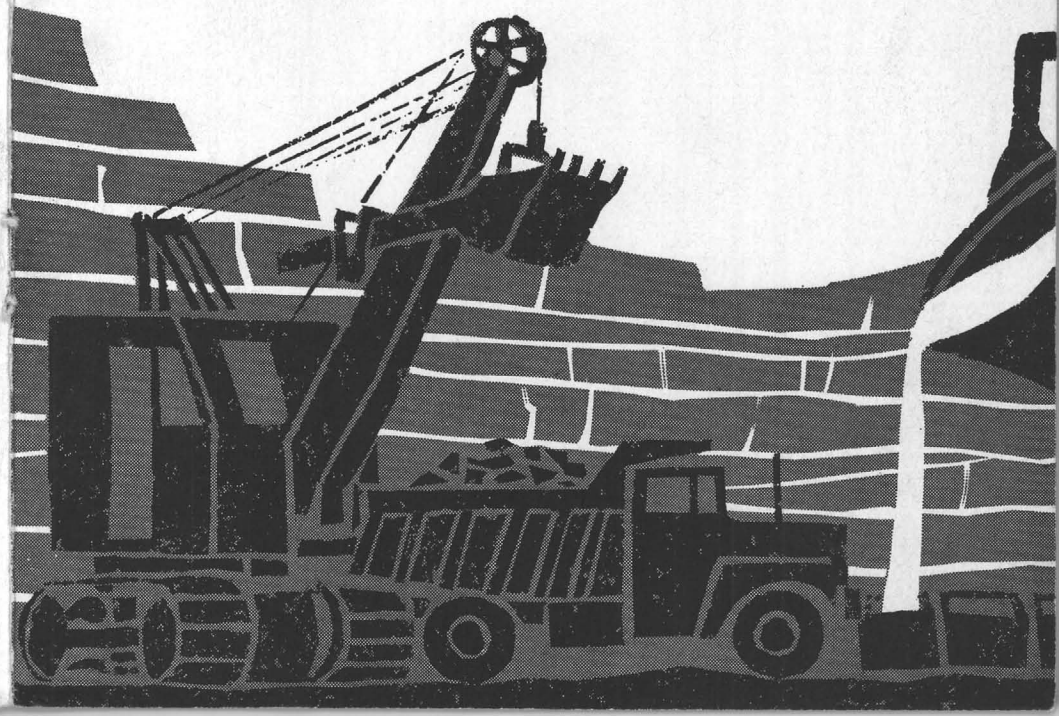
mining in arizona

ITS PAST
ITS PRESENT
ITS FUTURE

ARIZONA DEPT. OF MINERAL RESOURCES



Superstition

DEPARTMENT OF MINERAL RESOURCES
STATE OF ARIZONA

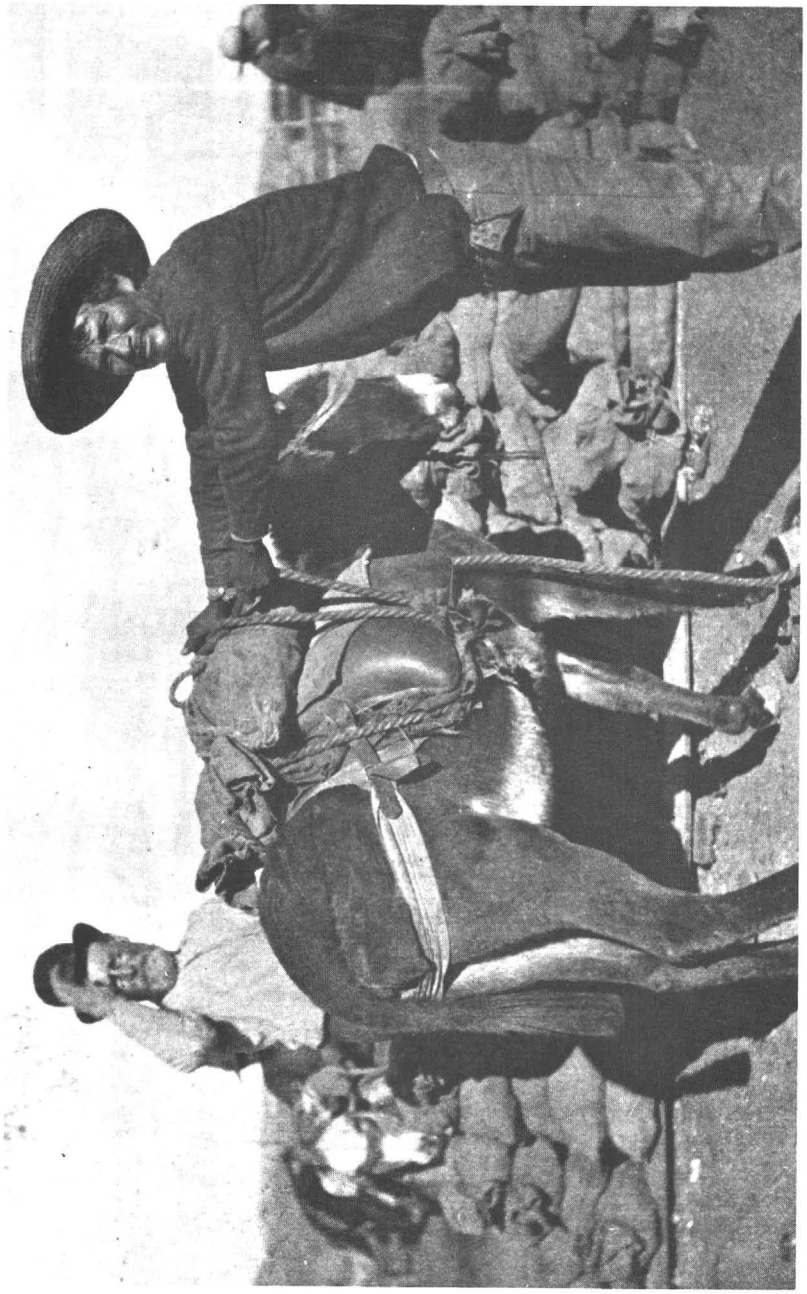
FRANK P. KNIGHT, DIRECTOR

MINING IN ARIZONA

Its Past
Its Present
Its Future

REVISED EDITION
BY
F. P. KNIGHT

APRIL 1970



Early Day Ore Packing

TABLE VIII

Mineral Production of Large and Small Producers in Arizona in 1968[1]

Source: U. S.B.M. Area Report for Arizona, 1968

LARGE COPPER PRODUCERS:*		PRODUCTION	VALUE
Copper	(short tons)	619,675	$518,631,000
Gold	(troy ozs.)	89,419	3,511,000[2]
Silver	(troy ozs.)	4,697,394	10,074,000
Molybdenum (in concentrates)	(lbs.)	12,127,000	19,207,000
			$551,423,000
SMALL MINERAL PRODUCERS:			
Clays	(short tons)	77,000	$ 347,000
Copper (Recoverable)	(short tons)	8,286	6,935,000
Gem Stones		NA	149,000
Gold (Recoverable)	(troy ozs.)	6,580	258,000[2]
Helium, Grade A	(thousand cu. feet)	64,800[3]	1,600,000[3]
Iron Ore (Usable)	(long tons)	16,000	124,000
Lead (Recoverable)	(short tons)	1,704	450,000
Lime	(short tons)	260,000	4,561,000
Mercury	(76 lb. flasks)	192	103,000
Natural Gas (Marketed)	(million cu. ft.)	881	142,000
Petroleum (crude)	(42 gal. bbls.)	3,370,000	9,606,000
Pumice	(short tons)	1,033,000	974,000
Sand and Gravel	(short tons)	13,981,000	14,423,000
Silver	(troy ozs.)	260,768	559,000
Stone	(short tons)	3,293,000	6,239,000
Tungsten Concentrate (60% WO_3)	(short tons)	1	3,000
Uranium (Recov. Cont. U_3O_8)	(pounds)	295,000	1,923,000[4]
Zinc (Recoverable)	(short tons)	5,441	1,469,000
Value of items withheld to avoid disclosing individual company confidential data: Asbestos, Cement, Diatomite, Feldspar, Gypsum, Mica (Scrap), Perlite, Pyrites, Vanadium, Vermiculite, and Zeolite			16,255,000
Small Mine Sub-Total			66,120,000
TOTAL			$617,543,000
Percentage Due to Small Mines			10.7%

* Phelps Dodge, Kennecott, Miami, Inspiration, Magma, ASARCO, Pima, Bagdad and Duval.

NA — Not Available.

[1] Production as measured by mine shipments, sales or marketable production (including consumption by producers).

[2] Based on Average U. S. Treasury Price ($35.00) Jan. 1, 1968 through March 15, 1968, and the New York selling price for the remainder of the year.

[3] Bureau of Mines estimate from non-company sources.

[4] Estimate based on $8.00 per pound for sales to the Atomic Energy Commission and an assumed price of $6.50 per pound for commercial sales.

TABLE VII

Value of Mineral Production in Arizona, by Counties

Source: U.S. Bureau of Mines

County	1967	1968	Minerals produced in 1968 in order of value
Apache	$ 11,895,000	$ 12,190,000	Petroleum, helium, sand and gravel, clays, natural gas, pumice, uranium, vanadium, stone.
Cochise	30,675,000r	W	Copper, lime, silver, stone, gold, sand and gravel, zinc, lead.
Coconino	3,541,000	6,055,000	Uranium, stone, sand and gravel, pumice, copper, silver, lead, zinc.
Gila	43,680,000	61,248,000	Copper, lime, asbestos, molybdenum, silver, stone, gold, sand and gravel, mercury, clays.
Graham	311,000	157,000	Sand and gravel, copper, pumice, stone.
Greenlee	64,893,000	92,925,000	Copper, lime, silver, stone, gold, sand and gravel, molybdenum.
Maricopa	6,229,000r	7,134,000	Sand and gravel, lime, mercury, mica, stone, clays, copper, gold, silver, vermiculite.
Mohave	26,682,000	31,535,000	Copper, molybdenum, silver, sand and gravel, stone, feldspar, zinc, gold, clays, lead.
Navajo	802,000	W	Sand and gravel, iron ore, stone.
Pima	151,151,000r	198,077,000	Copper, cement, molybdenum, silver, sand and gravel, gold, stone, zinc, clays, lead, tungsten.
Pinal	91,310,000r	129,325,000	Copper, molybdenum, silver, gold, sand and gravel, perlite, gypsum, stone, lime, pyrites, diatomite, iron ore, lead.
Santa Cruz	581,000r	W	Sand and gravel, silver, stone, lead, tungsten concentrate, copper.
Yavapai	30,488,000	30,312,000	Copper, cement, zinc, molybdenum, stone, silver, lime, lead, sand and gravel, gold, gypsum, clays, iron ore, pumice.
Yuma	2,869,000r	W	Copper, sand and gravel, stone, silver, lead, tungsten concentrate, zinc.
Undistributed[1]	150,000	48,580,000	
Total[2]	$465,255,000r	$617,541,000	

r — Revised. W — Withheld to avoid disclosing individual company confidential data; included with "Undistributed."

[1] Includes gem stones that cannot be assigned to specific counties and values indicated by symbol W in 1968.

[2] Data may not add to totals shown because of independent rounding.

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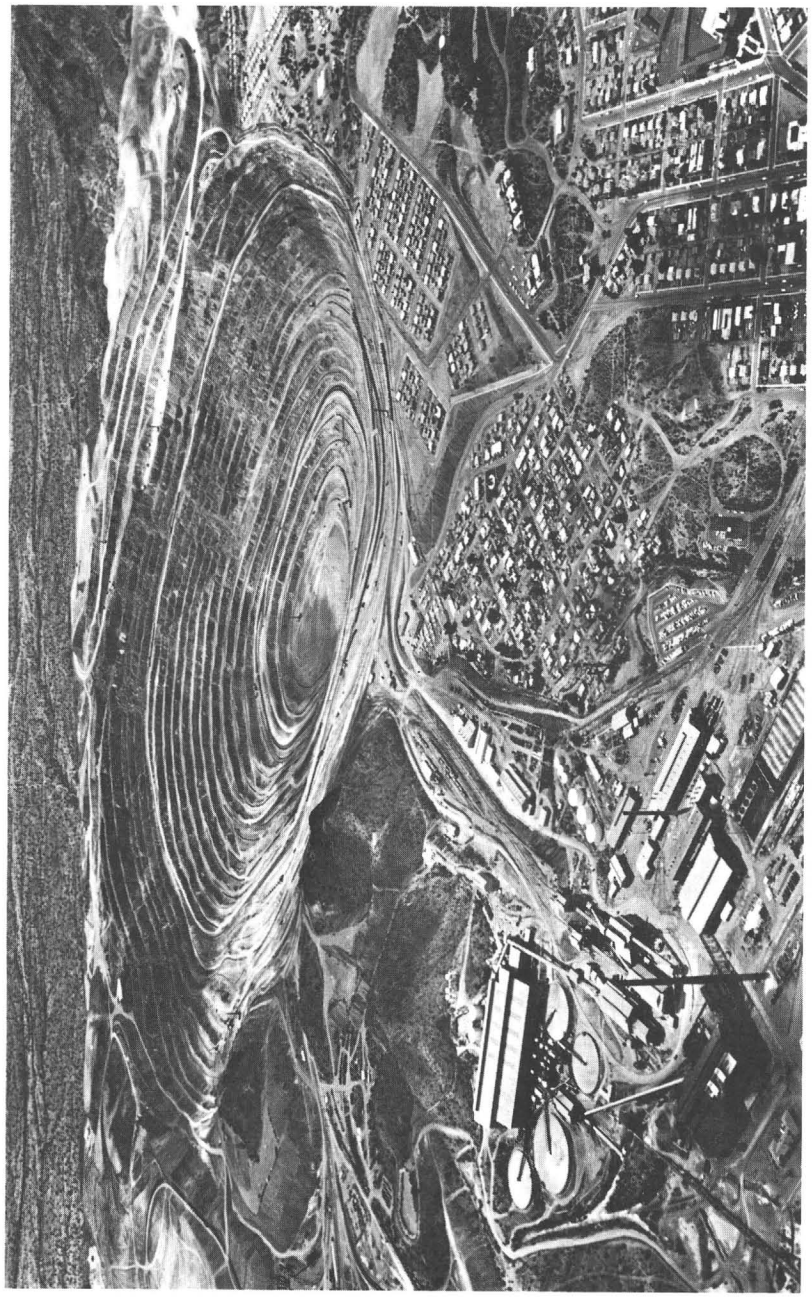


An Open Pit Copper Mine — A Copper Town — Ajo

The State flag represents the copper star of Arizona rising from a blue field in the face of a setting sun. The lower half is a blue field, the upper half is divided into 13 equal rays which start at the center, continue to the edges of the flag and consist of six yellow and seven red rays. A five-pointed copper star is superimposed on the center of the flag.

Arizona's State bird, the tiny cactus wren, likes to build his home in the protection of the thorny desert plants. Because of this he often builds his nest in the arms of the giant sahuaro cactus. He builds several nests but lives in only one—the rest are decoys. He is a woody brown bird with a speckled breast.

The State flower is the pure white, waxy flower of the sahuaro cactus, which blooms in the late spring. Blooms are found on the tips of the sahuaro arms. Many sahuaros are more than 100 years old, and some attain a height of 50 feet.

The Census of 1960 showed the population of Arizona to be 1,302,161; 74 percent higher than the census figure for 1950. The population as of July 1969 has been estimated at 1,741,000. In 1900, it was 122,931. Arizona is one of the Nation's fastest growing states.

Population figures by counties are as follows:

	1960[1]	1969[2]		1960[1]	1969[2]
Apache	30,438	46,500	Mohave	7,736	21,000
Cochise	55,039	66,500	Navajo	37,994	49,900
Coconino	41,857	56,200	Pima	265,660	343,200
Gila	25,745	26,900	Pinal	62,673	63,600
Graham	14,045	15,400	Santa Cruz	10,808	14,400
Greenlee	11,509	9,700	Yavapai	28,912	34,700
Maricopa	663,510	930,000	Yuma	46,235	63,000
			Total	1,302,161	1,741,000

[1] Census.
[2] July 1, 1969 Estimate — Employment Security Commission of Arizona.

ciation has assumed the burden. Besides the minerals in the display, there is a fine collection of almost every type of rock found in Arizona. The Museum is valuable for study purposes as well as interesting and informative to visitors, regardless of their interest in mining as an industry.

"LOST" MINES

Arizona is rich in legends of many "lost" mines.

Perhaps 98 percent of the stories of "lost" mines are pure fiction. The mines exist only in one's imagination. True, the stories are interesting, especially to newcomers, but they are likewise dangerous. Many lives have been lost searching for these mythical mines, and in addition, the communities are put to extra expense for posses and searching parties.

"Don't believe" is sound advice regarding lost mines. Forget the lost mines shown on the "old-map-my-grandfather-bought-from-an-old-Spaniard-he-befriended." It simply doesn't exist. The rich ore that is supposed to have been obtained from a "lost" mine—and some were very rich—in all probability was "high-graded" (stolen) from some of the early-day rich mines then working.

To a tourist in good health, and accompanied by an experienced prospector, the search for a "lost" mine is a healthful and interesting diversion during the winter months. Such trips always have the possibility of discovering some overlooked mineralized out-crop of promise—a neglected, rather than a "lost" mine.

ARIZONA

The word "Arizona" is believed to have been derived from two Indian languages—Papago and Pima—and means "Little Spring." "Ari" means small and "Zonac" spring.

Arizona is the 48th state admitted to the Union, the seventh largest, and has an area of 113,956 square miles. The State was organized as a territory in 1863, and was admitted to the Union on February 14, 1912.

Mining In Arizona

Arizona is by far the largest producer of non-ferrous metals in the United States. In 1969, it produced over one-third (35%) of the dollar value of all of these metals produced in all of the 50 states. It ranked first among the states in copper production; second in silver; second in molybdenum; fourth in gold; thirteenth in zinc; and sixteenth in lead. A tabulation of its annual production of these metals for the years 1957 to 1969 is given on the next page.

HISTORY — GENERAL

In the period from 1858 to 1969 inclusive, Arizona's mines have yielded more than $13.0 billion, 94 percent of which came from their six associated metals: copper, molybdenum, silver, gold, zinc and lead in order of importance. While all phases of the mining industry contributed to this achievement, it is to the pioneer prospectors and miners we of this "machine age" owe an everlasting debt. They blazed the trails through the deserts, into the canyons, and over the mountains; braving their terrors, conquering their difficulties, and in the end, wresting wealth from their age-long secrets and hidden hoards.

Their search for gold and silver—and later copper, lead and zinc—resulted in the eventual supply of metals so essential to our Nation's defense efforts and space age accomplishments. Other important metals were recovered also. The most important of these to Arizona today is molybdenum, now second only to copper in value of minerals produced in the State. It is recovered as a by-product from the copper ores of 13 Arizona mines, some of which are so low in copper content that they could not be mined economically were it not for the value of the associated molybdenum content.

It is known that the Indians did little mining except for coal to burn, turquoise for jewelry, iron oxide for paint, clay for pottery, and salt for seasoning. Neither did the first white men do any.

TABLE I

	Gold oz.	Silver oz.	Copper lbs.	Lead lbs.	Zinc lbs.	Molybdenum lbs.
1957	152,499	5,279,323	1,031,708,000	24,882,000	67,810,000	2,385,000
1958	142,979	4,684,580	971,678,000	23,780,000	54,064,000	2,320,000
1959	124,627	3,898,336	860,594,000	19,998,000	74,650,000	3,181,000
1960	143,064	4,774,992	1,077,210,000	16,990,000	71,622,000	4,359,000
1961	145,959	5,120,007	1,174,106,000	11,874,000	59,170,000	4,878,000
1962	137,207	5,453,585	1,288,484,000	13,932,000	65,776,000	4,412,000
1963	140,030	5,373,056	1,321,954,000	11,630,000	50,838,000	5,553,000
1964	153,676	5,810,510	1,381,976,000	12,294,000	49,380,000	6,296,000
1965	150,431	6,095,285	1,406,754,000	11,826,000	43,514,000	9,399,000
1966	142,528	6,338,696	1,479,138,000	10,422,000	31,970,000	10,161,000
1967	80,844	4,588,081	1,003,482,000	9,542,000	28,660,000	9,261,000
1968	95,999	4,958,162	1,255,922,000	3,408,000	10,882,000	12,127,000
1969[P]	110,300	6,071,000	1,594,700,000	400,000	17,920,000	12,698,000

P = Preliminary

erties. Many valuable bulletins, maps and pamphlets also are available, although a number of them are out of print and must be sought at a library or at such bureaus as above.

"Pay Dirt," a publication devoted to the interests of the Arizona Small Mine Operators and connected with their Association, contains mining news and information of value to those interested in the industry.

Mining conditions change. New facts are discovered each day, to the advancement of mining and metallurgical technology. Today's waste rock will be tomorrow's ore. The demand for metals will continue to mount, and the mining industry will continue to meet the demand.

ARIZONA DEPARTMENT OF MINERAL RESOURCES

This department, with offices in the Mineral Building at the Fairgrounds in Phoenix, is a state agency established to assist the more extensive exploration and development of the mineral resources of the state. The department engineers render assistance within the limitations of their public position. The department's files contain information on many properties, and its library includes many out-of-print U. S. Geological Survey and U. S. Bureau of Mines publications, all very valuable for reference. Technical trade journals, late information on pending legislation, market and price data, mineral rights and other mining information are on file.

MINERAL MUSEUM

The Mineral Building, finished in 1919, houses a fine collection of minerals. For many years this valuable display was open to the public only during the 10-day period of the Arizona State Fair in November of each year. Early in 1953, the following mining companies provided funds to keep the exhibit open on a year-round basis under the supervision of a director: American Smelting and Refining Company, Inspiration Consolidated Copper Company, Kennecott Copper Corporation, Magma Copper Company, Miami Copper Company and Phelps Dodge Corporation. More recently the Arizona Mining Asso-

Leaching in 1969 was used in the recovery of 8.6 percent of Arizona's total copper production. Most of the material leached was in dumps of the major copper mines. It had contained too little copper to be processed in the regular manner and had to be put in dumps.

Economical recovery of metals by large tonnage mining requires enormous amounts of capital investment. For each ton of annual capacity of copper production, a mine today may have to have two or three thousand dollars invested. This means that all mining ventures must be very carefully considered. It takes several years to bring a mine to the point of profitable production, and the risk of never getting there is higher than it is for the average industry. Costs of labor, supplies, and taxes have multiplied since 1940, and trends of such costs are important in considerations of investments in mine developments, especially those which appear at all marginal. Laws, regulations and taxes which might repel such investments should be carefully considered in the light of the needs of Arizona and the Nation for maintained mineral production and new mines coming along as needed. The importance of minerals to the Nation's welfare and security is recognized by the President, the Congress and most of the people.

Arizona seeks and welcomes new mining venture capital. Investors are cautioned to "investigate before venturing," because mining is a highly specialized industry, requires special know-how, and is risky, especially when a small mine is involved. Those considering a mining investment need the best advice they can get.

The small investor in mining now has several advantages over venture capital of early days. Legally, they are better protected in their investments. Technically, they can enlist the aid of the Arizona Department of Mineral Resources, the Arizona Bureau of Mines, and the United States Geological Survey, and the United States Bureau of Mines. These agencies can and will furnish data as to the geology and mining history of Arizona mining districts and of many mining prop-

Long before the white man had begun settling in America he had explored portions of Arizona. It was the lure of the metals—gold and silver—that prompted Coronado's famous expedition in search of the Seven Cities of Cibola, and in 1540, eighty years before the Mayflower left England, Coronado's Army Captain, Cardenas, stood on the brink of Arizona's Grand Canyon. Coronado, however, wanted his gold and silver already mined, smelted and minted. Consequently, he did no prospecting.

In 1583, thirty-seven years before the landing of the Pilgrim Fathers, a white man, Antonio Espejo, found a deposit thought to be silver ore in what is now Arizona. It was Arizona's first recorded mineral discovery.

There appears to have been little prospecting done following Espejo's discovery until early in the 18th century when some silver mining was done. However, neither the Spaniards nor the Mexicans did other than small scale gold or silver mining in the 18th century; and what was done was near Tucson and other presidios where there was some protection from Indian raids.

From about 1824 to 1842, much of Arizona was covered by American trappers and explorers, among them Bill Williams, Pauline Weaver and Kit Carson. Apache raids prevented settlement and mining, however, until well after 1848, when that portion of Arizona north of the Gila River became part of the United States. 1848 was the year gold was discovered in California at Sutter's Mill, and while thousands of emigrants crossed Arizona in 1848-1849 enroute to the "gold diggins," few stopped to prospect. There are, however, authenticated stories that Papago Indians had found gold near Gila City, Yuma County, in 1846, or two years prior to the California discovery.

Following the Gadsden Purchase in 1854, southern Arizona was actively prospected. In that year claims were located at Ajo. Mines were worked in the Santa Rita, Patagonia, and other Mountains and places south of Tucson. With the outbreak of the Civil War in 1861, and withdrawal of U. S. soldiers, the Apaches "took over" for some 10 years. However, soldiers

came in from California in 1862-63 and rich gold placers at La Paz, Rich Hill, Lynx Creek and elsewhere were found and mined. Soldiers stationed at Fort Mohave discovered gold lodes near what is now Oatman. It was about that time too, that many other famous mines were discovered—Vulture, Planet, Castle Dome, and many of the rich mines of the Prescott region.

The '70's witnessed the discovery and development of many great Arizona mining camps, some of which are still yielding great mineral wealth. Globe-Miami, Silver King, Superior, Bisbee, Jerome, Tombstone and Clifton-Morenci are among the mining districts founded in that period.

All these camps etched for themselves colorful pages in Arizona's early history, but perhaps the once-riotous Tombstone succeeded in leaving the most indelible impression. "Instead of a mine, you'll find a tombstone," said a fellow soldier to Ed Schieffelin in 1877 as he set out from Fort Huachuca, near the Mexican Border, to "look for stones." Schieffelin recalled the warning, and when he came across some rich appearing ore, said to himself, "Here is my tombstone." That is how the camp received its name. Since then stories of its development, its frontier sheriffs who brought law and order to one of the wildest mining camps in the then very wild West, and its rugged inhabitants, have appeared in many articles and books.

Untold centuries ago there was locked away in Arizona's mighty mountain vaults, stores of precious metals—an important supply necessary for our increasing commerce, industry and population. The doors of these vaults were fitted with time locks. Those already opened have given the world rich treasures. Others as yet unlocked await but the same combination—need, capital, science, brains, courage, faith and work.

Table II is a summarized tabulation of Arizona's production of its six principal metals.

THE FUTURE AND ARIZONA'S MINERALS

Arizona has been the Nation's richest storehouse of metals and is likely to remain so for many years. Its chief metal, copper, has a bright future. Millions are being spent on mineral exploration in the State. New orebodies have been found and new ones are coming into production. New findings are being investigated for possible development. Improvements are being made in the already remarkable methods of detecting mineralized areas below the surface. Holes will be drilled into such areas and new ore deposits will be found.

Large areas of the older mining districts of Arizona have contained valuable minerals in quantities previously considered to be submarginal profitwise. Some of these areas are now being mined profitably, thanks to greatly improved methods and equipment for mining their ores and recovering their metals. The improvement continues at an ever increasing rate, a fact that gives assurance that the difficult problems of meeting the mineral demands of the rapidly expanding population of the world will be met.

Mines long shut down may become attractive for exploration; may be found to be the center of what now is an extensive orebody instead of the waste it was previously thought to be. Present-day equipment for handling large tonnages cheaply, has made the difference.

A number of known mineral deposits containing amounts of oxides, carbonates and silicates of copper and other metals, until recently have remained undeveloped because processing methods for economically extracting the metals were not known. Several deposits of this nature are now being mined by open pit methods, the metals being extracted by chemical leaching. At the Blue Bird mine near Miami, Arizona, a process known as solvent extraction followed by electrolytic precipitation is producing quality copper from leach solutions from oxide ores, thus avoiding smelting. Intensive research is being done to try and find a method of chemically extracting copper from sulphide ores in order to avoid smelting and its emissions of gases containing oxides of sulphur.

liquid helium were sold after a liquefier was installed in 1964. Production from the Navajo Springs field was first reported in 1965. In 1966 the Navajo plant was independent of the Government helium program. Two new plants were added in 1968, one at Navajo and the other at Teec Nos Pos. The latter, owned by Air Reduction Company, shipped some of its helium in the crude state. The one at Navajo, built by Arizona Helium Corporation, began production in May 1969 but closed before the end of the year.

TABLE II

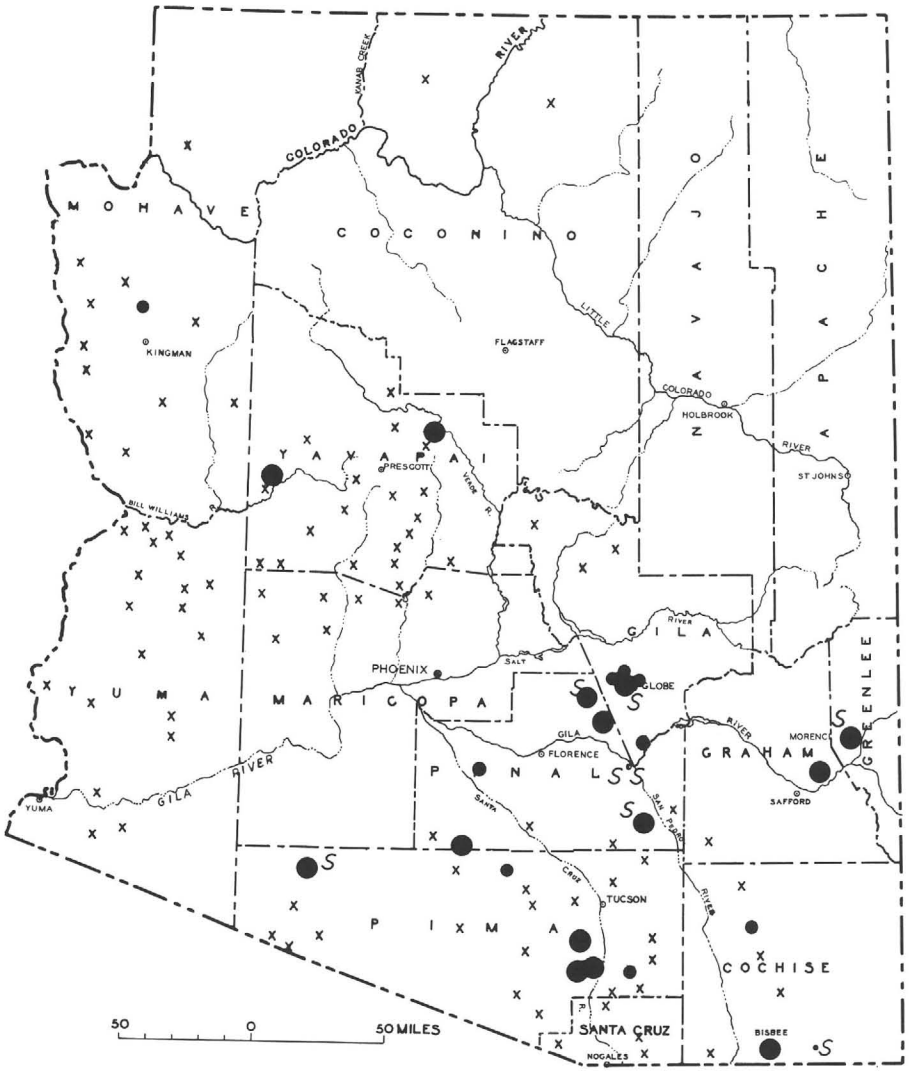
Total Production to the end of 1969:

23,148,600 tons of copper	worth	$11,027,200,000
651,500 tons of lead	worth	129,087,000
1,029,800 tons of zinc	worth	251,700,000
13,750,700 ounces of gold	worth	369,970,000
409,121,800 ounces of silver	worth	347,290,000
111,724,000 pounds of molybdenum	worth	153,307,000 (a)
Total Value		$12,278,554,000

(a) Of this amount 53,646,000 pounds (almost 50%), valued at $89,011,000, were produced in 1965-1969.

And that isn't all of the story. It is estimated that approximately fifty percent of the value of all these metals has been expended in Arizona for wages, supplies, and state, county, city and school taxes. The balance has gone for out-of-state purchases, refining, marketing, dividends to investors, many of the latter being citizens of Arizona, and federal taxes which have reverted to the State in the form of dams, roads, army camps, air fields, and defense plant construction.

Copper in Arizona



EXPLANATION

Copper producing districts, mines, or properties, showing relative amount of production plus estimated potential in tons of copper. Adapted from Figure 18, Ariz. Bur. Mines Bull. 180 (1969).

●	•	x	s
More than 1,000,000	50,000 - 1,000,000	10 - 50,000	Smelter

pipeline from the Black Mesa area. The plant, pipeline, and mining and preparation facilities are now under construction.

In 1969, Peabody Coal, by then a subsidiary of Kennecott Copper Corporation, was reported to have agreed to supply a further 210 million tons of coal for a large electric generating plant near Page, Arizona, the coal to supplied from the Black Mesa field by shuttle trains or pipeline as is found most feasible.

Arizona's petroleum discoveries were very disappointing until February 1967 when the new Dineh-bi-Keyah field was found near Red Rock in Apache County. Arizona's cumulative oil production to the end of 1966 was 634,563 barrels. At the end of 1969 the all-time figure was 9,322,985 barrels. Production jumped in 1967 to 2,922,595 barrels from a total of 131,251 in 1966, a record year. 1969 production was 2,433,366 barrels from 18 wells, down from 3,369,430 in 1968. The usual period of flush output at the start of the field had ended.

Natural gas output in Arizona increased after the advent of the Dineh-bi-Keyah field, but because of lack of facilities for marketing, considerable gas was reported lost. In 1969 the total gas produced was 1,608 million cubic feet, of which 508 million was not marketed. The total of all natural gas produced in Arizona to date is 9,793 million cubic feet of which 1,308 million have been reported lost.

HELIUM

Arizona's production of helium gas from the Pinta Dome field in Apache County began in 1961. Figures for 1961 and 1962 are not available, but 1962 production was reported to be 60 times that of 1961. From 36.2 million cubic feet in 1963, output grew to 73.8 million in 1967 then fell off to 62 million in 1969, according to estimates of the U. S. Bureau of Mines. Production figures for the years 1963-1969 add up to 404 million cubic feet of helium gas recovered from 5,368 million cubic feet of natural helium-bearing gas.

Prior to 1969, the helium was recovered by Kerr-McGee Corporation in its plant at Navajo, and both gaseous and

Crushed stone, used for concrete, road material, railroad ballast, and smelter flux, has been the chief source of income for Arizona stone producers.

The following production figures tell the story of the increase in stone production in Arizona.

	Tons	Value
1889-1948 (Ariz. Bur. Mines)		$14,234,000
1949-1954 (U. S. Bur. Mines)	2,776,000	3,586,000
1955-1960	13,570,000	19,622,000
1961-1966	19,676,000	30,856,000
1967-1969 (1969 Preliminary)	8,036,000	14,694,000
Total Value 1889-1969		$82,992,000

MISCELLANEOUS NON-METALLICS

Barite, and nitrates and phosphates in Guano, have been produced in Arizona but not in recent years. Fluorspar has been taken from the Lone Star mine in the Whetstone Mountains of Cochise County as recently as 1967. Decomposed sandstone with unique, nearly round grains has been processed by washing and screening at Houck and shipped to oil fields for strata fracturing, by Arizona Silica Sand Company since early 1959. Mining of salt from a bed near Phoenix has started, under close control. A small amount of vermiculite has been mined and processed for a floor cleaning compound in recent years. Pozzolanic pumice material was produced north of Flagstaff for use in the concreting of Glen Canyon Dam.

MINERAL FUELS

Small amounts of coal long have been mined yearly and coal exploration has continued in the last decade in the Black Mesa area of the Navajo and Hopi Indian Reservations in Arizona.

Early in 1967, the Peabody Coal Company contracted to deliver 117 million tons of coal to be delivered over a period of 35 years to a Mohave Power Project in Nevada near Bullhead City, Arizona, the coal to be pumped as slurry 273 miles by

THE MAJOR METALS

The major metals now being produced in Arizona are, in order of value, copper, molybdenum, silver, gold, zinc and lead.

COPPER

For 90 years the copper mines of Arizona have poured a ceaseless stream of metal into the nation's industries. The state for 60 years has ranked as the leading copper producer in the United States. Its output up to the end of 1969 has amounted to 23,148,600 tons of copper worth $11,027,200,000. For each of the past nine years Arizona has produced more copper than all the other states combined. There is no reason to believe that she cannot continue as leader for many years to come. Nature has endowed her with one of the world's most important sources of copper.

The record of Arizona's steady growth and progress is closely linked with the development of her copper industry. This development has been achieved through decades of courageous perseverance in the face of repeated discouragements. Thousands have devoted their lifetimes to the development of the mines and the building of their communities with their schools, banks, churches, public buildings and homes; and the roots of these communities extend down into the earth to the bodies of copper-bearing ore which still continue to nourish them.

From 1880 to 1910 copper mines in Arizona were of the "bonanza" or high-grade type. Such properties as the Old Dominion at Globe, the Copper Queen at Bisbee, the United Verde at Jerome, and those at Clifton-Morenci were the major producers during this period. The Copper Queen is the only one of the above mines which is still a producer of a substantial amount of high-grade copper ores. Morenci now produces low-grade ores from the second largest open pit mine in the United States. The Old Dominion and United Verde mines were exhausted more than fifteen years ago. However, the Magma Mine at Superior has been a high-grade producer since

1910, and is still operating as such. The United Verde Extension Mine at Jerome was another high-grade producer that operated from 1916 to 1938. Beginning about 1924 and through the next 46 years, the low-grade "porphyries" were the chief copper producers.

Copper ores and minerals are of practically no value until they have been processed into metallic copper. They earn no interest, furnish no employment, produce no benefits to anyone. An active mining industry is the agency which converts them into tangible assets and, in the process of conversion, the benefits derived therefrom are distributed widely among other industries and businesses. The direct and indirect beneficiaries of the copper industry are many; not only the miner and smelterman but also their families, the storekeepers with whom they trade, the truckers who bring the wares to the stores, the professional men whose services they use, doctors, barbers, cleaners, etc.—are all dependent upon the wages of the miner and smelterman. Purchases of supplies and equipment supply the life blood to shops, equipment and auto dealers, doctors, dentists, restaurateurs — namely a healthy cross section of the entire State.

In 1969, the copper mining and smelting industry payroll for Arizona residents amounted to $172,600,00. This figure includes about half of the total of fringe benefits received by the employees. It is estimated that the total amount of fringe benefits is equivalent to about 30 percent of the annual labor cost of the Arizona nonferrous metals industry.

It is calculated that Arizona copper mines spend over $137,000,000 annually within Arizona for supplies and equipment and use nearly 3 billion kilowatt hours of electricity.

In 1969, over $44,000,000 were paid to Arizona's various units of government levying property, sales, use, vehicle and income taxes. Included in this figure are over $14,000,000 paid to the state as a "severance" tax on copper amounting to 2 percent of "the gross proceeds of sale or gross income from the business" within the state of "(a) mining, quarrying,

SAND AND GRAVEL

Sand and gravel are products of all States in the Union, and Arizona is no exception. Records of Arizona production were first reported statistically in 1917, and the following tabulation shows the tremendous increase since then:

	Tons	Value
1917-1948 (Ariz. Bur. Mines)		$ 15,668,000
1949-1954 (U. S. Bur. Mines)	15,741,000	12,147,000
1955-1960	66,130,000	57,635,000
1961-1966	100,067,000	105,982,000
1967-1969 P	46,694,000	47,582,000
1917-1969 Total Value		$239,014,000

P = Preliminary (1969)

STONE

Commercial stone in Arizona is broadly classified as dimension stone and crushed stone.

Dimension stone is used in buildings, walls, pavements, curbs, flagging and ornaments. Commercial shipments of sandstone have been made from Coconino, Navajo and Yavapai Counties. Coconino sandstone of various colors is now quarried near Ash Fork and Drake. Granite rock for building and monument purposes has been quarried in several Arizona localities, chiefly near Prescott, Phoenix, Casa Grande and Salome. Volcanic tuff also has been quarried in several counties for buildings.

Marble has been quarried in Cochise County over a period of many years; in the Dragoon Mountains; and earlier in the Chiricahua Mountains. In recent years, much of the production has been crushed and sized for roof coatings. Marble also has been produced in Pima, Yuma and Yavapai Counties. Onyx marble has been produced in Coconino, Maricopa, Pima and Yavapai Counties. Dimension limestone, crushed limestone and very recently some dimension slate also have been produced in Arizona.

some mica has been produced for many years, published records are incomplete. The Arizona Bureau of Mines has estimated that the value of Arizona production for the period 1949-1961 was $417,000. The annual average since then is probably higher and the capacity of the Buckeye plant was increased in 1969.

PERLITE

Perlite is a glassy rock that pops like pop-corn when it is heated. The crude perlite is ground to particles no larger than fine sand before heating. The lightweight popped material then is used in insulation, plaster, filtering, and other materials.

Perlite deposits near Superior were the first to come into production in Arizona, in 1946. The output for several years was small due to technical problems, but beginning with 1951, it started to climb. Since 1960, Arizona Perlite Roofs, Inc. and Harborlite Corporation have been the principal producers. Arizona Perlite Roofs has mined and prepared a dried, minus 30 mesh perlite for shipment mainly to expanding plants out of state, but also to one at Phoenix. Harborlite has mined and shipped similar material to out-of-state plants supplying expanded perlite mainly for filter media.

Total Arizona production of crude perlite probably has exceeded $2,500,000 in value.

PUMICE

Arizona is the largest producer of pumice, commonly called and reported as cinders and scoria. The chief source is in the northern part of the state where large and variable quantities are used for road construction.

According to the U. S. Bureau of Mines, Arizona has produced 5,188,000 tons of pumice valued at $5,816,000 in the past five years. The tonnage is about one-third and the value about one-fifth of the totals for the United States.

smelting, or producing for sale, profit or commercial use" a mineral product.

Arizona's severance tax rate on copper mining is 60 percent more than the highest of the like rates for the other copper producing states.

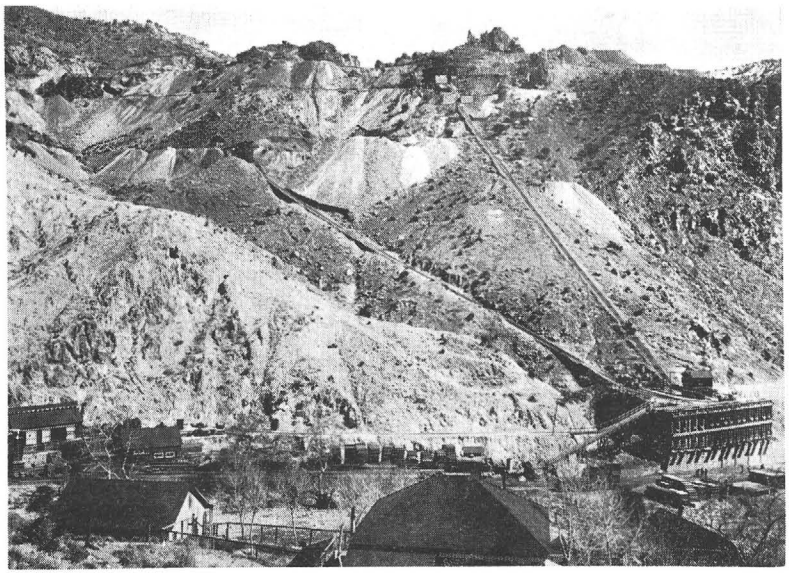
The railroads and truck lines handle a large volume of business through the movement of copper ores and metal as well as supplies and equipment for the mines, mills and smelters. Copper mining brought the railroads to Arizona and continues to furnish much of their freight into and out of the state.

Agricultural, lumber and livestock producers in Arizona derive much benefit from the copper industry through its purchases of their products and its large, abnormal tax assessments.

The copper companies are heavy purchasers of electrical power generated at irrigation storage dams. These large power purchases by the copper mining companies make possible the cheaper power and water supply for agriculture and industry.

The copper mining industry has a vital and far-reaching effect upon the State's economy. It is one of the few industries which creates new indestructible wealth. It is vital to the Nation's security, and it is necessary that the mines of this country be kept in operating condition at all times.

In the decade 1910-1919 the average ton of copper ore mined in Arizona yielded 48.4 pounds of copper. In 1968, the average yield for 101,294,000 tons of Arizona ore treated was 11.3 pounds per ton. This drop of 77 percent in yield per ton of ore is accompanied by several hundred percent increase in the cost of labor and large increases in costs of supplies, power and equipment. Great credit is due the producers and their suppliers for the tremendous progress in mining and metallurgical technology which has enabled them to mine the waste rock of yesterday and to continue in business in competition with the foreign producers, who have much higher grade ores and lower costs. Old and recent waste dumps carrying small



Copper Mining About 1900 — Metcalf

amounts of copper are being leached to recover all of the metal possible. Some of the smelters have built or are building plants to make sulphuric acid for this leaching from some of the smelter smoke, thus reducing the amount of SO^2 going into the atmosphere. Unfortunately, present technology does not permit the conversion of a high percentage of the SO^2 in smelter smoke to disposable sulphuric acid and leaching will not take all that could be made.

Copper Tariff

The copper industry is a world industry and copper is an important world commodity. In 1968, 49 percent of the Free World's copper was produced in countries of Africa and Latin America, none of which consumes very much copper. The United States is not only the largest producer in the world; it also is the largest consumer of copper in the world; and in 1968 it produced about 74 percent of the new refined copper it consumed.

GYPSUM

Arizona's gypsum production, which is used mostly in cement, but also in wallboard and soil conditioning, increased from 6,686 tons in 1951 to 96,000 in 1956, and to a record 147,000 in 1964. It was 88,000 tons valued at $460,000 in 1966. The output has come chiefly from the Arizona Gypsum Corporation's properties near Feldman, Pinal County, and Camp Verde, Yavapai County, and the National Gypsum Company's property near Feldman. The latter company ships to its wallboard plant at Phoenix, built in 1955.

The value of gypsum production in Arizona to the end of 1966 is estimated to be $7,000,000. Figures for later years are not available.

LIME

Lime for building purposes has been produced in Arizona since 1894. The lime plant at Nelson at the northwest corner of Yavapai County, now owned by the U. S. Lime Products Division of Flintkote, is said to have furnished most of the lime used in the rebuilding of San Francisco after the earthquake and fire of 1906. Since 1915, the larger proportion of the lime produced in Arizona has been used in the flotation process at the large copper concentrators, and most of this has come from the Paul Lime Plant at Paul's Spur in Cochise County and from the Hoopes plant near Miami in Gila County. Some copper companies make lime for their mills from limestone quarried at their own properties.

The total value of lime produced in Arizona to date is approximately $48,000,000. 1968 production was 260,000 tons valued at $4,561,000.

MICA

The mica produced in Arizona has been of the scrap variety, which is ground for use in roofing, wallpaper, rubber, paint and other products. Four operators in Maricopa, Mohave, Pima and Yuma Counties have accounted for most of it, but for a number of years the bulk of the production has been made by the Buckeye Mica Co. with mill at Buckeye. Although

Pima County for clay products; in Yavapai County for cement; and, in lesser amounts from Apache, Gila and Maricopa Counties, has exceeded the value of bentonite clays.

The total value of miscellaneous clays (exclusive of bentonite) from 1949 through 1961 has been approximately $1,725,000, according to the Arizona Bureau of Mines. According to the U. S. Bureau of Mines, the total value for the years 1962 through 1969 is $1,701,000. The Arizona Bureau has estimated a total value of bentonite for the years 1925-1961 at $24,500,000.

Figures for later years are not available.

DIATOMACEOUS EARTH (Diatomite)

Diatomite is a rock composed of siliceous shells of minute plants left in the bottoms of lakes and seas. The chief deposit in Arizona is the White Cliffs, northeast of San Manuel. Diatomite is mined and processed for use in insecticides, cement and fertilizer. Its most important use is as a filtering aid, but to date the Arizona product has not entered this market, nor outside markets for use in fillers, insulations, absorbents, abrasives and other products.

FELDSPAR

High quality potash feldspar is mined and ground near Kingman, Mohave County, by International Minerals and Chemicals Corp., for use in glass and pottery.

It is estimated that the value of Arizona production to date is approximately $6,000,000.

GEM STONES

Turquoise, tourmaline, opal, agate, garnet, peridot and other gem stones have been produced in Arizona, each county having contributed several varieties. The value of the commercial production through 1969 is estimated at $2,800,000, but the substantial amount taken by amateur collectors is not known.

Until 1940, the United States mined more copper than it consumed and was an exporter of copper—except for 1929 and the depression years 1930-1932. At such times as production exceeded consumption in the world, competition developed with foreign producers for part of the United States market. In order to protect the American industry against the competition from the foreign miners, who operated their higher grade mines with a much lower per-hour labor cost, it became necessary to take steps to prevent curtailment of United States mine production with resultant decrease in employment.

Therefore, effective June 21, 1932, Congress imposed an excise tax on copper imports of 4 cents per pound and it was in effect until 1949. However, the tax was not operative from 1940 to late 1946 when United States purchases of foreign copper for a defense stockpile, were being made.

In 1949, demand exceeded supply. Foreign copper was needed and the tariff was suspended by Congress. Impositions and suspensions have been recurrent since. International trade conferences have resulted in successive decreases in the copper excise tax. If the tax, suspended at the end of 1968, is resumed at the end of the two-year period, it will be only 1.1 cents. However, should the market price decline to 36 cents, it would become 1.7 cents and at 24 cents it would become 2 cents per pound.

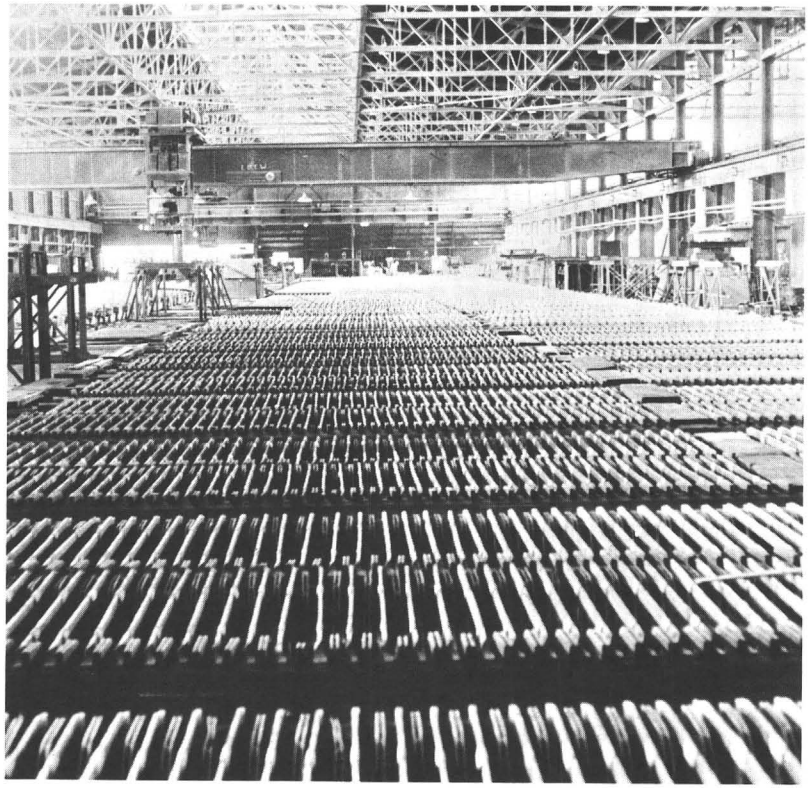
Great expansion of capacity for copper production has occurred in South America and Africa. The producing countries of the two continents are increasingly dependent upon copper mining, which is their major source of income. They not only are controlling production, prices and markets, but are nationalizing mines of copper companies foreign to them. When world consumption again falls behind copper supply, these countries will sell at prices necessary to move their copper, and import protection may again be necessary in order to preserve domestic mines.

Another Open Pit and Copper Town — Bisbee

project. The plant was started in operation in the fall of 1959. Its initial capacity was 5,000 barrels per day. An additional kiln installation was completed in mid-1961 to bring plant capacity to about 2,600,000 barrels per year. A fourth kiln was added in 1969.

CLAYS

Clays have been produced in Arizona for centuries for pottery and adobe, and since 1894 for brick. A white bentonite or bleaching clay from open pits near Sanders, Apache County, has been of chief importance since 1925 except for some recent years in which the total value of miscellaneous clays mined in



Refining Copper in Arizona

by a government purchasing program started in December, 1952. Depression again struck the industry at the end of 1958, when the Government stopped purchase of fiber for stockpiling. However, two modern asbestos processing mills were built near Globe in 1959, and a third soon followed.

Most of the Arizona asbestos is short fiber, grading through crudes Nos. 3 to 7. Only a very small percentage is longer fiber, high-priced crude Nos. 1 and 2 for which the market is small. The very low iron content of the long fiber chrysotile makes it eminently suitable for use in electrical insulation. However, the bulk of the fiber is sold for filter media and is of the short fiber grades.

The period of Government purchases from 1952 to 1958 resulted in the opening and reopening of a number of asbestos mines. The largest of these were the Regal, Phillips, Crown, Chrysotile and Rock House. The bulk of the more recent Arizona production has come from the Regal mine of the Jaquays Mining Co.

The Arizona Bureau of Mines estimates the total value of Arizona asbestos produced from 1914 through 1961 at approximately $15,820,000. Figures are not available for the years 1962 to date, excepting for 1965 when 3,469 tons valued at $441,000 were produced. It seems probable that Arizona asbestos has grossed over $19,000,000.

CEMENT

The first cement plant in Arizona was built by the Arizona Portland Cement Company at Rillito, Pima County. The present plant was started up in December, 1949, with a capacity of 2,000 barrels per day. Capacity was increased to 4,000 barrels per day in 1951 and to 7,000 barrels per day in 1955. Present capacity is above 8,000 per day, or 3,000,000 barrels per year, and is to be expanded to 4,200,000 in 1971, by the addition of a fourth kiln.

The next of the two Arizona cement plants was built by the Phoenix Cement Co. at Clarkdale to meet its commitment to supply 3 million barrels of cement to the Glen Canyon Dam

Recent Developments

In the last ten years Arizona has increased its copper production from 540,000 to 800,000 tons per year. Yet search for new deposits and expansion of operations at existing ore bodies, to keep up with the expected demand for the metal, and research for improved methods of recovering copper from its deposits, continue to be very active.

New Arizona mines which were brought into production during the ten-year period had an aggregate capacity of about 160,000 tons of copper per year. They included: Trans-Arizona's Lakeshore mine south of Casa Grande, 1960-1962, resumed by El Paso Natural Gas, 1968-; Asarco's Mission mine southwest of Tucson, 1961-; Inspiration's Christmas mine north of Winkelman, 1962-; Rancher's Blue Bird mine near Miami, 1962-; Duval's Mineral Park mine near Chloride, 1963-; McAlester Fuel's Zonia mine near Kirkland Junction, 1966-; Arizona Ranch's Mineral Hill mine (PMC Corp's in 1969) east of Parker, 1966-; El Paso Natural Gas' Emerald Isle mine near Chloride, 1967-; Inspiration's Ox Hide mine near Miami, 1968-; Kennecott's Ray Leach mine at Ray, 1969-; Anaconda's Twin Buttes mine south of Tucson, 1969-. Duval's new Sierrita mine started operations in the spring of 1970.

Although these Arizona mines are listed as new, they mostly are expansions of previously mined areas discovered years ago by small prospectors.

Expansion of production facilities and improvements in equipment and technology in the ten-year period, caused further combined increase in annual productive capacity of approximately 130,000 tons of copper. Most all of Arizona's copper mines increased productive capacity. The more important projects completed were those at Pima Mining's Pima mine with increase from 3,000 to 30,000 tons per day of ore capacity in 4 steps; Kennecott's Ray Mine, up 20,000 tons of copper per year; Asarco's Mission mine, up 50 percent to 25,000 ore tons per day; Duval's Esperanza and Mineral Park mines, each up 25% in ore capacity; Phelps Dodge's Morenci

Making Sulphuric Acid from Smelter Smoke at Hayden

mine, up 10,000 tons per year of copper from pit operation and 15,000 per year from leaching, in 1965.

Major expansions projects are under way at the Lakeshore mine; Newmont's San Manuel and Magma mines. Phelps Dodge has started a major project at its Metcalf mine near Morenci. Several companies are exploring, developing or mining ore bodies near Safford and there are projects under study at other potential new mines and presently operating mines.

Some 250,000 tons of additional capacity for copper production in Arizona is in prospect within the years 1970 to 1975. It is estimated that the total cost of this increase would be about $500 million.

The tonnages of ore mined from the major Arizona copper mines in 1969 are listed in Table III.

It has been said that development of metals made more progress during late wars and space efforts than 50 years of ordinary peacetime effort would have accomplished. Many new uses for metals and new alloys have passed the experimental stage, and many more will be discovered. That statement applies particularly to the more obscure metals, the newcomers to important industrial use, such as selenium, tellurium, germanium, indium, columbium, beryllium, tantalum, niobium, thorium, uranium, europium and hafnium.

The term "rare metals" is misleading insofar as it may imply scarcity. Uranium and lithium are more widespread in the earth's crust than is zinc; thorium than lead; and beryllium and rubidium than tin. Indeed, spectrographic analyses of rocks and minerals are demonstrating that many so-called rare elements are rare only in the sense that they are neither well known or easily recognized. Today's tremendous advances in technology are calling more and more for new substances having special qualities. Singly or in combination, these unfamiliar elements are now in important articles in everyday use. Arizona now produces substantial amounts of uranium and vanadium. Because of its varied and widespread mineralization, this state could easily become an important source of more of these "rare metals."

NON-METALLIC MINERALS

ASBESTOS

Gila County is the only area in the United States which produces high-grade, chrysotile asbestos with low iron content. These Arizona deposits once were the only ones of their kind known in the Western Hemisphere; but now the Cassiar deposit in British Columbia is a strong competitor. The Cassiar asbestos is cheaper to mine, but the Arizona asbestos has advantageous transportation costs and lower iron content.

Exploitation of Arizona deposits started in 1913 and rose to 1,200 tons in 1920. There were periods of decline in the mid 1920's and 1930's, but a decline after World War II was relieved

Arizona's vanadium production prior to 1945 came largely from complex ores mined in the Mammoth District in Pinal County, but more recently it has come from uranium ores of Apache County and, to a lesser extent, of Navajo County. The vanadium production from this Four Corners area of Utah, Colorado, New Mexico and Arizona furnishes the most of the United States supply. U. S. Bureau of Mines reports of values of this northeastern Arizona production are available only for the year 1964 ($575,000), 1965 ($381,000) and 1966 ($453,000). No other annual figures have been reported for the period 1948 to date. The total Arizona vanadium production prior to 1948 is estimated at $460,000.

IRON

Arizona's iron occurrences are varied. Four areas of hematite-magnetite deposits, east of Young near the Gila-Navajo County line, near Seligman in Yavapai, Pikes Peak northwest of Phoenix in Maricopa and east of Parker in Yuma County, have had considerable attention, but production to date has been small. Claims have been located on large areas of sands containing magnetite in Pinal, Yavapai, Maricopa, Yuma, Mohave and other counties. A deposit southeast of Florence has been the supplier of magnetite concentrates for a 75-ton sponge iron and steel plant constructed near Coolidge, Arizona in 1960-61. This plant was equipped for use of the Madaras process. Production to date has been small.

Two of the major copper companies have plants for making sponge iron for use in precipitating copper from leach solutions.

There is a large amount of iron in the copper slag dumps in Arizona. This no doubt will be recovered in the future.

RARE METALS

Of the 92 chemical elements of which the earth is composed, 68 may be classed as metals. Perhaps half of these are commercially important, although only about 20 are used now.

TABLE III

Major Arizona Copper Mines, 1969

Mine	County	Operator	Tons Ore Mined
Open Pit			
Morenci	Greenlee	Phelps Dodge Corp.	19,270,608
Pima	Pima	Pima Mining Co.	14,104,752
Ray	Pinal	Kennecott Copper Corp.	12,208,877
New Cornelia	Pima	Phelps Dodge Corp.	10,736,239
Inspiration	Gila	Inspiration Cons. Copper Co.	8,514,309
Mission	Pima	Asarco	7,939,500
Mineral Park	Mohave	Duval Corp.	6,030,700
Lavender Pit	Cochise	Phelps Dodge Corp.	5,550,147
Esperanza	Pima	Duval Corp.	5,487,589
Copper Cities	Gila	Cities Service Co., Miami Copper Ops.	4,644,525
Ox Hide	Gila	Inspiration Cons. Copper Co.	3,908,540
Silver Bell	Pima	Asarco	3,874,100
Twin Buttes	Pima	Anaconda Co.	3,014,557
Bagdad	Yavapai	Bagdad Copper Corp.	2,030,112
Christmas	Gila	Inspiration Cons. Copper Co.	1,913,813
Sierrita	Pima	Duval Corp.	1,034,473
		Total Open Pit	110,262,841
Underground			
San Manuel	Pinal	San Manuel Div., Magma Copper Co.	15,280,816
Copper Queen	Cochise	Phelps Dodge Corp.	781,959
Magma	Pinal	Superior Div., Magma Copper Co.	422,629
		Total Underground	16,485,404
		Grand Total	126,748,245

The year 1969 was the first year of full operation following the long copper strike which lasted 8½ months from mid July 1967 through March 1968. The loss of Arizona copper production was 425,000 tons. An average of 10,257 miners, mill and

smeltermen lost an average of $5,843 in wages and won a 40-month contract involving an increase for the period equivalent to $1.13 per hour.

Smelters and Refineries

There are 8 copper smelters, 1 each at Morenci, Ajo, Douglas, San Manuel, Superior and Inspiration, and 2 at Hayden (Kennecott's and Asarco's). Inspiration Consolidated Copper Company operates an electrolytic refinery at Inspiration in addition to its smelter. Bagdad Copper Corporation in a joint venture with Chemetals Corporation has completed construction of a plant to refine cement copper to copper powder of high purity by a chemical process. The plant has a capacity of 4,000 tons per year. The powder is for use chiefly "for bearings, friction materials, and melting stock briquettes." Bearings and many other items are molded under pressure.

Kennecott's Ray Mines Division completed an electrowinning facility in 1969 which since has operated in conjunction with its leach mine and plant at Ray to produce thick 100 pound sheets of refined cathode copper.

Ranchers Exploration and Development Company completed a new solvent extraction-electrowinning plant at its Blue Bird mine in 1968. It was the first of its kind in the state although there had been a solvent extraction plant for recovery of uranium oxide at Tuba City and electrowinning of copper had been done at the Inspiration refinery for many years.

In February 1969, Inspiration started production of continuous copper rod at its new mill in Miami. The 5/16-inch rod is furnished in five or six-ton coils to the Phoenix plant of Western Electric for manufacture of wire and cable. Inspiration thus became the first integrated copper producer (mine to manufactured product) in Arizona.

In 1969 Magma Copper Company announced plans for a $34 million refinery to produce 200,000 tons of refined copper annually beginning in 1972, and also plans to double the ca-

Since 1956, production of Arizona tungsten ores has practically ceased. The mines have been unable to compete with low-priced tungsten imported chiefly from Korea, Portugal, Bolivia, Australia and Peru. However, demand for tungsten has increased considerably in recent years and the price has risen, in spite of releases of several million pounds from the National Stockpile, to a point where interest again is being taken in Arizona's deposits.

The total value of Arizona's tungsten production from 1910 to date is approximately $7,000,000.

MERCURY

Mercury (quicksilver) is the only metal that is liquid at common temperatures. It also has high specific gravity, high electrical conductivity and other valuable properties.

Quicksilver deposits have been worked in the Dome Rock Mountains near the western boundary of Arizona; in Copper Basin, southwest of Prescott; in the Phoenix Mountains; and in the Mazatzal Mountains, north of the Roosevelt Dam. From 1910 to 1928, none of these reported appreciable production. At best, the yield probably did not exceed a few hundred 76-pound flasks, with a total value of perhaps $25,000.

The period of greatest Arizona production was from 1940-1944 inclusive in World War II. All of these years exceeded the production in 1955 of 477 flasks, the record outside of these World War II years. In 1966, however, 363 flasks had a total value of $160,000. The record 873 flasks produced in 1941 had a value of only $161,500 or $185 each, compared with $441 each in 1966.

The total mercury production of Arizona to date exceeds 10,000 flasks of 76 pounds each, which sold for a total of over $2,000,000.

VANADIUM

One of the important uses of vanadium is in the production of high quality steels.

MISCELLANEOUS METALS

TUNGSTEN

Tungsten is an important metal with the highest melting point of any metal. Its carbides and alloys are very hard and wear-resistant even at elevated temperatures.

Arizona was a relatively small producer of tungsten from 1910 to 1956, when the government ceased purchases of tungsten for the National Stockpile. The Boriana mine in the Hualpai Mountains has produced over one-half of the total. Most of the remainder has come from the areas of the Little Dragoon, Las Guijas and Huachuca Mountains and Camp Bonito in the Santa Catalinas.

Loading Copper Ore

pacity of the smelter at San Manuel, which will process concentrates from both its San Manuel and Superior mines and allow the Superior smelter to be shut down.

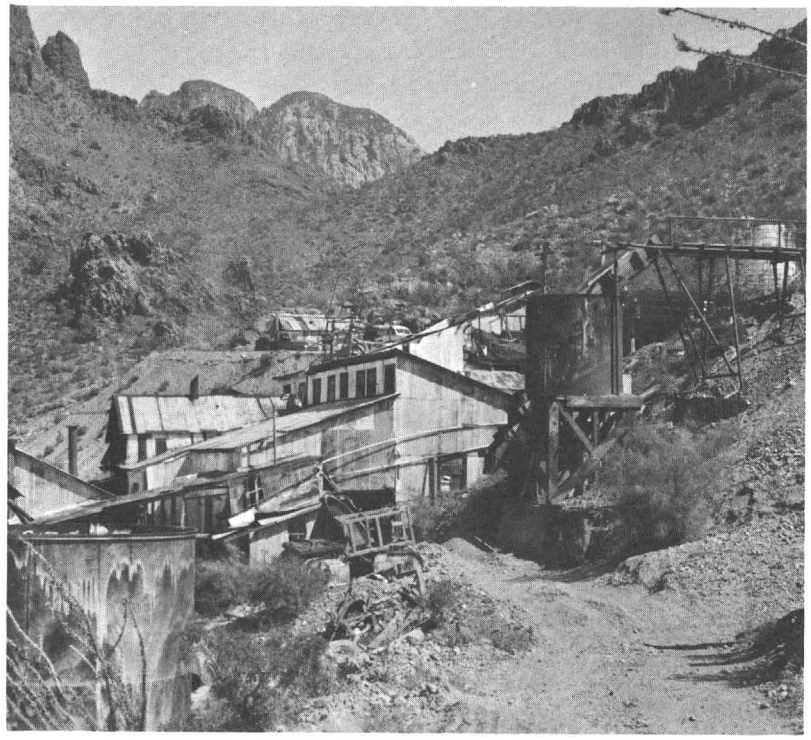
MOLYBDENUM

In 1924 the United States Bureau of Mines listed molybdenum among the "Rare Metals" and reported that it was produced by only two companies. The use of molybdenum then was "confined to the addition of 0.25 to 0.75 percent to steel as a toughener taking the place of nickel and possibly vanadium." Molybdenum in ore and concentrates produced in the United States and sold in the 8-year period 1917-1924 totalled only 1,864,504 pounds.

For 1969, production of 98,400,000 pounds of molybdenum contained in concentrates was reported. 12,698,000 pounds of this was reported from Arizona alone. In spite of the large production, consumption has nearly kept pace, due more to foreign expansion than domestic.

Molybdenum metal and molybdenum-base alloys are virtually indispensable in a wide range of applications in the electronic and electric industries, in missiles and aircraft, in metalworking, in the chemical, glass and metallizing industries, and in nuclear energy applications. The iron and steel industries account for about 85 percent of the molybdenum consumed, mainly in high speed and tool steels, in stainless steel, in gray and malleable castings, and in coating for welding rods and high temperature alloys. Molybdic oxides and chemical compounds of molybdenum are used in the manufacture of inorganic and organic pigments and catalysts and miscellaneous material such as magnets, friction material, lubricants, pesticides, refractories, packings, etc.

Arizona now is the second largest molybdenum producer in the United States, with about 13 percent of the total production. Molybdenum is second only to copper in importance of metals produced in Arizona. The value of its 1969 production was over $20 million—more than the total value of Arizona's 1969 production of gold, silver, lead and zinc combined. Its



The Old Allison Gold Mine

production comes entirely as a by-product of copper ores; and presently it is recovered from thirteen of the State's copper mines, some of whose ores are so low in copper content that it hardly would be profitable to operate them without the income from the recovered molybdenum.

It is anticipated that the production of molybdenum in Arizona will increase substantially in the near future due to new production started from the Twin Buttes' mine of the Anaconda Company, and the Sierrita mine of the Duval Sierrita Corporation.

The following summary of Arizona's molybdenum production brings out the growing importance of this metal to the economy of the State:

URANIUM

The use of uranium as a source of atomic energy is well known.

Discoveries of uranium-bearing minerals have been made in all counties of Arizona, but production has come mainly from Apache, Navajo and Coconino Counties. The largest mines of Apache and Navajo Counties are the Monument No. 2 and the Moonlight in the Monument Valley area, and the Mesa in the Lukachukai Mountains area. Most of the ores of these counties was shipped to processing plants in Utah, New Mexico or Colorado.

The former principal producer of Arizona, the Orphan mine at Grand Canyon, closed down in 1966. Its ore was the principal feed for the only Arizona uranium processing plant, at Tuba City, which not only was closed when the Orphan mine ore stopped, but also was dismantled. However, 1966 saw a rise of several hundred percent in projects for nuclear power plant installations, and the mine resumed production in 1967, ore being shipped to Colorado. It was again closed in 1969.

The large and most of the small uranium mines of Arizona now are closed. Other than the above, the more important of the areas no longer producing are the Cameron in Coconino County, the Sierra Ancha in Gila County and the Santa Maria River near the line between Yavapai and Yuma Counties.

Production was reported from 86 uranium operations in the state in 1958. In 1968 there were six. Arizona ranked 5th in the nation in 1958 and 6th in 1968. The total value of her production from the beginning in 1942 to 1968 is $76 million.

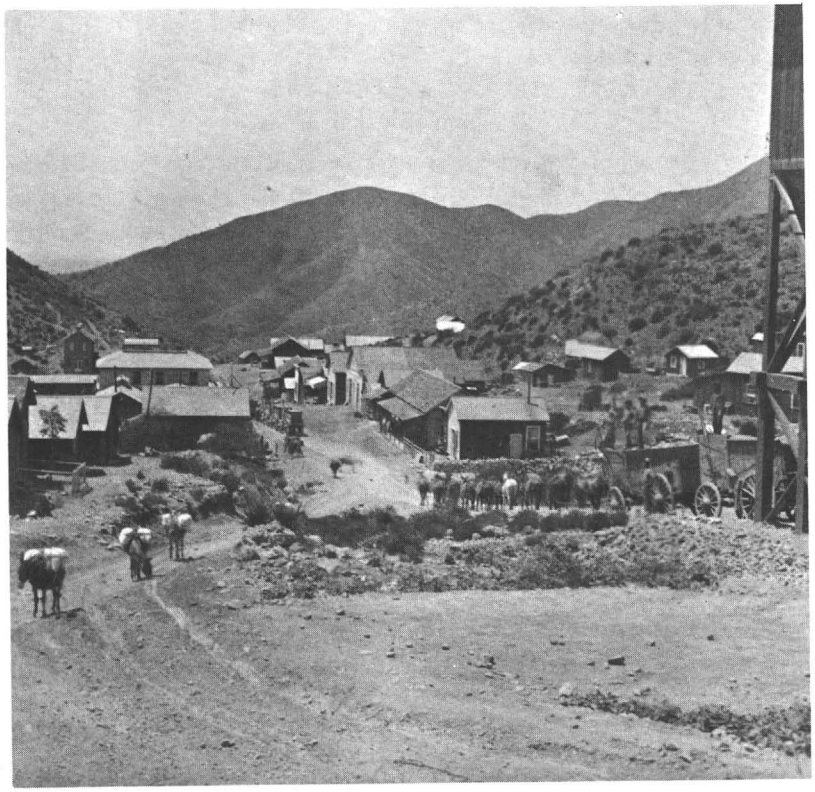
Although uranium production has stopped almost entirely, exploration for uranium deposits continues, stimulated by expectation of expanding demands for this important source material for nuclear power.

TABLE VI

Manganese Ore and Concentrates

	Years	Long Tons	Value	Per Ton
	1915-1952	75,000	1,956,000	$ 26
Wenden —	1953-1954	152,000	10,743,000	70
Carlot —	1955-1959	262,000	21,591,000	82
	1960	1,626	40,000	25
	1961-1970*	—	—	—
		490,626	34,330,000	$ 70

* Figures not available, small amount in 1961 only.



Ore Wagons at Silver King Mine About 1900

Years	Production (pounds)	Value
1914-1948	13,425,000	$ 8,726,000
1949-1954	7,380,000	7,048,000
1955-1959	11,775,000	14,098,000
1960-1964	25,498,000	34,423,000
1965	9,399,000	15,880,000
1966	10,161,000	17,812,000
1967	9,261,000	15,385,000
1968	12,127,000	19,207,000
1969 P	12,698,000	20,727,000

P = Preliminary, U. S. Bur. Mines

GOLD AND SILVER

Antonio Espejo's discovery of rich silver ore in 1583 was reported to be 40 or 50 miles north of what now is Prescott. It is very probable that Espejo's samples came from the rich outcrops known to have been prominent at Jerome. The Indians long had taken colored copper minerals from the outcrops and could have told about them.

There is record of but little prospecting or mining after Espejo's discovery until about 1705 when Father Kino did some silver mining. In the period 1736-1741 the Spaniards discovered a rich silver deposit, Planchas de Plata, at Arizonac, "apparently just south of the Arizona line," and numerous prospectors came into the area; including what is now southern Arizona. Tucson became a Spanish settlement in 1769 and it is known that the Spaniards mined gold and silver in the region then. Gold placers are said to have been worked at Quijotoa in 1774. Apache raids confined the mining to the vicinity of the presidios, and production of gold and silver was small, but it increased some in the last decade of the century when the Apaches for the most part were at peace.

This more peaceful period lasted nearly until 1820 and mines were worked in a small way in various parts of what is now Pima County. Apache raids then were renewed and

mining was suspended during the period of Mexican independence prior to the acquisition of Arizona territory during the Mexican War and through the Gadsden Purchase in 1853.

The gold strike at Sutter's Mill in 1848 brought many prospectors and in 1854, Americans like Poston and Mowry began to open mines. A few years later the Mowry mine in the Patagonia district was shipping rich lead-silver ore and employing 400 men. Eastern capital financed mills and furnaces for the southern silver mines—those of Poston and Ehrenberg near Tubac; others in the Santa Ritas, at Cerro Colorado, in the upper and lower Gila valleys, and elsewhere over a large area. There also were said to be 500 to 1,000 miners at Gila City where gold placers were worked for four years from 1858, and not abandoned then. Other placers were found and worked on the Colorado River.

The outbreak of the Civil War in 1860-61 took away the soldiers and let the Apaches in, but in 1862, as soldiers came in from California, placers were worked and settlements were started at La Paz, Olive City, Ehrenberg and Quartzsite. Pauline Weaver and Joseph Walker pushed to the northeast to the districts in the Bradshaw Mountains of Yavapai County, which took their names in 1863. The Rich Hill, Lynx Creek, Hassayampa, and Big Bug placers, were discovered and found to be rich in gold. Ledges from which placer gold came, were found and worked in a crude way; but only the Vulture mine south of Wickenburg was mined on a large scale.

By 1864, numerous silver veins also had been found, along with gold and copper deposits, in what are now Yavapai, Mohave, Gila, and other counties, the principal one being Yavapai. The territory of Arizona was established in 1863-64, and Prescott was made its capitol, perhaps because of the surrounding mining activity.

From the close of 1865, the Apaches extended their wars to the northwest and mining was more hazardous until 1874 when General Cook quieted the wars. Meanwhile, higher commodity prices and mining costs had made gold mining less attractive, and miners started looking for silver. From 1874 to 1878 many

TABLE V

	Tons Lead Annual Rate	Tons Zinc Annual Rate
1894-1910	2,075	1,045*
1911-1936	7,203	2,627
1937-1941	12,520	9,900
1942-1946	18,400	30,233
1947-1952	25,388	56,734
1953-1959	10,566	28,145
1960-1965	6,546	28,358
1966	5,211	15,985
1967	4,771	14,330
1968	1,704	5,441
1969 P	200	8,960

* Annual Rate from 1905-1910

P = Preliminary, U. S. Bur. Mines

MANGANESE

Low grade manganese deposits in Arizona contain a quantity of material estimated by the United States Geological Survey at 200,000,000 tons carrying about 4% manganese. Such reserves have yielded needed manganese in past wars when foreign sources were blocked off.

Government purchases of manganese ores from 1953 to 1955 resulted in a stockpile at Wenden, Arizona of over 300,000 tons containing less than 20 percent manganese. This stock is yet to be up-graded for use in the steel industry.

Additional Government purchases were made until August 5, 1959 when the quota was reached and purchases ceased. Production in 1959 was reported from 82 mines in 9 counties. Yuma and Maricopa counties were the largest producers, followed by Pinal, Pima and Mohave. There were attempts in 1960 and 1961 to continue in business by shipping to steel plants, but they were not successful and no mines have reported production since.

A summary of Arizona production is given in Table VI. These figures are approximate.

The Magma copper mine at Superior installed facilities for separating zinc and lead and in 1943 it was the largest producer of zinc in the state. The Copper Queen mine at Bisbee did likewise and was an important producer prior to 1951. The Bruce (Old Dick) mine near Bagdad, now the state's largest producer of zinc, separates the zinc and copper minerals in its ores, zinc being dominant in quantity.

The Iron King mine near Humboldt was by far the principal producer of both lead and zinc in 1952-1968. In 1967 and for most of 1968, it was the only producer of important quantities of these metals, as the Bruce was idle except for shaft sinking and development work. In 1965, Iron King ranked 10th in lead and 13th in zinc production in the United States. In 1967, near its closing, it still ranked 12th in lead and 19th in zinc.

During World War II, Arizona miners were encouraged to open up and develop their lead-zinc mines. In 1949 they attained a production of 33,568 tons of lead and 70,658 tons of zinc from a total of 181 mines. A flood of lead and zinc imports from 1952 to 1959 caused their prices to collapse, and over 100 mines were compelled to shut down. Others have closed since. The Iron King was the only large lead-zinc mine able to operate continuously from 1952 to 1968, and it was dependent upon its unusually high income from gold, silver and copper by-products.

Now, Arizona's lead industry is dormant and the state is no longer among the major zinc-producing states. Table V shows the rise and fall of the lead-zinc industry of Arizona. Another Iron King is needed.

silver mines were discovered and mined. Among the richest were the famous McCracken mine near Signal, Silver King near Superior, Tip Top near Rock Springs, several mines at Tombstone, and others in the areas of Globe, the Bradshaw Mountains and south of Tucson.

Prior to 1880 gold and silver were the only metals which could be profitably taken from the vast, rugged, scarcely populated lands of Arizona. Some high grade copper ores were shipped to Wales from Ajo as early as 1855 and some copper mining started at Clifton in 1873, but it is doubtful that the ventures were very profitable.

The more refractory of the gold and silver ores also were shipped to Swansea or other Welsh smelters in the early days of lode mining, but smelters soon were built at El Paso and San Francisco. Free milling gold ores were fed to stamp mills along with mercury and water. The resulting amalgam was recovered by concentrating tables, the mercury was distilled from the amalgam and the gold was left.

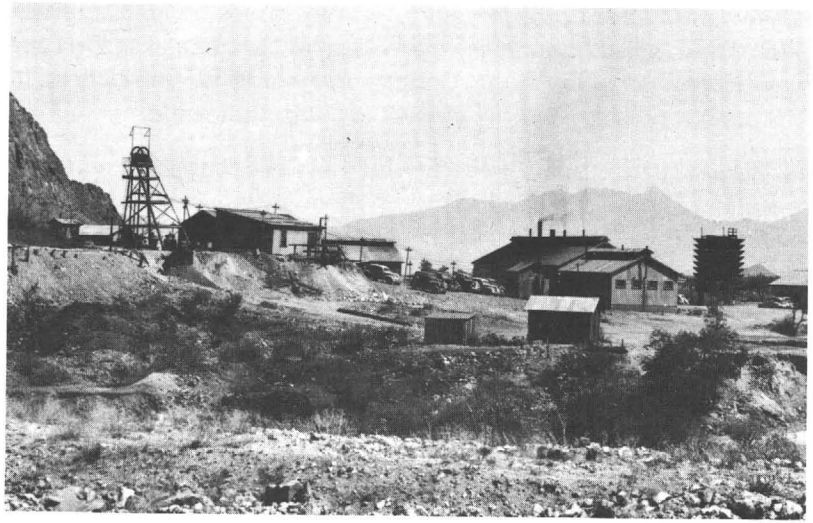
Gold started to increase in purchasing power in 1884 and when silver was demonitized in 1893 most silver miners went after gold. The Congress and Octave mines near Congress, Mammoth near Mammoth, and King of Arizona, La Fortuna and Harquahala in Yuma County, are some of the richest of the many gold mines developed around that time.

About at the turn of the century a new process of extracting gold and silver by dissolving them in weak cyanide solution, precipitating them with zinc, and finally volatilizing the zinc to leave the gold and silver, caused a new gold rush. The first of the cyanide plants in Arizona reportedly was at the Vulture mine.

But, from 1900 to 1930, rising commodity prices decreased the purchasing power of gold and therefore its mining attraction. However, a number of Arizona mines kept producing, and the rich new gold veins of the Gold Road and Tom Reed mines discovered in 1900, and the United Eastern mine found in 1916, yielded approximately $35 million in the period.

Gold prospecting and mining increased during the depression of 1930-1936 but fell off thereafter until in 1942 all gold mines were closed in order to release miners for production of the copper then important to World War II. Thereafter nearly all of Arizona's gold production has come as a by-product of her copper mines. In 1968, so-called gold and gold-silver mines yielded only 0.2 percent of the total gold production. If it were not for the value of their ores as flux for the smelters, they would not operate. The price of gold has been maintained at $35 since 1933, while mining costs have multiplied.

Most of the production from the silver mines had come before 1893 and thereafter only Tombstone and the Commonwealth mines have yielded richly. Since 1903, the copper mines have yielded the greatest amount and in 1968 silver mines produced less than one percent of the total silver production of the state. The world's silver production has not kept up with consumption; the metal has been demonetized in the United States; and the price of silver has more than doubled in recent years. However, there is almost no silver mining in Arizona.



Old Lead Zinc Mine — San Xavier

The Arizona copper ores of 1941 yielded 0.0059 ounces of gold and 0.207 ounces of silver per ton. Those of 1968 yielded only 0.00088 and 0.046 ounces per ton respectively. The 1968 ores also contained much less copper per ton. However, the tonnages of ore have increased greatly so that in 1969 they gave up over $15 million worth of gold and silver, a new record. In 1968, six of the 25 leading gold producers and 7 of the leading silver producers in the United States were Arizona mines. The New Cornelia mine at Ajo ranked 8th in gold and the Pima mine south of Tucson ranked 10th in silver. Both are copper mines in Pima County.

LEAD AND ZINC

The first production of lead in Arizona reported statistically by the Arizona Bureau of Mines, was in 1894, and that of zinc, in 1905. However, there are records of actual production of both metals prior to that time. For example, some lead was mined in the Bisbee or Warren District prior to 1880. Some silver-lead ore was shipped during the period 1882 to 1893 from the San Xavier, Fortuna, Banner, Chloride and other mines of the Pima District. Mineral deposits, including lead carbonate and other silver-lead ores, were discovered in the Aravaipa District before 1880. In the Mammoth (St. Anthony) District, producion of lead or zinc was not reported until 1934, though silver and gold concentrates associated with some lead and zinc had been shipped from the district as early as 1880. The Johnson Camp area in Cochise County had been worked as a source of copper from 1881, but it was not until 1941 that zinc concentrates were produced from the copper-zinc ores.

Prior to development of techniques for making separate concentrations of the minerals in complex ores, an ore predominantly copper but with some lead was sent to a copper smelter and received no credit for the lead, and vice versa. The flotation process has made it possible for copper, lead and zinc together in an ore to be separately concentrated and shipped to their respective smelters.