reduced over 1972 levels. (see Table II)

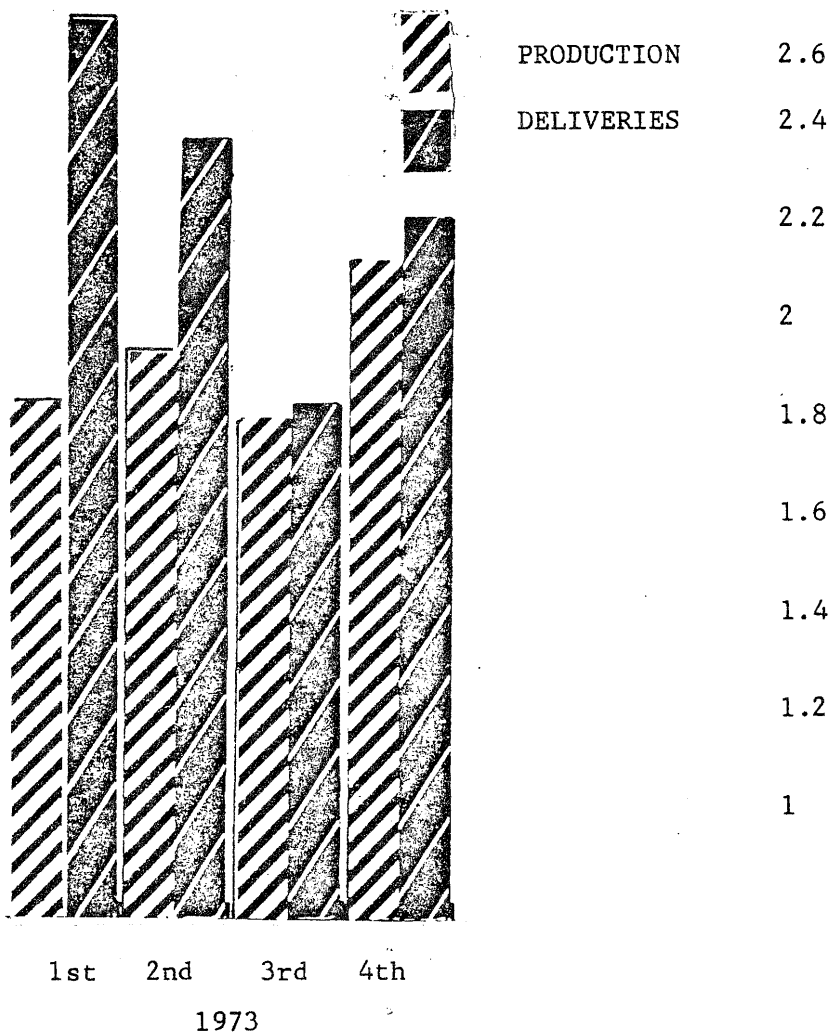

Figure 3. Quarterly Changes in Production and Deliveries

Source: Merrill Lynch Pierce Fenner & Smith, Inc.

TABLE II
STOCKS OF REFINED COPPER
(in 000 m.tons)

	End Of Year			
	1971	1972	1973	1974
Producer Stocks:				
U.S.A.	75	90	39	138
Outside U.S.A. & Japan	197	189	220	271
Japan	75	66	102	172
London Metal Exchange	140	183	35	126
Comex	18	52	5	39
U.S.A. fabricators	122	70	66	131
Total	627	650	467	877

Source: World Bureau of Metal Statistics

Prices in 1973 reflected the increase in consumption and high level of speculative buying. In fact, a special correspondent writing for Mining Journal had this to say about the extraordinary copper price situation in 1973:

> ...the present scale of speculation is another matter and its effect is not in doubt; it has sent the price of copper perhaps 200 or 300 [pounds] above the level which the present balance of market forces would justify or command, though such an estimate can never be more than a guess. What is certain is that the price would be lower without the current level of speculation.

Copper price on the LME began 1973 at 48¢ per pound. U.S. producer price started at 50.5¢ per pound. By March, U.S. producer price had reached historic heights - 60¢ per pound. LME price rose to 71¢ per pound by the middle of March. Price controls were placed on the domestic copper industry in June, freezing U.S. producer price at 60¢ per pound. Copper prices exceeded $1.00 per pound on the LME in November and continued to climb reaching nearly $1.20 per pound in early December. (see Table III). The domestic industry was allowed to increase their price by 8.5¢ per pound to 68¢ per pound at the close of 1973.

TABLE III
LONDON METAL EXCHANGE COPPER PRICES —
MONTHLY AVERAGES, 1973

Month	U.S. cents per pound	Pounds Sterling per metric ton
January	50.76	474.91
February	56.41	512.03
March	68.47	610.52
April	72.00	639.11
May	70.41	613.36
June	79.32	678.81
July	91.70	795.93
August	94.82	844.14
September	87.82	800.25
October	93.70	850.20
November	103.10	951.36
December	101.08	961.22

Source: Engineering and Mining Journal

Through mid-1974, demand for copper remained high and copper supplies were tight. This demand was partly due to the fear of strikes in July following domestic labor contract negotiations. Partly, no doubt, it was also a feedback from speculative activity in the market which did not fall off till early May. In the first quarter of 1974, production and deliveries were about even. Second quarter production dropped, mainly because of strike losses. As a result, deliveries rose over production. (see Figure 4.) As business and speculative activities began to decline in the second half of the year, copper deliveries followed suit, especially to end users, like the automobile, housing and electrical appliances industries.

Declining deliveries were paralleled by production cutbacks. However, the copper industry's pipeline is long and productive capacities increase each year. Thus, the effects of the curtailments were slow in coming which illustrates the great difficulty of rapidly reducing output to match a sudden fall in demand. The result was an acceleration of stockpiling and surpluses which were a worldwide problem and plagued the industry through 1975. (see Table II)

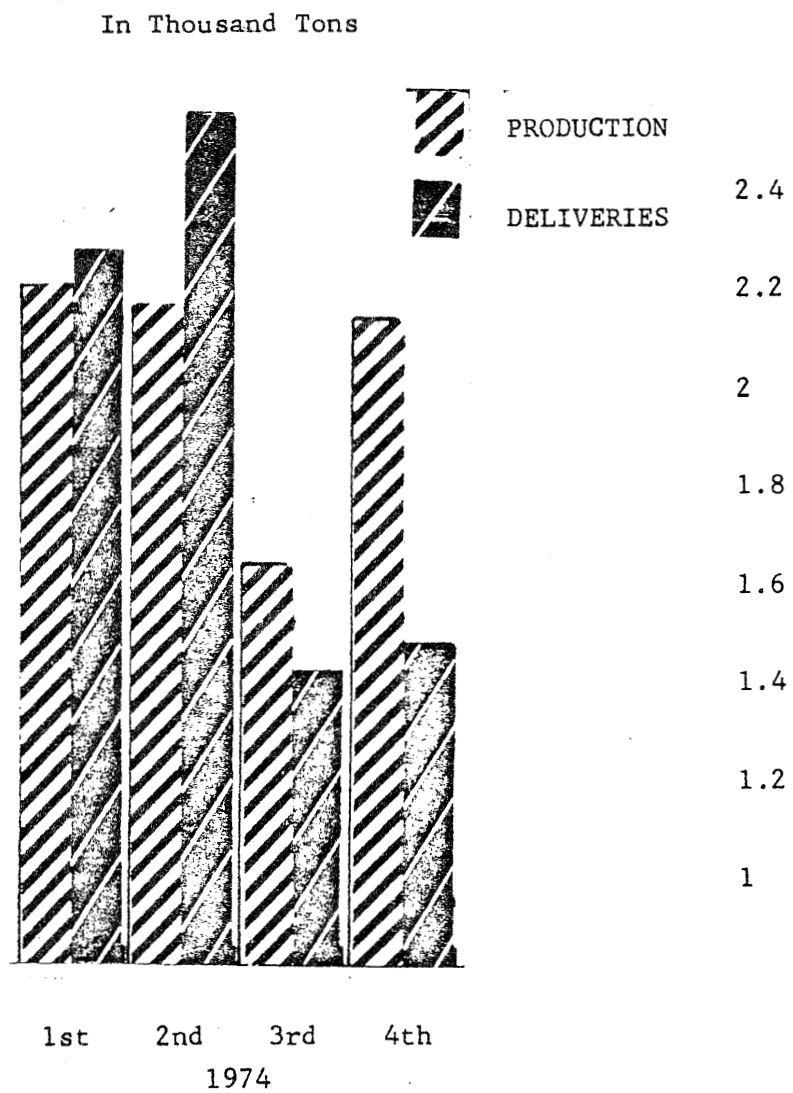

Figure 4. Quarterly Changes in Production and Deliveries

Source: Merrill Lynch Pierce Fenner & Smith, Inc.

Prices on the LME continued their upward spiral through mid-1974. The LME price peaked on April 1 at a $1.52 per pound. As one correspondent so aptly put it, "perhaps a fitting date." (Simpson, 1975) From that point on, there was a sharp downward trend to a closing quote of 56.3¢ per pound. (see Figure 5.)

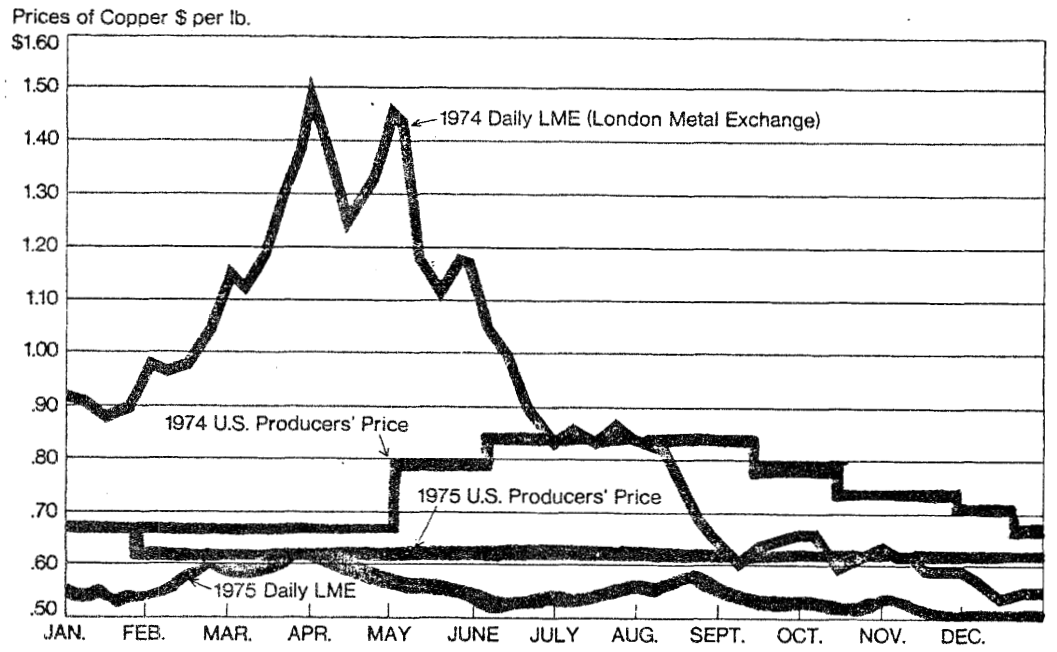

Figure 5. Copper Prices in 1974 and 1975
Source: Newmont Mining Corporation Annual Report

The U.S. producer price, which by decree of the Cost of Living Council closed in 1973 at 68¢ per pound, remained at that price until April 30, 1974. When price controls expired on May 1, U.S. producer increased their price to 80¢ per pound. That price held until early June when prices were raised to 85¢ per pound, where they remained until mid-September. U.S. producer price began its downward trend in late September, with the first of three, successive price cuts to end the year at 72¢ per pound. As 1975 began, a fourth reduction to 68¢ per pound was made. (see Figure 5.)

1975 surfaced as the worst year for the copper industry since the 1930's. A hoped for upturn in demand did not materialize. In its stead, U.S. demand for copper was off 31 percent from 1974 and 38 percent from 1973. Additional reduction in mine

production was initiated by (1) further reduction of production at existing properties (2) delaying bringing scheduled new properties on line or bringing them on line at rates considerably below rated capacities (3) slowing down or stopping development on projects which were scheduled to come on-stream in the near future and (4) by closing marginal properties. Nevertheless, like 1974, producers were unable to stem the increase in stock buildup. (see Table IV)

TABLE IV
STOCKS OF REFINED COPPER
(in 000 tons)

	End Of Year		
	1973	1974	1975
Producer stocks			
U.S.A.	39	138	227
Outside U.S.A. and Japan	197	290	302
Japan: all stocks	102	172	280
LME	35	126	504
Comex	5	39	91
U.S. Consumers	66	131	151
U.S. Stockpile	228	32	24
European Consumers (France, Germany and U.K.)	125	175	200
Total	797	1103	1779

Source: Copper Studies

As stated earlier, the U.S. producer price began 1975 at 68¢ per pound. At the end of January, the producer price was reduced by 5¢ per pound to 63¢ and there it stayed until mid-year when Asarco and Phelps Dodge cut their price to 60¢ per pound. The rest of the industry did not follow suit. By late June, there was a slight upturn in the market, at which time Asarco and Phelps Dodge upped their price to 63¢ per pound. U.S. producer price closed the year at 63¢ per pound. (see Figure 5.)

IV. THE COPPER MINING COMPANIES IN ARIZONA

This section of the report summarizes Arizona's mining companies in terms of their Arizona operations. The data on each company includes: (1) the location of the company's operation(s) (2) the type of operation(s) conducted at the property (3) the design capacity of plant facilities (for many reasons this may vary from actual production output) and (4) the production data for 1974-1975.

Arizona retained its standing as the largest copper producing state in the U.S. through 1974-1975. In 1974, Arizona's production accounted for 54 percent of the nation's total output. The 1975 output rose to 57 percent, placing it far ahead of the second ranked state, Utah, which accounted for only 13 percent of the total production.

Most of Arizona's producers are vertically integrated. However, not all of the processing facilities are located in Arizona. Two of the corporations have vertically integrated operations in the state. Other producers mine, concentrate and smelt ore in Arizona. Some companies mine and concentrate their ores on site and ship the concentrates to custom plants, either in Arizona or other states, for smelting and refining on a toll basis. (see Figure 6.) Currently, all but one Arizona company is conducting some leaching and recovery operation.

Information on individual operations was obtained from (1) company annual reports (2) Securities and Exchange Commission Form 10-K's (3) professional journals (4) other published sources and (5) personal communications.

Company	Where Smelted	Where Refined	Sold By
ASARCO Incorporated	Own plants.	Own refineries.	ASARCO Incorporated
Anamax Mining Co., Twin Buttes, Ariz.	Inspiration Consolidated Copper Co., Miami, Ariz., Asarco, Hayden, Ariz.	U.S. Metals Refining Co., Carteret, N.J.	Anaconda and Amax Copper Inc.
Cyprus Bagdad Copper Corp.	Phelps Dodge, Ariz.,	Phelps Dodge, Laurel Hill, N.Y.	Cyprus Mines Corp.,
Cities Service Company Miami Operations	Inspiration Sm., Miami, Ariz.	Asarco Inc., Amarillo, Texas, Tacoma, Washington	Cities Service Company Metal Sales Dept.
Duval Corporation	Asarco, Tacoma, Washington, Hayden, Ariz., and El Paso, Texas	Asarco, Amarillo, Texas, Tacoma, Washington	Asarco, Duval Sales Corp.
Inspiration Consolidated Copper Company	Own plant, Inspiration, Arizona	Own plant, Inspiration, Ariz.	Inspiration Consolidated Copper Company
Kennecott Copper Corp.	Own smelters, Garfield, Utah; Ray, Ariz.; McGill, Nevada; Hurley, N.M.	Own refineries at Garfield, Utah; Hurley, N.M., Kennecott Refining Corp. at Anne Arundel County, Md.	Kennecott Sales Corp.

(continued next page)

Company	Where Smelted	Where Refined	Sold By
Magma Copper Company			
Superior Division	Own plant, San Manuel, Ariz.	Own refinery.	Magma Copper Company
San Manuel Division	Own plant, San Manuel, Ariz.	Own refinery.	Magma Copper Company
Phelps Dodge Corp.	Own plants, Douglas, Morenci and Ajo, Ariz.	Phelps Dodge Ref. Corp.	Phelps Dodge Sales Company, Incorporated
Cyprus Pima Mining Co.	Phelps Dodge Corp., Magma Copper, San Manuel, Ariz.	Phelps Dodge at El Paso, Texas; Magma Copper, San Manuel, Arizona	Ametalco, Inc.

Figure 6. Principal Arizona Copper Producers and the Disposition of Their Copper
Source: American Bureau of Metal Statistics, Inc.

Anamax

Anamax Mining Company is a 50-50 partnership between the Anaconda Company and the American Metal Climax (Amax) Company.

In June, 1973, Amax acquired the Banner Mining Company, owner of extensive mineral properties in Pima County, which included the Twin Buttes copper mine. This mine is located near Green Valley in the Santa Cruz River Valley. Anaconda, holder of a long term lease from Banner Mining Company on the Twin Buttes mine, formed a joint venture with Amax at that time. The purpose of the new Anamax Mining Company is to operate the open-pit mine, the concentrator and the new solvent extraction-electrowinning plant at Twin Buttes.

Each partner purchases its own share of production of copper concentrates and is responsible for its own smelting, refining and sales. Amax's share of Twin Buttes concentrates is toll smelted and is refined partly at Amax's refinery at Carteret, New Jersey, and partly on toll at other facilities. A portion of Anaconda's share of concentrates is toll smelted; the balance is shipped to its Anaconda, Montana, smelter. Anamax is responsible for the solvent extraction-electrowinning plant through the production of cathode copper. Each partner purchases its share of cathode copper from the electrowinning plant.

Twin Buttes has been the scene of an extensive, three-year expansion program. The sulfide concentrator's capacity was increased from 30,000 tons per day (tpd) to 40,000 tpd. Development work was undertaken on the east pit which contains a high grade of sulfide ore. The solvent extraction-electrowinning plant has the capacity for treating 10,000 tpd of oxide ore and for producing 100 tpd of cathode copper. Approximately $246 million were expended in this program through December 31, 1975.

Overburden removal was completed at the east pit during the first part of 1976. Unanticipated, poor ground conditions in the west pit resulted in slides which limited access to previously exposed ore. This, coupled with an extremely weak copper market, led management to two important decisions: (1) to commit more men and equipment in an intensified overburden removal project at the east pit and (2) to close the sulfide concentrator.

Twin Buttes' concentrator operated at approximately 100 percent capacity in 1974 producing 92.95 million pounds of recoverable copper; shut down for ten months in 1975, it produced only 18.31 million pounds of recoverable copper (see Table V).

The completion of the intensive overburden removal which increased the stripped ore reserves and the expansion of the concentrator's capacity placed the mine in an excellent position to raise production with improved cost performance.

Asarco Incorporated
(American Smelting and Refining Company)

Asarco was incorporated in 1899 as "The American Smelting and Refining Company." In April, 1975, at their annual meeting, the stockholders adopted a new name - ASARCO Incorporated.

ASARCO Inc. (ASARCO) owns and operates four open-pit mines and one smelter in three of Arizona's counties. The Mission Unit, the San Xavier Unit and the Silver Bell Unit are in Pima County. The fourth mine, the Sacaton Unit, is located in Pinal County. ASARCO's Arizona smelter, the Hayden smelter, is in Gila County.

Mission Unit

The Mission Unit is ASARCO's largest Arizona mining property and is located in southcentral Arizona near Tucson. The open-pit mine takes its name from a famous southwestern landmark — the Mission San Xavier del Bac.

Design capacity of the Mission concentrator is 22,500 tons of ore per day (tpd). Late in 1974, a cutback in production was initiated. In the latter part of 1975, a reduction in the work week and a three week vacation shutdown kept Mission's production well below capacity. The Mission Unit processed 7.54 million tons of copper ore in 1974 as compared to 5.09 million tons in 1975 (see Table V).

A new computer program is in operation at the Mission Unit which analyzes the operation of open-pit mines. This program, called Optimum Resource Extraction (ORE), has been used successfully to optimize operations at the Mission Unit. ORE exploits a computer built model of the orebody. The computer model is derived from drill hole data, geologic information, topographic contours and general economic factors affecting pit design. It is used to determine the best practical pit form, including bench contours and haul roads. (Phillips, p. 14, 1973)

The company has continued with its revegetation program at the Mission Unit. The project is designed to stabilize and improve the appearance of tailings dam slopes and overburden dumps. The overall operation consists of (1) covering selected areas with alluvial topsoil (2) installing a temporary irrigation system and (3) planting grass and desert vegetation. For the year 1975, approximately 12,000 tons of alluvium were used for revegetation at the Mission Unit.

San Xavier Unit

The San Xavier Unit is currently mining two separate orebodies. The oxide ore which overlies both orebodies is being treated at the unit's vat leach plant. Sulfide ore, which underlies the oxide capping, will be treated at the Mission concentrator. The unit consists of three operations: (1) the San Xavier Vat Leach Plant (2) the South San Xavier pit and (3) the North San Xavier Pit.

Cutbacks in 1975 production, which affected two of Asarco's other Arizona units, were not reflected in San Xavier's production. In 1975, the unit mined 1.37 million tons of copper ore as opposed to 1.22 million tons in 1974 (see Table V).

San Xavier Vat Leach Plant The San Xavier leach plant is Asarco's newest copper recovery operation. It is designed to process 4,000 tpd of copper oxide ore and recover the copper as cement copper precipitates. For each ton of ore processed, approximately 16 pounds of copper are produced.

Yearly, the plant is expected to consume about 50,000 tons of sulfuric acid and approximately 15,000 tons of shredded tin cans in the leaching process. The San Xavier vat leach plant is one example of hydrometallurgical technology. It uses consumer-generated solid waste and acid generated by pollution abatement to produce copper from low-grade ore which previously was disposed of as waste rock.

The South San Xavier Pit The south pit is an extension of the Mission Unit's present orebody. The pre-mining operation of overburden removal began in March, 1973. Actual mining of ore began mid-year 1975, following a year and a half of stripping. This mine is expected to supply copper oxide ore to the unit's vat leaching plant for approximately 3 years.

The North San Xavier Pit Stripping at the north pit began in 1967. Nine million tons of unmineralized overburden were removed to allow access to the oxide ore. 340,000 tons of this overburden, containing 77 percent silica, were crushed and shipped to Asarco's smelters at Hayden, Arizona, and El Paso, Texas, for converter flux (Roberts, 1974). Copper oxide ore from this pit is expected to supply the unit's vat leaching plant for 5 years of the plant's expected 8 year life.

Silver Bell Unit

The Silver Bell Unit was Asarco's first important mining operation in Arizona and is located in the Silver Bell Mountains northwest of Tucson, Arizona. The company has operated the Silver Bell mines since 1952. This unit consists of (1) two open-pit mines, the Oxide pit and the El Tiro pit (2) a 10,500 tpd concentrator and (3) a dump leach operation. Silver Bell's normal production of 10,500 tpd was cut 14 percent in late 1974. Likewise, reduction in the work week and a vacation shutdown cut the unit's production by approximately 57 percent of capacity during the latter part of 1975. 2.54 million tons of copper ore were mined at the unit in 1975 compared to 3.85 million tons in 1974 (see Table V). The unit's molybdenum concentrator was closed through 1974-1975.

Sacaton Unit

The Sacaton Unit, situated 5 miles northwest of Casa Grande, is Asarco's newest producing Arizona mine. The mine, named after the Sacaton Mountains, came on-stream in March, 1974.

Pre-production stripping began at Sacaton's west orebody in May, 1972. Approximately 33.5 million tons of overburden were removed. A 9,000 tpd concentrator, related surface facilities and a 2.3 mile railroad spur were constructed at a cost of about $40 million.

The Sacaton Unit was unaffected by production cutbacks during 1975. The unit mined 1.93 million tons of copper ore in 1974 and increased that figure to 3.61 million during 1975 (see Table V).

Sacaton's story goes back beyond the pre-production work which started in 1972. Asarco's geologists made the original discovery in 1961. Drilling operations delineated two separate orebodies during the intervening years. Geological evaluations and metallurgical testing were conducted after which the decision was made to mine the shallow west orebody by open-pit methods. Two years were spent planning the open-pit mine, concentrator and surface facilities. Design studies are still underway to mine the east orebody by block-caving methods. It is expected that this phase of the Sacaton Unit will be on line in 1980.

Hayden Unit

Asarco's Hayden Unit, located in Hayden, Arizona, is composed of (1) a copper smelter with the capacity to treat 960,000 tpy of input material and (2) a sulfuric acid plant capable of producing 1,000 tpd of sulfuric acid.

Big Hole Mining Company

The Big Hole Mining (Big Hole) Company's operations at Jerome, Yavapai County, Arizona, includes (1) the contract mining of high-grade ore pockets (2) conducting dump leaching operations and (3) operating a precipitation plant.

In the early 1950's, Phelps Dodge Corporation closed down its United Verde mining operations at Jerome. At that time, Big Hole contracted with Phelps Dodge to mine remaining ore and to recover leachable copper from the dumps. Big Hole's operations continued from that time until the company shut down their operation in June, 1975.

Cities Service Company's Miami Division

Cities Service Company's Miami Division operations are located in the Globe-Miami area, about 90 miles east of Phoenix, Arizona, and approximately 120 miles north of Tucson, Arizona.

Cities Service Company announced, on April 23, 1976, that its Miami Operations became a separate division within their newly organized Minerals Group. The new division controls the following major facilities: (1) Pinto Valley operations (2) Miami Leaching (3) Miami East underground mine (4) Copper Cities open-pit mine and (5) Copper Cities leaching unit. All facilities are located in Gila County, Arizona.

Pinto Valley Operations

Cities Service Company's newest development, Pinto Valley, was placed in production during 1974. The operation consists of (1) an open-pit mine (2) a 40,000 tpd concentrator and related surface facilities and (3) a 10 mile concentrate slurry pipeline to the Inspiration smelter.

Pre-production stripping began at the Pinto Valley orebody in 1972. About 60 million tons of overburden were removed. The current pit design contains reserves of approximately 350 million tons of ore averaging 0.44 percent copper. Based on an initial production target of 40,000 tpd ore and 60,000 tpd waste, mine life is estimated at 24 years.

The current stripping ratio is 1.5:1, requiring the ultimate removal of more than 500 million tons of waste and leach-grade material (Li and Carter, 1975). The 40,000 tpd concentrator, according to Pinto Valley engineers, will be monitored and controlled by sophisticated electronic monitoring systems complete with automatic analog control systems suitable for future computer hookup, and an X-ray mineral analysis system (Li and Carter, 1975).

Pinto Valley's 1974 production of 3.26 million tons of ore mined reflect the mid-year start-up. For 1975, the operating rate averaged approximately 90 percent of capacity or 13.90 million tons. (see Table V)

Miami Leaching Unit

By 1959, ore from the old Miami Inspiration orebody which could profitably be mined by underground methods was exhausted. Yet, as in any mining operation, scattered, small, high-grade pockets remained unmined. Also, most of the mineralized rock that was too low in copper content for mill feed remained in place. To extract this copper, leaching solutions are fed into the block-cave subsidence area and recovered through old underground openings. The pregnant solutions are pumped to the surface for cement copper production.

Currently, copper recovered by solution mining is being precipitated on shredded tin cans. A solvent extraction-electrowinning unit is under construction which will replace the older operation. This new leaching plant is expected to be on-stream sometime in 1976 (on-line May, 1976, expected output is 30,000 pounds per day). The new plant will produce cathode copper. Currently, precipitate copper is being smelted and refined elsewhere.

Miami East Underground Mine

This deep, underground orebody is located in the down-faulted section of the old Miami-Inspiration orebody. Discovery of this large mineralized zone was the result of an extensive surface drilling program. Once development work is completed, the mine is expected to produce about 5,000 tpd of copper ore, using the cut and fill mining method.

Cities Service announced September 24, 1975, that start-up of the Miami East Mine, scheduled for early 1976, had been postponed and activities at the mine will be gradually reduced. The project is to be placed on standby maintenance in early 1976 until economic conditions warrant resumption of development.

Copper Cities open-pit mines

The Copper Cities and the Diamond H open-pit mines, which have been in production since 1954, were shut down on May 9, 1975, because of depletion of ore reserves. Milling of a low-grade stockpile continued until September 12, 1975, when all mining and milling operations ceased.

Copper Cities Leaching Unit

This unit is responsible for the dump leaching activity at Copper Cities mines. Copper from the pregnant leach solution is recovered at the unit's precipitation plant. Since 1962, the unit has been leaching copper values from low-grade, non-millable ores.

Continental Materials Corporation

Continental Materials Corporation, through its wholly-owned subsidiary, Continental Copper Company, is developing an underground ore deposit at the Control mine property. The property is patented and lies within the Coronado National Forest, on the northeast slopes of the Santa Catalina Mountains, Pima County, Arizona. Continental Copper acquired the property in 1969 and since that time has conducted an active exploration program. In August, 1976, Continental Materials Corporation announced that it had signed a letter of intent with Union Miniere of Brussels to jointly develop an underground mine on the Control group property. The completed project will cost an estimated $35 million and will result in the development of a small, but high-grade, underground copper mine, a 2,000 tpd concentrator and related ground facilities.

Continental Oil Company

Continental Oil Company (Conoco) is evaluating the feasibility of constructing an open-pit mine and related facilities near Florence, Pinal County, Arizona.

In 1970, Conoco announced the discovery of porphyry copper mineralization while conducting preliminary drilling near Florence. Test mining and operations at the pilot metallurgical recovery plant were completed during 1975. A comprehensive engineering and economic analysis of a commercial mine and plant is being prepared. This study will use data obtained during operation of the test mine and pilot recovery plant, ongoing environmental and hydrological studies and industry marketing forecasts.

Archaelogical studies conducted by the University of Arizona and sponsored by Conoco disclosed several prehistoric sites lying within the proposed mining area. The major site, the Escalante ruin, and several outlying sites were excavated by a team of archaeologists from the University of Arizona. The company is conducting further archaeological studies.

Cyprus Mines Corporation

The Cyprus Mines Corporation wholly owns or controls, as subsidiaries, four mining companies in three of Arizona's counties. They are: (1) Cyprus Bagdad Copper Company, Yavapai County (2) Cyprus Bruce Copper & Zinc Company, Yavapai County (3) Cyprus Johnson Copper Company, Cochise County and (4) Cyprus Pima Mining Company, Pima County.

Cyprus Bagdad Copper Company

Cyprus' Bagdad operation is located 102 miles northwest of Phoenix, Arizona, and 68 miles west of Prescott. The present operation consists of (1) an open-pit mine (2) a 5,800 tpd concentrator producing copper and molybdenum concentrates (3) an oxide dump leaching system (4) a solvent extraction-electrowinning plant and (5) a town with a hospital, schools, a shopping center and other facilities for its 550 employees and their families.

In May, 1973, at their annual meeting, the stockholders voted to merge Bagdad Copper Corporation into Cyprus. The merger was completed in June of that year. The basic reason for this merger was to facilitate expansion of the Bagdad operation. Immediately following the merger, Cyprus undertook a major feasibility study for the expansion of the mine, mill and the possible construction of a smelter and a refinery. Authorization to proceed with the expansion project came in 1974.

In October, 1974, Cyprus Bagdad chose Holmes & Narver, Inc., in conjunction with Fluor Utah, Inc., to complete the design, engineering and procurement for the project. The planned expansion is to include (1) a 40,000 tpd concentrator using an autogenous grinding method with secondary ball mills (2) a water-supply system (3) a tailings disposal and reclaim water systems (4) warehouses and (5) mine and mill offices and shops. A greatly enlarged and improved employee community also is to be a major part of the expansion.

Proven ore reserves of approximately 300 million tons containing an average of 0.49 percent copper will assure operation at the accelerated rate for about 20 years. Meanwhile, detailed drilling is being conducted in the surrounding area of mineralization with the intent of developing ore for further expansions and extended mine life.

At the end of 1975, all major construction projects were on schedule. The entire program, estimated to cost $240 million, is expected to be completed during the last quarter of 1977.

Stripping activities for the current expansion project are expected to add approximately 28 million tons of leachable oxide material to the existing 88 million tons. However, Cyprus Bagdad does not propose any expansion of its copper oxide leaching system.

Electrowon cathodes, produced at the company's solvent extraction-electrowinning plant, were certified for New York Commodity Exchange contracts. This was an important milestone for the plant because Cyprus Bagdad's cathodes were the first electrowon cathodes to receive such certification. The cathodes have consistently had the same or better quality than cathodes made by conventional electrorefining.

Cyprus Bruce Copper & Zinc Company

Cyprus Bruce is located 5 miles southwest of the Cyprus Bagdad Mining complex. The mine property consists of (1) a small, high-grade, underground, copper and zinc mine (2) a 270 tpd concentrator and (3) related facilities.

New factors have been introduced into the mining system. These factors greatly improved production and have significantly reduced mining costs. The cut and hydraulic fill mining system has been mechanized by addition of LHD (load, haul and dump) equipment. In 1975, a new, large, mobile drill jumbo was placed in service.

The Bruce mine is Arizona's largest zinc producer. In 1975, the ore treated at Cyprus Bruce contained an average of 12.5 percent zinc and an average of 3.73 percent copper. The concentrator treated 94,608 tons of ore containing 6.54 million pounds of copper and 19.12 million pounds of zinc. (see Table V)

Intensive underground exploration activity was carried out through 1975 and will continue in 1976. Thus far, no additional ore has been developed. Proven reserves of 195,000 tons are sufficient for little more than two years of operation at the current mining rate.

Cyprus Johnson Copper Company

The Cyprus Johnson property is situated 65 miles east of Tucson near Benson, Arizona. It consists of a small oxide-copper open-pit mine with a solvent extraction-electrowinning plant and related facilities. Production began in March, 1975. It is expected that by 1976 design capacity of 5,000 tons per year (tpy) of high-quality copper cathodes will be achieved.

At the planned mining rate, Cyprus Johnson's reserve of nearly 13 million tons of oxide-copper ore, with 0.50 percent acid-soluble copper content, will assure an operating life of nine years.

Cyprus Pima Mining Company

Cyprus Mines Corporation is the operator and owner of 50.01 percent of the Cyprus Pima Mining Company located near Tucson, Arizona. The non-operating partners, Union Oil Company of California and Utah International, each own approximately 25 percent. The operation consists of (1) an open-pit mine (2) a concentrator and (3) a research and development section.

Results of an extensive drilling program completed in September of 1974 are being evaluated to determine if expansion of the present pit to the east and southeast might be profitable. If such expansion proves feasible, the operating life of the mine will be extended significantly.

The 53,500 tpd concentrator produces both copper concentrate and molybdenum sulfide. Silver contained in the copper concentrate is an important byproduct. The semi-autogenous grinding mills installed in the concentrator in 1973 have continued to prove satisfactory with a resultant reduction in per ton milling costs.

The Research and Development Section is continuing with the development of the Cymet process. The process, being developed jointly by Paul R. Kruesi, Hazen Research and Cyprus, has as its objective the direct reduction of copper from copper sulfides. Such a process could reduce the need for the pyrometallurgical process of smelting and its resultant production of sulfur gases. Testing and improvement of the Cymet process continued during 1975 at the demonstration plant. Another result of the research and development program is a new patented process for removing talc from molybdenum ore by flotation separation. The process makes possible significant metallurgical improvements in the treatment of copper-molybdenum ores containing talc.

DUVAL CORPORATION

Duval Corporation (Duval) is the mining subsidiary of the Pennzoil Company. Duval operates three, large, open-pit mines in two of Arizona's counties: (1) the Esperanza property in Pima County (2) the Mineral Park property in Mohave County and (3) the Sierrita property in Pima County, operated through its wholly-owned subsidiary, Duval Sierrita Corporation. The company also completed construction of a new CLEAR-process hydrometallurgical plant near its Sierrita property. Copper production from this plant began in the first quarter of 1976.

Esperanza

The Esperanza property, located near Tucson, Arizona, consists of (1) a copper-molybdenum open-pit (2) an 18,000 tpd concentrator and (3) a leach-precipitation operation.

This copper-molybdenum property resumed operations early in 1973 following a one-year shutdown intended to reduce the copper concentrate inventory which had accumulated during a smelter strike. A 25 percent increase in production was made possible through plant modification initiated during the shutdown. However, in February, 1975, because of the weak demand for copper, Duval was again forced to reduce production at the Esperanza property to 5.49 million tons of copper ore. The 1974 production was 6.41 million tons. (see Table V) The molybdenum output was not affected by the cutback in copper production. Esperanza's concentrates and precipitates are to be treated at Duval's new CLEAR-process hydrometallurgical plant.

Mineral Park

Mineral Park is located approximately 16 miles northwest of Kingman, Arizona. Production began at this Duval property in late 1964. The operation consists of (1) a copper-molybdenum open-pit mine (2) an 18,500 tpd concentrator (3) a dump leaching operation and (4) molybdenum trioxide plant (not in use at this time).

In line with a general policy of curtailment of copper production, Duval reduced copper production at Mineral Park in 1975. Because of a mechanical problem, the mine had been operating at a reduced capacity for two months prior to this larger cutback. 6.38 million tons of copper ore were mined in 1974 as compared to 5.57 million tons in 1975. Copper concentrates and copper precipitates produced at this property are expected to be treated at the new CLEAR-process hydrometallurgical plant at the Sierrita property. Mineral Park's molybdenum concentrates are shipped to Duval's Sierrita property where they are processed.

In 1975, Duval Corporation's Mineral Park Division participated in the construction of two historical markers. The markers were constructed as a Bicentennial-approved project and were placed along U.S. Highway 93, north of Kingman. Constructed of redwood and placed on native stone foundations, the markers commemorate the old mining camps of Cerbat and Mineral Park.

Duval Sierrita Corporation

Duval Sierrita Corporation, a wholly-owned subsidiary of the Duval Corporation, owns and operates the Sierrita mine. This property is located adjacent to Duval's Esperanza mine near Tucson, Arizona. Duval acquired the Sierrita property in 1964. The purpose of this acquisition was to provide future reserves for the Esperanza property.

The Sierrita property is composed of (1) a copper-molybdenum open-pit mine (2) a 90,000 tpd concentrater and related ground facilities (3) a 2.2 mile long conveyor system (4) a molybdenum processing plant which produces molybdenum trioxide (5) a new ferro-molybdenum plant which came on-line February, 1975, and (6) the CLEAR-process hydrometallurgical plant.

In May, 1966, the General Services Administration (GSA), in the interest of national security, announced a program to encourage additional domestic production of copper. Duval formed the Duval Sierrita Corporation (Duval Sierrita) which successfully conducted negotiations with GSA for the development of the Sierrita property. The contracts were signed November, 1967. Under the contract, Duval Sierrita was advanced $83 million against future delivery of copper to the government at a fixed price of 38 cents per pound. Total cost for the development of the property approached $200 million.

Unlike Duval's other Arizona properties, Duval Sierrita's production was not curtailed during the general 1975 production slowdown. Substantially all of Duval Sierrita's 1975 copper production was delivered to the GSA pursuant to an accelerated loan repayment schedule. Duval Sierrita mined 30.50 million tons of copper ore in 1974. Production rose to 31.43 million tons of copper ore mined (see Table V) in 1975.

In February, 1975, Duval Sierrita's new ferro-molybdenum plant began production. The plant is designed to process 3.61 million pounds of molybdenum trioxides annually for the production of 3.5 million pounds of ferro-molybdenum per year. Prior to the opening of this plant, that portion of Duval's molybdenum concentrates which were marketed as ferro-molybdenum were converted on a toll basis. The remaining concentrates are now marketed as molybdenum sulfide or are processed and sold as molybdenum trioxide.

The CLEAR-process, a new hydrometallurgical process developed by Duval and tested over a two-year period, is no longer in the experimental stage. The absence of solid, liquid and gaseous pollution is one of the major design features of the patented CLEAR-process. The process recovers metallic copper from chalcopyrite and other copper-containing materials by ferric chloride oxidation to produce cupric chloride. The cupric chloride is reduced to cuprous chloride and copper is recovered by electrolysis (Engineering and Mining Journal, June, 1976, p. 245).

Duval began construction in 1974 on the 32,500 tpy CLEAR-process plant. With construction completed, the plant commenced production of copper crystals (equivalent to a high-grade blister copper) during the first quarter of 1976.

Hecla Mining Company - El Paso Natural Gas Company

Hecla Mining Company (Hecla), the operating company, and El Paso Natural Gas Company (El Paso) each own 50 percent interest in the Lakeshore copper mining complex. The Lakeshore property is presently under development and is expected to come on-stream early 1976. Mine production will begin at a relatively low rate and will gradually increase over several months. Each partner will share equally in all preproduction and plant construction costs which are currently estimated at $195 million.

When production commences, Hecla and El Paso will each receive a one-half share of the production output and all production costs will be divided equally.

Lakeshore Mine

The Lakeshore mine is located in the Slate Mountains within the Papago Indian Reservation, approximately 30 miles south of Casa Grande and 3 miles east of Komelik, Pinal County, Arizona.

Lakeshore's orebody consists of three sections: (1) a thick, central core of sulfide zone porphyry-type ore mineralization similar to other Arizona deposits (2) a tactite sulfide ore occurring at the base and marginal to the porphyry-type mineralization and (3) an oxide zone. Present mine development allows for concurrent mining of the tactite sulfide ore and the oxide ore. The central core porphyry-type mineralization will be developed for later mining.

The Lakeshore property consists of (1) an underground mine (2) a 17,500 tpd fine crushing plant (3) a 6,450 tpd vat leaching plant (4) an 11,000 tpd sulfide concentrator and related ground facilities (5) a sponge iron plant and (6) a roasting, leaching and electrowinning plant with an associated acid plant. Hecla's Lakeshore facilities are designed to produce high-purity cathode copper using a pollution free, close-looped, hydrometallurgical ore treatment process.

Underground mining is carried out in two related, but distinct, operations. The sulfide ore is mined by a continuous panel-caving method. It is then transported to an underground primary crusher. From the crusher the sulfide ore is brought to the surface via a conveyor belt system and stockpiled. Oxide ore is also mined by a panel-caving method, but the ore is hoisted to the surface then crushed and stockpiled.

After crushing, the sulfide ore is concentrated and the concentrates are sent to the roasting, leaching and electrowinning plant (RLE plant). Waste products from the RLE plant, i.e., roaster gases, spent electrolyte and leach residue, are either converted

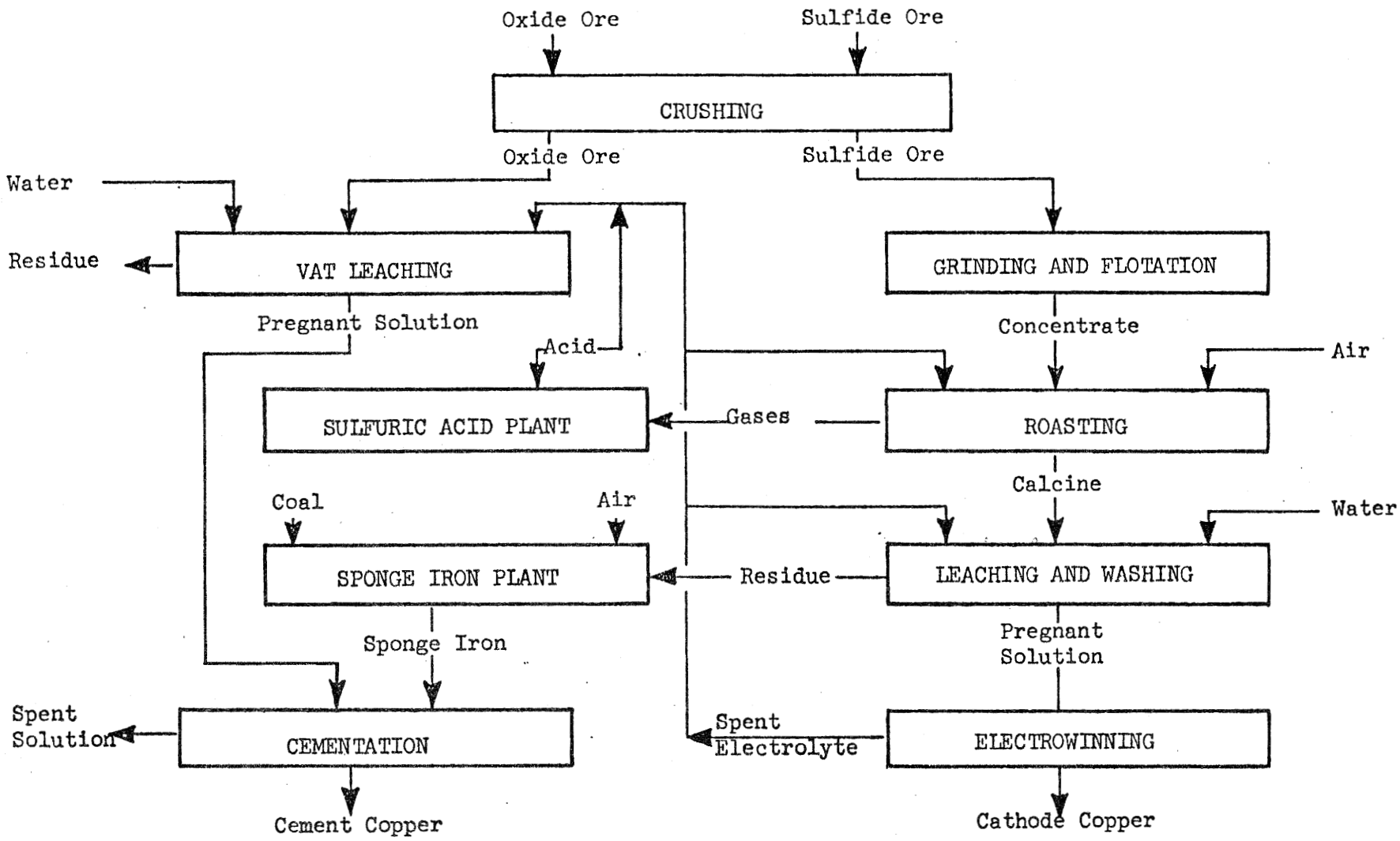

Figure 7. Lakeshore Project - Plant Flowsheet
Source: Hecla Mining Company

or are used "as is" and recycled through the oxide ore treatment system. (see Figure 7.) When operating at full production, the RLE plant is expected to produce 30,000 tpy of electrowon copper cathodes.

The oxide ore travels directly from the fine crushing plant to the vat leaching plant where cement copper is precipitated by the use of sponge iron. The waste products from the sulfide ore treatment — sulfuric acid from roaster gases, spent electrolyte from the production of cathode copper, and sponge iron from sulfide ore leach residue — are used in the production of cement copper at the vat leaching plant. At full production capacity the leaching plant will produce 55,000 tpy of copper precipitates containing 35,000 tons of copper. The precipitates are pelletized and shipped to ASARCO smelters for further processing.

Inspiration Consolidated Copper Company

The Inspiration Consolidated Copper Company (Inspiration) was the first Arizona copper company to mine, smelt, refine and fabricate Arizona copper in Arizona. The company's main operations, the Inspiration Division, are centered about 90 miles east of Phoenix at the town of Inspiration, Gila County, Arizona. The Christmas Division is located about thirty-eight miles south of Inspiration, at the town of Christmas, Gila County, Arizona. Still under consideration by the company is a joint venture wherein Inspiration would operate the Sanchez mine near Safford, Graham County, Arizona.

Inspiration Division

The Inspiration Division is composed of (1) three open-pit mines (2) a 20,000 tpd concentrator (3) heap and waste dump leaching operations (4) in-plant leaching (vat-leaching) (5) an electrowinning plant (6) an electric smelter with a capacity of 595,000 tpy of input material (7) an acid plant capable of producing 14,000 tpd (8) an electrolytic refinery with a capacity of 70,000 tpy and (9) a continuous-cast copper rod plant.

Inspiration area mines - Ore from the Inspiration area's three pits — the Thornton, Live Oak and Red Hill mines — contains varying degrees of sulfide and oxide minerals. That ore which has a predominance of oxide minerals is treated by heap leaching. Ore which has a predominance of sulfide minerals is sent to the concentrator. Dual process ore, ore which contains a more balanced amount of oxide and sulfide minerals, is first treated by vat-leaching. The leached material is then taken to the concentrator where the sulfide minerals are recovered by flotation.

Cities Service Company and Inspiration completed negotiations under which Inspiration will mine and treat, on a royalty basis, ore from Cities Service property adjacent to Inspiration's Joe Bush mine. The agreement will also allow the company to mine a substantial tonnage of material which otherwise could not be mined without disturbing a common boundary. Preproduction stripping for the Joe Bush mine began in the first quarter of 1975. By the end of 1975, some 5.21 million tons of overburden had been removed.

Inspiration's mines began 1975 on a seven-day-per-week schedule. Early in 1975, the work week was reduced to five days, but the daily mining rate of 27,500 tons was maintained. For economic reasons, at mid-year Inspiration stopped mining oxide ore and mined only dual process and sulfide ores for the remainder of the year. The division mined 8.45 million tons of copper ore in 1974 as compared to 6.29 million tons in 1975.

Ox Hide and the Willow Springs Mines

Inspiration operates two properties where heap-leaching operations are conducted. They are the Ox Hide mine which has been in production since 1968 and Willow Springs which came on-stream in the second quarter of 1974.

Heap-leaching differs from waste dump leaching in several important aspects. Heap-leaching material is usually crushed or ripped, then placed on specially prepared "leaching pads", whereas, generally, in dump leaching the material is not specially prepared prior to the leaching process.

Sulfuric acid for these two operations and for Inspiration's other leaching projects is supplied by the new, 1400 tpd, double-absorption acid plant. This plant produced 175,000 tons of sulfuric acid in 1975.

Christmas Division

The Christmas Division consists of (1) an open-pit mine, formerly an underground mine (2) a 5,500 tpd concentrator and (3) related ground facilities. Inspiration acquired the Christmas property in 1955 and from that time until late in 1966 the property was mined by underground methods. In late 1966, open-pit mining was introduced and still continues. Studies are being conducted to determine the advisability of resuming underground operations.

The division entered 1975 with a seven-day work week which was reduced to a five-day work week in February. Later in the year, shutdowns were scheduled from November 24 to December 7 and from December 20 to January 5. The latter period was extended through January 20 because of the shutdown at the Inspiration smelter where

Christmas concentrates are treated. Consequently, the 1975 production of 1.40 million tons of ore mined was down from 1974's 1.68 million tons. (see Table V)

Tests were conducted by the division on the practicality of leaching ore from a new, large, low-grade orebody whose near-surface ores do not yield adequate recovery by flotation. Plans are also underway for an oxide ore mining facility with dump leaching, solvent extraction and electrowinning operations. A new $632,000 primary crusher was installed during the latter part of 1974.

Kennecott Copper Corporation

Kennecott Copper Corporation's Arizona division, the Ray Mines Division, operates (1) an open-pit mine (2) a 25,400 tpd concentrator with related ground facilities (3) dump leaching in conjunction with a precipitation plant (4) a 10,000 tpd silicate ore leach-electrowinning plant (5) a smelter capable of treating 420,000 tpy of input material (6) an acid plant designed to produce 1,970 tpd of sulfuric acid and (7) a 6 mile railroad from the mine to the Southern Pacific junction at Kelvin. The Ray Mine is located 10 miles northwest of Kearny, Pinal County, Arizona. Located at the mine site is the silicate leach-electrowinning plant along with the dump leaching operations. The other facilities are approximately 18 miles south at the town of Hayden, Gila County, Arizona. The Ray Mines Division's headquarters are also located at the Hayden plant site.

The Ray Mine was mined by underground methods until 1955 when Kennecott initiated open-pit operations at the site. In the mid-1960's, as this pit expanded, the company began stockpiling silicate ores containing 0.8 percent copper and began experimenting to develop a leaching system (Beall, 1973, p. 45). The result was a 10,000 tpd silicate leach-electrowinning plant, designed and completed by 1969. Kennecott announced plans in 1973 to expand the leaching facilities by 40 percent to 14,000 tpd. The expansion was expected to cost $7 million. The expanded plant began production mid-1976.

The Ray Mine Division mined 11.72 million tons of copper ore in 1974. The 1975 production was considerably lower at 6.69 million tons. Ray was shut down for 12 weeks during the summer of 1975. (see Table V)

Kennecott is continuing to evaluate a large copper deposit near Safford, Arizona. The company has been experimenting with a solution mining process. This process would use high pressure to force a leach solution through injection holes which are several thousand feet deep. The copper-bearing rocks at that depth would be soaked with leaching solution which would attack

the copper minerals. Recovery wells in the leach area would establish a circulation system returning to the surface the pregnant solutions (Dimock, 1976, p. 58).

McAlester Fuel Company

McAlester Fuel Company (McAlester) operated the Zonia mine located 22 miles southwest of Prescott near Kirkland Junction, Yavapai County, Arizona.

McAlester began mining operations at the Zonia mine in 1966. The operation consisted of an open-pit mine which supplied low-grade oxide ore for heap-leaching. The company changed its mining methods in 1973 by preparing the mine area for in-situ (in place) leaching.

In-situ leaching differs from other leaching practices in that the material to be leached is not transported. Preparation of the ore for in-situ leaching sometimes requires fracturing which is accomplished by blasting or hydraulic fracturing. McAlester prepared a part of the Zonia ore deposit with (as of April, 1973) the world's largest, man-made, non-atomic blast. The blast utilized 4,125,000 pounds of explosives. The blast area covered 10 acres.

Economic reasons forced McAlester to cease operations at the Zonia mine in March, 1975. The company plans to re-open when the economic climate improves.

Newmont Mining Corporation

Newmont Mining Corporation is represented in Arizona by its wholly-owned subsidiary, Magma Copper Company (Magma). Magma is the second Arizona mining company to mine, smelt, refine and manufacture Arizona's copper in Arizona. Its operations are divided into two divisions — the San Manuel Division and the Superior Division.

The San Manuel Division is located in southeastern Pinal County, Arizona, approximately forty-five miles northeast of Tucson. The concentrator, smelter, electrolytic refinery, administration building and other plant facilities are located some seven miles southeast of the mine area, adjacent to the town of San Manuel.

The Superior Division is situated at Superior in Pinal County, Arizona, approximately 70 miles southeast of Phoenix and 21 miles west of Miami.

San Manuel Division

San Manuel is Magma's larger division. It is the largest underground mining operation in the U.S. It consists of (1) an underground mine with a rated output of 62,000 tpd (2) a 62,000 tpd concentrator with related ground facilities (3) a smelter with a rate capacity of 1 million tpy of input material (4) an acid plant capable of producing from 1,000 to 2,000 tpd of sulfuric acid and a neutralization plant with related facilities for disposal of the sulfuric acid produced by the acid plant (5) an electrolytic copper refinery with an annual production capacity of 200,000 tons of refined copper (6) a continuous cast copper rod mill capable of converting 120,000 tpy of refined copper into rod (7) a thirty mile standard gauge railroad system and (8) a modern, employee town.

The Division was the largest producer of copper in Arizona for the years 1974 and 1975. The mine is an underground block caving operation which produced 248.85 million pounds of recoverable copper in 1974. Its 1975 production was 187.49 million pounds. (see Table V)

Magma's San Manuel Division, like many other Arizona copper producers, began reducing production early in 1974. The reduction continued through 1975 with a corresponding temporary reduction in the work force. This measure was designed to prevent further increases in the copper metal inventories and it succeeded, but as a partial consequence, unit operating costs per pound of copper in 1975 were close to 21 percent higher than in 1974. The weak copper market forced Magma to defer previously announced plans for expanding the capacity of the mine and concentrator from 62,000 tpd to 75,000 tpd and for doubling the capacity of the continuous cast copper rod mill.

Superior Division

The Superior Division consists of (1) an underground mine with a rated output of 3,300 tpd and (2) a 3,300 tpd concentrator with related ground facilities. Concentrates have been shipped to the San Manuel smelter since July, 1972, when the Superior smelter was closed down after 47 years of operation.

A program of modernization and expansion was completed in 1973 at the Superior Division's mine and concentrator. This expansion approximately doubled the division production capacity.

Magma's Superior Division mine, unlike most other Arizona mines, did not suffer from production cutbacks in 1974 or 1975. The division mined 732,937 tons of ore in 1974 and in 1975 increased that to 1.087 million tons. (see Table V)

Phelps Dodge Corporation

Phelps Dodge Corporation (Phelps Dodge) is Arizona's largest copper producer. The company owns and operates mines, concentrators, leaching operations, smelters and acid plants in three of Arizona's counties. Two projects under development by Phelps Dodge, in Arizona, are (1) the Safford Project, an underground mine near Safford, Arizona, where preproduction work is in progress and (2) the Copper Basin Project, an area of copper mineralization southwest of Prescott, Arizona, where the company is studying the feasibility of developing an open-pit copper mine. Phelps Dodge is also constructing a new smelter, a modern employee town and a 36 mile industrial railroad in Hidalgo County, New Mexico.

Phelps Dodge's Arizona operations are divided into four operating units: (1) the Copper Queen Branch (2) the Douglas Reduction Works (3) the Morenci Branch and (4) the New Cornelia Branch.

Copper Queen Branch

The Copper Queen Branch operations are located at the town of Bisbee, Cochise County, Arizona. The operations currently consist of (1) dump leaching (2) underground leaching and (3) a precipitation plant. The Lavender pit mine, concentrator and related ground facilities were closed down on December 14, 1974. Underground mining operations continued until June 13, 1975, (Friday the 13th) when Phelps Dodge terminated the last of its ore mining operations in the Bisbee area. This ended 95 years of continual mining activities. Reasons cited for the closure were a combination of depleted ore reserves, rapidly dropping copper prices and a decreasing demand for copper. However, the Copper Queen Branch will continue to contribute to Phelps Dodge's copper production by recovery of copper through leaching activities.

Douglas Reduction Works

The Douglas Reduction Works, at Douglas, Cochise County, Arizona, consists of a smelter with related ground facilities. The Douglas smelter has a rated capacity of 700,000 tpy of input material.

Phelps Dodge's western operations headquarters are also located at Douglas.

Morenci Branch

The Morenci Branch operations are located in the Clifton-Morenci area near the town of Morenci, Greenlee County, Arizona.

The Branch operations include (1) two open-pit mines, the Morenci and the Metcalf (2) two concentrators with related ground facilities (3) dump leaching operations (4) a new facility to leach concentrator tailings (5) a smelter with a rated capacity of 900,000 tpy of input material and (6) an acid plant with a capacity to produce 2,500 tpd of sulfuric acid.

Morenci Mine Mining operations at the Morenci mine consist of (1) a rail and truck haulage, open-pit mine (2) a 60,000 tpd concentrator with related ground facilities (3) dump leaching operation with a precipitation plant and (4) newly constructed facilities for leaching concentrator tailings from the Morenci and Metcalf concentrators.

The Morenci mine is the oldest mining operation in the Clifton-Morenci area. Mining operations began in the Morenci area in the 1860's. The present open-pit was started in 1938 and has expanded until mining is being conducted in what was once part of the old town of Morenci. Phelps Dodge constructed the current townsite providing it with housing units, a motel, a hospital, a shopping center, a library and schools.

Production cutbacks reflecting the decreasing demand for copper were initiated at the Morenci Mine through 1974 and 1975. For a time during 1975, mine operation was equivalent to a 4-day work week. The Morenci mine mined 16.79 million tons of ore in 1974 as compared to 16.17 million tons in 1975. (see Table V)

Metcalf Mine The Metcalf mine is located several miles north of the Morenci mine. The operation consists of (1) an open-pit mine and (2) a 30,000 tpd concentrator with related ground facilities. Metcalf is Phelps Dodge's newest producing Arizona copper property. The mine and related facilities came on-stream in January, 1975. It is expected that copper production from the Metcalf mine will more than offset the production losses incurred by closure of the Bisbee area mines. Development work on the Metcalf mine began in 1969. Phelps Dodge has spent more than $200 million and 6 years time bringing this new mine on-stream. Metcalf's 1975 production was 5.56 million tons of ore mined. (see Table V)

New Cornelia Branch

The New Cornelia Branch is located in western Pima County at the town of Ajo, Arizona. The branch's operations consist of (1) a rail haulage open-pit mine (the Ajo pit and the Morenci pit are the only Arizona mines which utilize rail haulage) (2) a 33,000 tpd concentrator with related ground facilities (3) a smelter with a rated capacity of 250,000 tpy of input material (4) an acid plant capable of producing 640 tpd of sulfuric acid and (5) the Tucson, Cornelia and Gila Bend Railroad Company.

The New Cornelia Branch, like Phelps Dodge's other Arizona properties, operated at a reduced capacity during the latter part of 1974 and through 1975. Production from the Ajo pit in 1974 was 9.04 million tons of ore mined and 7.27 million tons in 1975. (see Table V)

Safford Project

Phelps Dodge is developing a deep underground orebody approximately 10 miles north of Safford, Graham County, Arizona.

Preliminary development continued through 1974 and 1975. During 1974, work on the existing No. 1 shaft was finished for a total depth of 2,150 feet. Sinking of the new No. 2 shaft was started in conjunction with the beginning construction on underground and surface facilities required for the operation of a large underground mine. The No. 2 shaft was at a depth of 1,439 feet by the end of 1975. Construction continued through 1975 on the surface installations and the underground facilities. The development project will proceed through 1976 but at a slower pace.

The Safford orebody is estimated to contain 400 million tons of ore with an average grade of 0.7 percent copper.

Ranchers Exploration and Development Corporation

Ranchers Exploration and Development Corporation (Ranchers) operates in two of Arizona's counties (1) two mines, the Bluebird and the Old Reliable (2) a solvent extraction-electrowinning plant and (3) a precipitation plant.

Bluebird Mine

Rancher's Bluebird mine is located approximately 2 miles west of Miami, Gila County, Arizona. The operation consists of (1) an open-pit mine (2) specially constructed leaching pads and (3) a solvent extraction-electrowinning plant.

Bluebird's ore is ripped, loaded in scrapers and hauled to dump locations. The ore is stacked on heaps in layers 20 feet thick. Each new layer is sprinkled with a leaching solution which percolates through the heap. The pregnant solution is then collected. The heap currently extends a maximum of 180 feet above ground (production began at the mine in 1964).

In 1974, Ranchers cancelled a proposed venture in which Mitsubishi International would operate the Bluebird mine. The company then began plans to expand its own operations at the mine. However, the expansion planned for 1975 was postponed because of the unfavorable economic climate and the lower copper prices.

Mine production for 1974 was 15.34 million pounds of copper; the 1975 production was 15.12 million pounds. (see Table V)

Old Reliable Mine

The Old Reliable mine is situated nine miles east of Mammoth, Pinal County, Arizona. The mine is composed of (1) an in-situ leaching operation and (2) a precipitation plant. Rancher's owns 83 percent of the mine and is the operating company. E.I. du Pont de Nemours and Co. owns the remaining 17 percent.

The Old Reliable project represents a pioneering effort in copper production. The project is believed to be the first in mining history in which an entire orebody was fractured with explosives for in-situ leaching (Skillings Jr., 1974, p. 12) Four million pounds of explosives were used to fracture the orebody. The blast was detonated on March 9, 1972. (A larger blast was detonated by McAlester Fuel Co. in April, 1973).

Copper production from the Old Reliable mine for 1974 amounted to 4.35 million pounds of copper. The mine was placed on standby in 1975 by Rancher's management in anticipation of higher copper prices. Prior to shutdown, 466,506 pounds of copper were recovered. (see Table V)

APPENDIX A: TABLE V

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES

Company Mine	1974 Tons Copper Ore Mined	1974 Pounds Recoverable Copper	1974 Pounds Recoverable Molybdenum	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum
ANAMAX:						
Twin Buttes	10,822,187	92,947,158	1,477,145	2,307,331	18,306,894	273,228
Cathode Copper 1/					13,461,772	
Total	10,822,187	92,947,158	1,477,145	2,307,331	31,768,666	273,228
ASARCO:						
Silver Bell	3,848,500	39,089,608		2,541,900	28,037,459	
Precipitate Copper		7,860,146			8,496,533	
Mission	7,539,100	80,664,685	649,919	5,089,800	53,891,133	432,304
San Xavier						
Precipitate Copper	1,221,000	11,762,040		1,368,600	19,384,305	
Sacaton 2/	1,926,500	19,032,682		3,606,400	43,835,162	
Total	14,535,100	158,409,161	649,919	12,606,700	153,644,592	432,304
CITIES SERVICE-MIAMI OPERATIONS						
MIAMI-COPPER CITIES OPERATIONS:						
Copper Cities 3/	3,698,317	31,472,441	109,081	1,670,090	19,055,546	19,760
Copper Cities Precipitate		3,294,832			3,561,559	
Miami - Precipitate		11,968,789			13,075,798	
Total	3,698,317	46,736,062	109,081	1,670,090	35,692,903	19,760
Pinto Valley Operations 4/	3,263,331	19,036,823		13,895,820	107,498,466	159,136
Total	6,961,648	65,772,885	109,081	15,565,910	143,191,369	178,896

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES (contd.)

Company Mine	1974 Tons Copper Ore Mined	1974 Pounds Recoverable Copper	1974 Pounds Recoverable Molybdenum	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum
CYPRUS MINES:						
Bagdad	2,171,161	24,717,342	611,741	2,082,099	23,599,989	716,792
Cathode Copper		13,508,462			14,320,802	
Bruce 5/	92,820	6,493,966		94,609	6,536,000	
Pima	20,017,884	170,450,752	1,735,022	19,630,974	154,541,515	1,814,263
Johnson 6/						
Cathode Copper				1,709,804	6,143,024	
Total	22,281,865	215,170,522	2,346,763	23,515,486	205,141,330	2,531,055
DUVAL:						
Esperanza	6,405,712	36,728,004	3,666,926	5,490,362	24,914,864	3,194,830
Precipitate Copper		1,816,891			3,960,323	
Mineral Park	6,379,877	32,535,537	2,837,052	5,573,875	27,472,411	2,781,954
Precipitate Copper		6,801,301			6,915,242	
Sierrita	30,497,451	159,187,623	11,342,997	31,430,788	186,727,062	13,286,923
Total	43,283,040	237,069,356	17,846,975	42,495,025	249,989,902	19,263,707
INSPIRATION:						
Inspiration	8,454,428	81,513,656		6,288,363	68,527,498	
Copper recovered by dump, in-place and vat leaching		17,887,479			21,266,570	
Christmas Division	1,677,272	13,397,391		1,403,835	11,729,139	
Ox Hide Mine	3,382,260	9,678,652		2,302,230	10,107,194	
Total	13,513,960	122,477,178		9,994,428	111,630,401	

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES (contd.)

Company Mine	1974 Tons Copper Ore Mined	1974 Pounds Recoverable Copper	1974 Pounds Recoverable Molybdenum	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum
KENNECOTT:						
Ray	11,721,547	150,516,709	682,514	6,692,267	86,516,592	330,032
Precipitate Copper		25,478,119			24,338,397	
Total	11,721,547	175,994,828	682,514	6,692,267	110,854,989	330,032
McALESTER FUEL COMPANY:						
Zonia Mine 7/						
Precipitate Copper		2,716,714			619,263	
Total		2,716,714			619,263	
MAGMA:						
San Manuel	19,725,713	248,846,856	4,219,793	16,778,247	187,487,000	5,303,201
Superior	732,937	60,937,589		1,087,694	78,048,000	
Total	20,458,650	309,784,445	4,219,793	17,865,941	265,535,000	5,303,201
PHELPS DODGE:						
Morenci Branch						
Morenci Mine	16,785,756	202,874,739		16,173,658	177,767,689	
Metcalf Mine 8/				5,556,145	58,389,398	
Precipitate Copper 9/		22,703,862			23,777,527	
New Cornelia Branch	9,038,923	86,999,288		7,270,059	66,045,992	
Copper Queen Branch						
Lavender Pit 10/	3,529,578	17,264,710				
Precipitate Copper		6,402,132			8,376,532	
Copper Queen Mine 11/	480,375	30,113,233		108,167	11,331,843	
Total	29,834,632	366,357,964		29,108,029	345,688,981	

COPPER AND MOLYBDENUM PRODUCTION OF LARGE ARIZONA COPPER MINES (contd.)

Company Mine	1974 Tons Copper Ore Mined	1974 Pounds Recoverable Copper	1974 Pounds Recoverable Molybdenum	1975 Tons Copper Ore Mined	1975 Pounds Recoverable Copper	1975 Pounds Recoverable Molybdenum
RANCHERS EXPLORATION AND DEVELOPMENT CORPORATION:						
Bluebird Mine						
Cathode Copper	5,472,101	15,344,171		4,375,485	15,121,572	
Old Reliable 12/						
Precipitate Copper		4,350,885			466,506	
Total	5,472,101	19,695,056		4,375,485	15,588,078	
Total Large Companies	178,884,730	1,766,395,267	27,332,190	164,526,602	1,633,652,571	28,312,423
Total (Az. Dept. of Min. Res. estimate)		1,766,864,434			1,633,749,690p	
Total (USBM-Official)	178,913,296	1,717,566,000	28,346,000	n.a.	1,626,422,000	26,409,063

Footnotes:

p preliminary
n.a.-not available
1/ Twin Buttes oxide plant came on line August 1975
2/ ASARCO's Sacaton Unit was formally dedicated in March 1974
3/ Copper Cities open-pit mine shutdown May 9, 1975
4/ Pinto Valley's initial start-up was in July 1974
5/ Cyprus Bruce Copper & Zinc Company mines a copper-zinc ore. The company is Arizona's largest zinc producer. In 1974, the mine produced 20,211,000 pounds of zinc. The 1975 production was slightly less at 19,124,000 pounds of zinc.
6/ Cyprus Johnson came on-stream March 15, 1975
7/ Stopped production in March 1975
8/ Phelps Dodge's Metcalf Mine and concentrator began production in January 1975
9/ The 1974 figure reflects precipitate copper production for the Morenci Mine only. The 1975 figure reflects both the Morenci and Metcalf Mines.
10/ The Lavender pit and Bisbee concentrator operations were terminated December 14, 1974.
11/ Phelps Dodge's Bisbee underground mines ceased operations on June 13, 1975, thus ending 100 years of production
12/ Stopped production July 1975

APPENDIX B: GLOSSARY OF MINING TERMS

Acid plant: The plant at the smelter site that recovers sulfur dioxide and manufactures from it sulfuric acid.

Anode: Fire-refined copper cast at the smelter into slabs weighing 600 to 1200 pounds of about 99.5% purity; shipped to an electrolytic refinery for final purification process. (see Anode copper)

Anode copper: Special-shaped copper slabs, resulting from the refinement of blister copper in a reverberatory furnace, used as anodes in electrolytic refinement. (see Anode)

Autogenous: The secondary grinding of ore by tumbling the material in a revolving cylinder with no balls or bars taking part in the operation.

Ball mill: A rotating horizontal steel cylinder loaded with steel balls which grind the ore to a fine powder consistency.

Beneficiation: Concentrating the copper content of the ore; the crushing, screening and grinding of ore and removal of copper-bearing minerals by a flotation process prior to smelting the copper concentrates.

Billet: Refinery shape primarily for tube manufacture. Circular in cross-section, usually 3 to 10 in. in diameter and in lengths up to 52 in.; weight from 100 to 1500 lbs.

Blister copper: An impure intermediate product in the refining of copper, produced by blowing copper matte in a converter, the name being derived from the large blister on the cast surface that results from the liberation of SO_2 and other gases. Normally blister copper is further refined at the smelter into a fire-refined copper and cast into anodes.

Block caving: A form of underground mining wherein a block of ore is removed by undercutting it, causing it to fall by gravity through previously driven raises and is loaded through chutes into mine cars, hauled to the shaft and lifted to the surface.

Cake: Refinery shape for rolling into plate, sheet, strip or shape. Rectangular in cross-section of various sizes. Cast either horizontally or vertically, with range of weights from 140 to 4000 lbs. or more.

Cathode: Unmelted flat plate refined from anodes in the electrolytic refinery into plates of 99.99 percent pure copper; these are shipped to factories to be melted and cast into shapes ready for rolling, drawing or extruding into finished products. The customary size is about 3 ft. square and about ½ to 7/8 in. thick weighing up to 280 lbs.

Cathode copper: Electrolytically refined copper which has been deposited on the cathode of the electrolytic bath of acidified copper sulfate solution. Such copper is usually melted as electrolytic copper. (see Cathode)

Chemical precipitation: In the leaching process, displacement of a metal from solution by a less noble metal. Usually less costly than electrolytic precipitation, but the latter produces a purer metal and regenerates the solvent. Also called cementation.

Concentrate: Copper-bearing material from the flotation process; contains 15% to 30% plus various quantities of sulfur, iron and other impurities.

Concentrating: See beneficiation.

Concentrator: A plant where ore or metal is freed and separated from its containing rock or earth. The concentration of ores always proceeds in steps or stages, e.g., crushing, sizing and flotation to produce a concentrate.

Converter: A brick-lined cylindrical vessel in the smelter for processing molten copper matte from the reverberatory furnace; the impurities, principally iron and sulfur, are removed by blowing air through the molten bath; the result is blister copper, about 99% pure.

Copper powder: Finely divided copper particles produced by (1) high velocity atomization of molten copper with stream of compressed gas, steam or water (2) gaseous reduction of finely divided oxides and (3) precipitation from solutions.

Crusher: A machine for crushing rock or other materials. Among the various types of crushers are the ball mill, gyratory crusher, rod mill, rolls, stamp mill and tube mill.

Development: The process of preparing an orebody for mining; sinking a shaft and driving haulage tunnels for an underground mine, or removing the overburden for an open-pit mine; installing crushers, concentrators, transporation, power and water lines, offices, shops, warehouses, etc.

Dump: The site for disposal of waste rock from the mine, or slag from the smelter; may be extremely low-grade or where dump leaching takes place.

Electrolytic deposition: The production of a metal from a solution containing its salts by the passage of an electric current through the solution. (see Electrowinning)

Electrolytic refinery: The process in which fire-refined copper anodes are immersed in an acid solution with pure copper cathode startersheets. An electric current passed between them deposits 99.99% pure copper on the cathodes.

Electrowinning: Recovery of a metal from an ore by means of electrochemical processes. (see Electrolytic deposition)

Electrolytic winning process, wherein copper from copper sulfate (leach) solution is electroplated onto cathodes, ready for market.

Exploration: The process of locating and proving that a mineral occurrence is indeed an orebody; that is, determining that it is large enough, contains enough copper to be mined profitably.

Ferro-molybdenum: Ferro-molybdenum is a ferroalloy which considerably increases the mechanical and physical properties of steels.

Fire refining: Last step in a smelter wherein molten blister copper from the converter is deposited in the refining (or casting) furnace and gas blown through it to remove more of the impurities, principally oxygen. Also, general term for pyrometallurgical refining or smelting.

Flat products: A rectangular or square solid section of relatively great length in proportion to thickness. Included in the designation "flat product" depending on the width and thickness, are plate, sheet, strip and bar. Also included is the product known as "flat wire."

Flotation: The process of mixing powdered ore with water and chemical reagents to separate the metallic particles from the waste rock; the metallic particles are collected and dried and this concentrate is sent to the smelter for fire refining.

Flux: Any chemical or rock added to an ore to assist in its reduction by heat, such as silica and limestone with copper ore in a convertor furnace.

Gangue: Undesired minerals associated with ore; that portion of the ore rejected as tailing in the flotation process.

Hydrometallurgy: The treatment of ores, concentrates and other metal-bearing materials by wet processes, usually involving the solution of some component and its subsequent recovery from the solution. (see Leaching)

Ingot and Ingot bar: Refinery shapes employed for alloy production (not fabrication). Both used for remelting. Ingots usually weigh from 20 to 35 lbs. and ingot bars from 50 to 70 lbs. Both usually notched to facilitate breaking into smaller pieces.

Leach material: Material sufficiently mineralized to the extent that it can be economically recovered by selectively dissolving the wanted mineral in a suitable solvent.

Leach pile: Mineralized materials stocked so as to permit wanted minerals to be effectively and selectively dissolved by application of a suitable solute.

Leaching: A process of using a weak sulfuric acid solution to dissolve copper from low-grade oxide ores; may take place in vats, heaps, dumps or in situ (in place).

Matte: A mixture of sulfur, iron and copper containing approximately 20% to 45% copper tapped from reverberatory furnace in the smelter.

Mill: The facility containing rod mills (if used) ball mills and flotation cells where the ore is ground and copper concentrate extracted. Also called the concentrator. (see Concentrator)

Open-pit mining: A surface mining method in which overlying rock and soil are removed to expose the orebody which is then drilled, blasted and loaded into trucks or railroad cars for haulage from the pit.

Ore: Rock containing enough mineral value to warrant the expense of mining it.

Orebody: Generally a solid and fairly continuous mass of ore which may include low-grade and waste as well as pay ore, but is individualized by form or character from adjoining country rock.

Oxide ore: Ore containing copper minerals which have been altered by oxidation or weathering process.

Pelletizing: A method in which finely divided material is rolled in a drum or on an inclined disk so that the particles cling together and roll up into small, spherical pellets.

Pipe: Seamless tube conforming to the particular dimensions, commercially known as "standard pipe sizes."

Porphyry copper: a. Disseminated copper minerals in a large body of porphyry. b. In the commercial sense, the term is not restricted to ore in porphyry but is applied to deposits characterized by huge size, particularly with respect to horizontal dimension, uniform dissemination and low-average-per-ton copper content.

Pregnant solution: A value-bearing solution in a hydrometallurgical operation.

Prospecting: The process of searching for new mineral deposits.

Pyrometallurgy: Metallurgy involved in winning and refining metals where heat is used, as in roasting and smelting. It is the most important and oldest of the extractive processes.

Related ground facilities: Roads, power and water lines, offices, shops, warehouses, etc.

Reverberatory furnace: In the smelter, the furnace in which copper concentrates are melted, slag drawn off and molten copper-bearing matte tapped for further processing.

Rod: A round, hexagonal or octagonal solid section. Round rod for further processing into wire (known as "hot-rolled rod," "wire-rod," or "redraw wire") is furnished coiled. Rod for other uses is furnished in straight lengths.

Rod mill: A rotating horizontal steel cylinder in which steel rods initially grind the crushed ore.

Shape: A solid section, other than rectangular, square or standard rod and wire sections, furnished in straight lengths. Shapes are usually made by extrusion but may also be fabricated by drawing.

Sheet: see Flat products.

Slag: Waste rock from the smelter. The black lava-like material is primarily iron and silica.

Slurry: A liquid mixture of finely ground particles of rock and minerals in water.

Smelt; smelting: Any metallurgical operation in which metal is reparted by fusion from those impurities with which it may be chemically combined or physically mixed, such as in ores.

Smelter: In the United States, smelting works; an establishment where ores are smelted.

Smelting: The chemical reduction of a metal from its ore by a process usually involving fusion, so that the earthy and other impurities separating as lighter and more fusible slags, can readily be removed from the reduced metal.

Sponge iron: Either porous or powdered iron produced directly without fusion.

Sulfide ore: Ore composed of copper, sulfur and usually iron along with the various other minerals making up the host rock.

Tailing pond: Area closed at lower end by constraining wall or dams to which mill effluents are run. Clear water may be returned after settlement in dam, via penstock(s) and piping.

Tailings: The finely-ground residue or waste materials contained in the ore remaining after floating off the copper-bearing concentrate.

Tailings dam: One to which slurry is transported, the solids settling while the liquid may be withdrawn.

Tube: A hollow product of round or any other cross-section, having a continuous periphery.

Underground mining: Extraction of ore through vertical shafts from the surface or horizontal tunnels drifts or cross-cuts driven into the orebody.

Vat: A vessel or tub in which ore is washed or subjected to chemical treatment. Used as a synonym for tank.

Vertically integrated: A combining of business firms engaged in different phases of the manufacture and distribution of a product into an interacting whole.

Wire: A solid section, including rectangular flat wire but excluding other flat products, furnished in coils or on spools, reels or bricks. Flat wire may also be furnished in straight lengths.

Wire bar: Refinery shape for rolling into rod (and subsequent drawing into wire) strip or shape. Approximately 3½ to 5 in. square in cross-section, usually from 38 to 54 in. in length and weighing from 135 to 420 lbs. Tapered at both ends when used for rolling into rod for subsequent wire drawing and may be unpointed when used for rolling into strip. Cast either horizontally or vertically.

BIBLIOGRAPHY

Amax Incorporated. 1974 Annual Report, Amax Incorporated, New York, 1975.

Amax Incorporated. 1975 Annual Report, Amax Incorporated, New York, 1976.

Amax Incorporated. Prospectus, February, 1976.

Amax Incorporated. Securities And Exchange Commission, Form 10-K, 1975, Amax Incorporated, New York, 1975.

American Bureau of Metal Statistics Inc. NON-FERROUS METAL DATA 1975, American Bureau of Metal Statistics Inc., New York, 1976.

American Geological Institute. Glossary of Geology and Related Sciences with Supplement, American Geological Institute, Washington, D.C., 1966.

American Smelting And Refining Company. 1974 Annual Report, American Smelting And Refining Company, New York, 1975.

Asarco Incorporated. 1975 Annual Report, Asarco Incorporated, New York, 1976.

American Smelting And Refining Company. Securities And Exchange Commission, Form 10-K, 1974, American Smelting and Refining Company, New York, 1974.

Asarco Incorporated. Securities and Exchange Commission, Form 10-K, 1975, Asarco Incorporated, New York, 1975.

The Anaconda Company. 1974 Annual Report, The Anaconda Company, New York, 1975.

The Anaconda Company. 1975 Annual Report, The Anaconda Company, New York, 1975.

The Anaconda Company. Securities and Exchange Commission, Form 10-K, 1975, The Anaconda Company, New York, 1975.

Beall, John V. "Copper in the U.S.—a Position Survey." Mining Engineering, Vol. 25, No. 4 (April 1973):35-47.

Bennett, Harold J., et al. An Economic Appraisal of the Supply of Copper From Primary Domestic Sources. Bureau of Mines Information Circular 8598, 1973.

Bureau of Mines. A dictionary of Mining, Mineral and related terms, U.S. Dept. of the Interior, Bureau of Mines, 1968.

Cities Service Company. 1975 Annual Report, Cities Service Company, Oklahoma, 1976.

Cities Service Company. Securities And Exchange Commission Form 10-K, 1975, Cities Service Company, Oklahoma, 1975.

Clay, J.A. "Copper in the Mining Annual Review." Mining Journal, London, (June 1976):37-41.

Continental Oil Company. 1974 Annual Report, Continental Oil Company, Connecticut, 1975.

Continental Oil Company. 1975 Annual Report, Continental Oil Company, Connecticut, 1976.

Conway, Vincent J. and Threnthan, Robert E. Copper-Situation Report, Merrill Lynch Pierce Fenner & Smith Inc. September 1975.

"Copper in the Mining Annual Review." Mining Journal, London (June 1974):41-44.

"Copper in the Mining Annual Review." Mining Journal, London (June 1975):45-48.

Cyprus Mines Corporation. 1973 Annual Report, Cyprus Mines Corporation, California, 1974.

Cyprus Mines Corporation. 1974 Annual Report, Cyprus Mines Corporation, California, 1975.

Cyprus Mines Corporation. Securities And Exchange Commission Form 10-K, 1974, Cyprus Mines Corporation, California, 1974.

Cyprus Mines Corporation. Securities And Exchange Commission Form 10-K, 1975, Cyprus Mines Corporation, California, 1975.

Dimock, Robert R. "Solution Mining." Mining Engineering, Vol. 28, No. 2 (February 1976):58-61.

Evans, Lamar and Sheffer, Herman W. "Dump and Heap Leaching Practices in the Western United States." Mining Congress Journal, Vol. 54, No. 9, (September 1968):96-100.

Everett, Floyd D. "The Mineral Industry of Arizona in 1974." Mineral Industry Surveys, Bureau of Mines, Washington, December 1974.

Everett, Floyd D. "The Mineral Industry of Arizona in 1975." Mineral Industry Surveys, Bureau of Mines, Washington, December 1975.

Fletcher, James B. "In-Place Leaching." Skillings Mining Review, Vol. 63, No. 17 (April 27, 1974):1, 8-10.

Griffith, W.A. et al. "Development of the Roast-Leach-Electrowin Process for Lakeshore," Hecla Mining Company, Wallace, Idaho, 1973.

Hecla Mining Company. 1974 Annual Report, Hecla Mining Company, Idaho, 1975.

Hecla Mining Company. 1975 Annual Report, Hecla Mining Company, Idaho, 1976.

"Hydrometallurgy." Engineering and Mining Journal, Vol. 177, No. 6 (June 1976):244-46.

Inspiration Consolidated Copper Company. 1974 Annual Report, Inspiration Consolidated Copper Company, Arizona, 1975.

Inspiration Consolidated Copper Company. 1975 Annual Report, Inspiration Consolidated Copper Company, Arizona, 1976.

Kennecott Copper Corporation. 1974 Annual Report, Kennecott Copper Corporation, New York, 1975.

Kennecott Copper Corporation. 1975 Annual Report, Kennecott Copper Corporation, New York, 1976.

Kennecott Copper Corporation. Securities and Exchange Commission Form 10-K, 1974, Kennecott Copper Corporation, New York, 1974.

Leseman, Robert H. "Copper-Huge Stock Buildup Will Slow Market Recovery." Engineering and Mining Journal, Vol. 177, No. 3, (March 1976):88-91.

Li, Ta M. and Carter, Russ. "Pinto Valley Copper Mine - Blueprint for Insured Productivity." Mining Engineering, Vol. 27, No. 6 (June 1976):25-33.

McMahon, A.D. Copper A Materials Survey. Bureau of Mines Information Circular 8225, 1965.

Newmont Mining Corporation. 1974 Annual Report, Newmont Mining Corporation, New York, 1975.

Newmont Mining Corporation. 1975 Annual Report, Newmont Mining Corporation, New York, 1976.

Newmont Mining Corporation. Securities and Exchange Commission Form 10-K, 1975, Newmont Mining Corporation, New York, 1975.

Parkinson, Gerald. "Cyprus develops moly-talc separation float." Engineering and Mining Journal, Vol. 177, No. 5 (May 1976):97.

Pennzoil Company. 1973 Annual Report, Pennzoil Company, Texas, 1974.

Pennzoil Company. 1975 Annual Report, Pennzoil Company, Texas, 1976.

Pennzoil Company. Prospects offering debentures. Pennzoil Company, May 1975.

Pennzoil Company. Securities and Exchange Commission, Form 10-K, 1975, Pennzoil Company. Texas, 1975.

Perlman, Louis. "Copper-There has never been a year like 1973." Engineering and Mining Journal, Vol. 175, No. 3 (March 1974): 64-66.

Phelps Dodge Corporation. 1974 Annual Report, Phelps Dodge Corporation, New York, 1975.

Phelps Dodge Corporation. 1975 Annual Report, Phelps Dodge Corporation, New York, 1976.

Phelps Dodge Corporation. Prospectus offering debentures, June 1971.

Phelps Dodge Corporation. Securities and Exchange Commission Form 10-K, 1974, Phelps Dodge Corporation, New York, 1974.

Phelps Dodge Corporation. Securities and Exchange Commission Form 10-K, 1975, Phelps Dodge Corporation, New York, 1975.

Phillips, Ken A. THE COPPER INDUSTRY - Statistics For 1974 Compared With Other Years Arizona, The United States And The World. Arizona Department of Mineral Resources, Phoenix, Arizona, February, 1975.

Phillips, Ken A. and Miller, Glenn A. THE COPPER INDUSTRY - Statistics For 1974 Compared With Other Years Arizona, The United States And The World. Arizona Department of Mineral Resources, Phoenix, Arizona, February 1976.

Ranchers Exploration and Development Corporation. 1974 Annual Report, Ranchers Exploration and Development Corporation, New Mexico, 1975.

Ranchers Exploration and Development Corporation. 1975 Annual Report, Ranchers Exploration and Development Corporation, New Mexico, 1976.

Roberts, Rollin W. San Xavier Vat Leach Plant operation, presented at the 1974 Mining Convention/Exposition of the American Mining Congress, Las Vegas, Nevada, American Mining Congress, Washington, D.C., 1974.

Schroeder, Harold J. "Copper in 1974." Mineral Industry Surveys, Bureau of Mines, Washington, April 1975.

Schroeder, Harold J. "Copper in 1975." Mineral Industry Surveys, Bureau of Mines, Washington, March, 1976.

Sheffer, Herman W. and Evans, La Mar G. Copper Leaching Practices In The Western United States. Bureau of Mines Information Circular 8341, 1968.

Simpson, William A.B. "Copper-Demand drops, prices plunge, reflecting World economic blues," Engineering and Mining Journal, Vol. 176, No. 3 (March 1975):90-92.

Skillings Jr., David N. "Ranchers' Old Reliable Project Reaches Full Capacity." Skillings Mining Review, Vol. 63, No. 12 (March 23, 1974):1, 12-15.

Spendlove, Max J. Methods For Producing Secondary Copper. Bureau of Mines Information Circular 8002, 1961.

U.S. Congress. Senate Committee on Government Operations. Materials Shortages - Copper. S. Rept. 1975, 94th Cong., 1st Session, 1975.