STRATEGIC ECONOMIC DEVELOPMENT VISION FOR THE ARIZONA-SONORA REGION

THE MINING AND MINERALS CLUSTER

Strategic Economic Development Vision for the Arizona-Sonora Region

by J. Dale Nations
and
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The Mining and Minerals Cluster

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THE MINING AND MINERALS CLUSTER IN ARIZONA:

An Analysis for the Strategic Economic Development Vision for the Arizona-Sonora Region

Strategic Economic Development Vision
For the Arizona-Sonora Region

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1. INTRODUCTION

1.1 Scope of Study

This assessment was undertaken to examine the current status of, and make strategic recommendations concerning, the mining and minerals industry cluster in Arizona. It has been coordinated with a parallel study being undertaken in Sonora by Guillermo Salas, Victor Calles, and Hector Hinojosa. The assessment includes: metallic nonfuel minerals; industrial minerals; and energy resources, including uranium, coal, oil and natural gas. It also reviews the current infrastructure that exists in Arizona, which is necessary for economic development of mineral and energy resources.

The purpose of this report is to present an overview of the geographic, geologic, and operational status of the currently-developed mineral and energy resources in the State of Arizona, and to refer the reader to additional sources of information for greater detail on specific resources. This report consists of a narrative description of background information on the minerals and energy industry of Arizona including the existing infrastructural-institutional factors that affect those industries.

The infrastructure subsection explains the transportation (highway and railroad) and utility (electricity, natural gas, and water) networks in the State. It also contains general information on milling, smelting, and refining facilities as well as permitting and taxation procedures and policies with respect to mineral development in Arizona.

1.2 Objectives of Study

The primary goals are to analyze the current status of the mining industry in Arizona and to identify opportunities and develop strategies for economic development of the mining and minerals cluster in the Arizona-Sonora region. These will be accomplished through the following steps:

- review briefly the historical development of the mining/minerals industry in Arizona
- analyze the present status of the cluster, including description of types of firms, commodities produced and processed, and services that are available
- evaluate the potential for further development of the cluster; and identify obstacles to that development
- make recommendations for consideration by public and private sectors to facilitate development of the cluster, and to expand markets beyond Arizona and Sonora

ACKNOWLEDGMENTS

The authors wish to thank personnel of several agencies of the State of Arizona for their assistance and information and for providing maps and other illustrations for use in the preparation of this report. These include the: Arizona Department of Mines and Mineral Resources (ADMMR); Arizona Geological Survey (AzGS); Arizona Mining Association (AMA); Arizona Rock Products Association (ARPA); Arizona Department of Transportation (ADOT); Arizona State Land Department (ASLD); Arizona Corporation Commission (ACC); Arizona Department of Revenue (ADR); University of Arizona; Arizona State University; and Northern Arizona University. The Arizona Department of Mines and Mineral Resources (ADMMR) was the source of much of the technical information on minerals and mining, which has provided much of the technical information that is included in this report. The Arizona Geological Survey provided similar technical information on oil, gas and geothermal resources. The U.S. Geological Survey in Tucson, Flagstaff and Denver provided access to the Mineral Resources Data System and advice and information on water resources. Many individuals who have been particularly helpful as resource persons are listed in Appendix 5.3. In particular, Mason Coggin contributed most of Section 1.3 on the *Economic History of the Mineral Industry in Arizona.* The basic format and data in this report follows that of Sawyer, M.B., A.C. Gurmendi, M.R. Daley, and S.B. Howell, 1992, *Principal Deposits of Strategic and Critical Minerals in Arizona;* U.S. Bureau of Mines Special Publication. Several other authors have published comprehensive articles on the mineral and energy resources of Arizona, which are up-dated and incorporated to varying degrees in this report. These are listed in the Selected References, Appendix 5.5 of this report. Detailed reference citations in the text of this report have been avoided, in the interest of easier reading by the general audience for which it is written. The authors have made numerous revisions and additions of material, from both published and unpublished sources.

This assessment was funded by the Arizona Department of Commerce and the Arizona-Mexico Commission.

1.3 Economic History of The Minerals Industry in Arizona

Mining has long influenced the history and economy of Arizona. Ranked first nationally in the value of its nonfuel mineral production for 1996, Arizona has led the nation in the output of copper for more than 75 years. Since 1961, Arizona has annually produced over one-half of all domestic copper. Arizona also produces important quantities of molybdenum, perlite, gemstones, lime, cement, sand and gravel, silver, gypsum, lead, pumice, and gold. The state often ranks among the top ten producing states for each of these commodities.

Although metals account for nearly 88 percent of the current value of Arizona's mineral production, the nonmetals or industrial minerals were the first used. Use of industrial minerals in

Arizona dates back for thousands of years. Many archeological sites in Arizona demonstrate the prehistoric mining and use of:

- stone and clay for building construction
- obsidian, chert, chalcedony, quartzite and basalt for manufacture of tools such as projectile points, axes, scrapers, and knives
- turquoise and other colored rocks and minerals for beads and jewelry
- colored clays for fired, nonporous, durable, ceramic pots
- salt for food and curing of hides
- iron and copper minerals for cosmetic use.

A prehistoric salt mine near Camp Verde is one of the oldest underground mines in the United States. Turquoise artifacts have been found in many archeological sites, and prehistoric turquoise quarries have been found in the Dragoon Mountains, at the juncture of Canyon Creek and the Salt River, and at Mineral Park near Kingman. Turquoise was highly valued by the early inhabitants of the Southwest and Mexico for personal decoration and trade, so search for this gemstone occurred throughout a wide area. These mines were operated as much as 1000 years prior to the first contact by the Spanish explorers in the 1500s.

The Spanish settlers had skills in building with brick and mortar including the construction of arches that required the use of lime mortar made from clean sand and calcined limestone. They also utilized deposits of dimension stone, marble, limestone, sand and gravel, gypsum, and clay as sources of local building materials. They also had the technology for manufacturing glass and glazes, for which the raw materials, silica sand, feldspar, sodium compounds, and limestone, were abundant in Arizona.

Exploration for metallic minerals in Arizona began in the 1540s soon after the Spanish conquest. The first metallic mineral discovery in Arizona was made by the explorer Espejo, who located a silver deposit in the Verde Valley during an expedition through New Mexico and Arizona in 1582-83. This was probably the deposit that was eventually worked as the United Verde Mine at Jerome.

In 1736 The Planchas de Plata deposit was discovered near the location of Arizonac, southwest of Nogales. This was a rich native silver deposit that stimulated much prospecting in the general area and eventually lent its name to the Arizona territory and state.

Copper was discovered at Ajo in 1750, but the low percentage of silver and lack of demand for copper soon led to its abandonment. It was rediscovered 100 years later after Arizona had become a U.S. Territory.

Between 1772 and 1820, prospectors exploited mainly placer deposits of gold and silver, with high grade pockets of ore. The copper mine at Ajo, which had first been worked by the Spaniards, was reopened in 1854. In order to get the ore to a smelter it was packed by mules to the Colorado River, loaded onto boats, and shipped to Swansea, Wales, where it was sold for $360 per ton and processed into metal. The entire mineral production of Arizona, prior to 1854 was likely less than one day's present production.

Shortly after the Gadsdsen Purchase, Arizona received the attention of investors and prospectors who had followed the 1849 gold rush to California. Among these were Charles D. Poston and Herman Ehrenberg, miners and promoters. They formed the Sonora Exploring and Mining Company to rework some of the Spanish and Mexican mines between Tucson and Mexico. Largely through the efforts of Poston and Ehrenberg, the Arizona Territory was established in 1863. Although their company was not particularly successful, Poston's ability to attract writers like J. Ross Browne focused the nation's attention on the struggles of miners in Arizona. Poston was eventually described as "the father of Arizona" for his work in promoting a separate Territory of Arizona.

While Poston was working south of Tucson, Jacob Snively and several 49ers developed the gold placers on the lower Gila River in 1854. Soon thereafter they prospected and developed other mines along the Colorado, Gila, and Hassayampa Rivers in western and central Arizona. Their success resulted in the founding of mining camps along Weaver and Lynx Creeks and the Hassayampa River. One of these camps, Prescott, grew rapidly and soon became the capital of the territory. Henry Wickenburg's discovery of a thick vein of gold ore at the Vulture Mine in 1863 resulted in one of the richest early gold mines in the territory. The town of Wickenburg was established on the Hassayampa River where they constructed a mill to treat the rich ores. For a while all of the roads into the area traveled to and through the new town of Wickenburg.

Because of Arizona's remoteness and inadequate transportation, silver and gold, especially placer gold, was the target of mineral exploration. These metals could be mined and recovered by primitive methods, quickly traded, and easily transported. Although a number of governmental explorations in Arizona immediately started reporting other minerals such as coal, limestone, gypsum, copper, lead, and zinc, these could not be developed until better transportation was available.

At the outbreak of the Civil War, troops protecting miners and settlers were suddenly called to fight the war in the East. Their marching orders included an order to destroy everything within 100 miles of their path that might support an army. This left the settlers and peaceful tribes of Native Americans without stored crops or military protection. Travel was hazardous and commerce essentially stopped. After the war, roads were improved, reliable trade became established, and the entire state was scoured by prospectors. They soon discovered many of today's great copper deposits although they were of little economic importance at the time. Some of the important mines that produced ore during the decade were Tombstone, Tip Top, Peck, McCrackin and Silver King.

When the railroads finally reached Arizona in the 1880s, they brought supplies and reduced the cost of getting ore and metals to their markets. The silver market collapsed in 1893 when silver ceased to be used for the monetary standard. Copper and gold became Arizona's dominant commodities. Although gold continued to play an important part in the development of Arizona's mineral resources and several new important gold discoveries were made at Oatman, the King of Arizona, Total Wreck, Congress, and several others, these were outproduced by gold that was being recovered from the copper mines. The use of copper to conduct electrical energy, carry messages, and transfer heat soon made copper an essential product for the industrial and electrical revolutions.

When Arizona's first copper mines were developed, the ore was shipped to the Colorado River by wagon, thence by water to Swansea, Wales. The grade required to support a profit was in excess of 25 percent. When the first smelters were being erected in Arizona in the late 1870s, the average grade being mined in the Territory was calculated at 17 percent. With the low-cost freight brought by the railroads for ores, supplies and equipment, the average grade was close to 5 percent. Most of the ore in Arizona was mined underground. Raw ore was hauled to a smelter where the ore was reduced to impure metals. Additional refining was required before the ores could be marketed. The mining and smelting of the time was labor intensive and most of the important towns in the territory were mining camps within walking distance of the mines they served. Arizona gained the position of being the nation's largest copper producer early in the twentieth century, beating out Michigan, Montana, and Utah.

By the start of World War I in 1917, several technological advances in copper mining and copper recovery were setting the stage for the exploitation of the vast low grade copper deposits in Arizona's Basin and Range Province. Development of exploration methods and procedures were allowing miners to accurately "block out" the size and tenor of large reserves of copper in deposits now recognized as porphyry. Increased sizes of steam shovels and rail haulage equipment allowed bulk mining of these low grade deposits cheaply and dependably as at the Sacramento Pit in Bisbee and the New Cornelia mine at Ajo. It was also found that many of the porphyry deposits were amenable to "block caving," a method by which large deposits can be mined underground without extensive drilling and blasting. This method was applied to the copper deposits at Ray, Miami, Morenci, and elsewhere around the state. Improved methods of copper recovery, first by vat leaching of oxide ores as developed at Ajo and the flotation process developed elsewhere, allowed low grade ores to be reduced by electrowinning or to be concentrated for smelter feed. These developments provided a great deal of confidence in copper mining and stabilized the industry. With recognized reserves, predictable production and controllable costs, large amounts of capital could be mustered for the development of mines. When the war effort was in need of copper in 1917, mining technology was ready to increase production. The result was a drop in the required profitable grade to 1.5 percent.

After the war the demand and the price of copper dropped dramatically. Many operations that had been profitable were closed and the miners were laid off. Only those properties that had developed into low cost producers survived the glut of 1919 and 1920. It took two years for the industry to recover. The remaining years of the decade were very profitable for most of the industry.

During the depression of 1929 and the 1930s, many Arizona miners survived by mining gold. The official U.S. gold price was raised from $20 to $35 in 1935. Another gold rush followed, and when the Roosevelt administration started loaning money to open and operate gold mines, a great number of gold mines were restarted. The cyanide method that had been perfected by 1900 was the basis for several new mills being constructed to treat the tailings left by past operations as well as new ores. The result was that while many copper mines were closing, many gold mines were opening. People were leaving the cities to become placer miners in the creeks or hard rock miners in the many underground gold mines. New plants were built for the gold at Oatman, Congress, and other mining camps around the state.

When the bombing of Pearl Harbor in 1941 plunged the nation into World War II, the nation's immediate need for military equipment created a great demand for iron, copper, lead, zinc and other mineral commodities. The federal government supported, through various programs, the production of copper, lead, and zinc in Arizona. As a result many mines and mills were developed. Among the mines benefiting from this program were Morenci, Bisbee, Bagdad, Globe Miami, Ray, Superior, Copper Dome, and Ajo. During the war nearly all of these plants were modernized and developed with assistance from government, either in the form of financial support or in obtaining materials through various rationing programs.

The post-war period presented Arizona and the rest of the nation with many challenges and many opportunities. The rebuilding of Europe and Asia and the development of a transcontinental highway system called for heavy investments in industry. This was based on strong economic predictions and the confidence that the country would not immediately slip into a situation similar to the depression of the 1930s. The assurance for these conditions came from the federal government, which continued to fund long-term construction contracts. The Cold War started shortly after World War II and with it came a military buildup and the development of the technological equipment that was dependent on metals and mineral products. The demand for copper and uranium started yet another exploration campaign across the state.

The added activity, especially in open-pit copper mining, brought about a revolution of this industry in the early 1950s. Several new open-pit copper mines shifted from the traditional rail haulage to truck haulage. Truck haulage in open-pit mining gave the method added flexibility. Coupled with a few technological breakthroughs in casting larger truck tires and the development of larger (9 cubic yard) shovels, the equipment manufacturers were able to achieve a 65 ton carrying capacity for the mechanical transmissions in the trucks. With trucks, pit walls could be steeper and the exit ramp grades increased. This reduced the amount of non-paying rock that must be removed to reach the ore. Ramps could now be built at 8 percent grades rather than the traditional 3.5 to 4 percent for rail haulage systems. These shorter ramps greatly reduced the stripping ratio in some pits. With the added emphasis on off-highway haulage a new market developed for these heavy haulers and some manufacturers (K.W. Dart and Euclid for example) started to develop larger and larger trucks for in-pit ore and waste haulage.

Exploration technology for copper and other metals and minerals also advanced very quickly in the decade of the 1950s. A greater understanding of the way porphyry copper deposits were formed and how to recognize them, coupled with a long and successful economic track record for bringing them into production, created a great market confidence that made them easier to finance and develop them. Beginning in the early 1950s geophysical prospecting started gaining recognition as a successful prospecting tool. Although, it still required extensive exploration drilling, testwork and feasibility to fully explore a deposit and block-out reserves, geophysics helped define new exploration targets and design intelligent exploration drilling programs. This tremendously increased the potential for finding deposits.

Rock mechanics, the study of the structural behavior of rock materials, started to become a serious science. With increasing confidence in this science, mining engineers could design optimum pit slopes for economics and safety. This allowed better control of the economics of mining operations and deeper deposits could be mined. The final result of these improvements had a dramatic effect on the grade of copper that could be mined. The Lavender Pit in Bisbee was designed based on a 0.76 percent copper average. By 1960 open-pits were being planned for further development on a 0.50 percent average copper grade. Most of the copper ores being mined at the time were drilled, blasted, loaded and hauled to a concentrator for upgrading to between 12 and 25 percent copper. Arizona became the undisputed copper capital of the world. Arizona copper miners were able to export their copper mining technology to the rest of the world.

Oxide copper deposits were not taken seriously by most of the Arizona copper industry. They were being leached and resulting solutions were merely being run over de-tinned cans to precipitate a "cement copper" product which was then smelted. Ranchers Exploration and Development, a small mining company that had its start in New Mexico's uranium deposits, was the first to consider oxide copper as an economic opportunity. They had first used the traditional iron precipitation launders but became the first company in the U.S. to install the newly developed solvent extraction electrowin system (SX-EW) in 1961. In this revolutionary process the copper bearing solutions containing copper and iron as sulfates in an acid solution are mixed with an organic compound carrying a lixivant to collect the copper sulfates and leave the impurities in the recycling leach solution. Next the organic compound is mixed with a concentrated solution of sulfuric acid where the copper sulfate is stripped from the organic compound and the lixivant. Since the organic compound does not mix with either the leach solution or the stripping sulfuric acid the copper ends up in a sulfuric acid solution where the copper can be directly electrolitically recovered. The result is copper metal of a purity that meets or exceeds the needs of the electrical industry. It can be sold immediately and thereby greatly shortening the amount of time between mining and a cash payment. Ranchers was highly successful with this process and set an example that was extensively imitated.

By the late 1960s the mechanical limitation of 65 tons for off-road haulage trucks was eliminated when General Electric and Unitrig of Oklahoma developed the electric-wheeled vehicle. These trucks were powered by a large diesel-powered direct-current generator. The electrical power was then transferred to four direct-current wheel motors and the apparent limitations of the mechanical transmission was avoided. A fringe benefit occurred in the ability to use the wheel motors as generators thus creating a opportunity to use this energy as a breaking mechanism for these very large loads. Freed from the limitations of mechanical transmissions in-pit haulage trucks increased in size from 75 tons to 90 tons and on to 110 tons before the end of the decade. The next major technological barrier was the construction of larger tires to carry heavier loads. Larger shovels proved to be little problem and the limitation was the efficient loading cycle.

Copper mining alone was not the only benefactor of the improvements in mine haulage. Coal mining was one of the first to take advantage of the rapidly changing technology and started using larger and larger equipment in its strip mining operations. In northeastern Arizona and northwestern New Mexico, several very large coal deposits were developed in conjunction with coal-fired power plants to provide electrical power for most of the Four-Corners states and eventually to be placed on the nationwide electrical grid. The economic value depends on where the electricity is sold and for how much.

The environmental effects of mining and ore processing became a major factor in the 1970s. Several pieces of federal and state legislation aimed at water and air pollution caused the closure of many smelters, and required changes in copper ore processing. One of the most dramatic changes was in the practice of smelting sulfide ores. While surplus sulfur was previously simply discharged to the atmosphere as SO_2, legislation and regulation now required complete removal of all sulfur and many other flue gasses from the smelter emissions to the atmosphere. This required major changes in the smelting technology. It also produced large amounts of sulfuric acid which became a major disposal problem. Ranchers Exploration and Development company was a prime example of an acid consumer and any operator that had any leachable copper was soon considering some kind of an acid leaching operation. If the operation was large enough to support an SX-EW plant it was soon incorporated into the mining plan. Some operators who did not have a available supply of oxide materials (San Manuel for example) had to purchase limestone to neutralize their surplus sulfuric acid production. This encouraged the exploration for oxide reserves. Some operations, in which the conversion could not be economically justified, were forced to close.

The 1970s brought an interesting and disrupting change in how copper companies and most of the minerals industry were organized. Increased fuel prices, beginning in 1973, increased the profits of petroleum companies, allowing them to buy into other natural resource companies. As a result, many of the nation's largest copper companies were owned, in whole or part, by major petroleum companies by the end of the decade. By 1982 over-production had resulted in a depression in the copper industry. The price of copper dropped to less than $ 0.60 per pound from highs of over $1.00. Many of Arizona's larger operations were suspended or had to curtail production. Strikes plagued the industry resulting in the decertification of many union chapters. Operators were in a survival mode and cost-cutting was their principal strategy. Inspiration's Miami operations were losing $2 million per month, and every month was considered a potential closure date.

This shake-out did much to improve the industry. Copper mining came out of the 1980s as a lean, clean and trim industry just as the large surpluses in the producers stock yards had disappeared and the copper price again exceeded $1.00 per pound. Suddenly in 1989 there was a profit in copper mining that had not been in the industry for over a decade. The technological advantages of larger and better equipment had solved the problems of larger trucks, larger tires, and mechanical transmissions. Haulage trucks could carry 210 tons and more. Shovels were using 47 cubic yard buckets and larger ones were being constructed. Solvent extraction electrowinning operations were producing over 50 percent of Arizona's copper and new records were being set for production at many operations. Where 0.50 percent copper operations were being planned in the 1960s and 70s, today's operations are operating at 0.35 percent copper and Arizona is producing more than 1,500,000 tons of copper each year.

In spite of Arizona's heavy copper production in the past and its current heavy production Arizona has a larger reserve of copper than it has ever had before, and of its 20 largest known reserves only 6 are currently in production. While mining was a dangerous occupation at the start of this century it has developed into one of the safest at the present time. Although perceived as a dirty smokestack industry it has become one of the most environmentally aware industries in existence today. At the present time, however, if we continue to use metals and minerals we will have to break some rocks.

In the future this may not be as true. ASARCO and Freeport are one of the first companies to try true insitu leaching of copper. At the Santa Cruz Joint Venture near Casa Grande these companies are conducting a pilot plant for a process where acid solutions are being injected into a deposit well below the surface and any ground water. The solutions are dissolving the copper from the deposit and returning it to the surface where it is sent to an SX-EW plant. If successful, and apparently it is working, the plant will produce copper without breaking or dislocating the ore. It is physically safe and environmentally safe and ASARCO is working on the questions of economic feasibility. BHP is also getting ready to start a similar operation at their Poston Butte project near Florence, Arizona.

1.4 Methodology of the Study

The analysis of the current status of the industry in Arizona was done by acquiring technical information on mineral commodities and production from a variety of governmental and industry sources, primarily from the Arizona Department of Mines and Mineral Resources, the Arizona Geological Survey, the U. S. Bureau of Mines, and the U.S. Geological Survey. This has included reviews of published information, unpublished information in data files, and personal interviews with geologists and mining engineers. Personal interviews were conducted with some of the principal players in the industry to assure technical accuracy of the report.

This study was based primarily on published literature, beginning with a review of the metallic mineral resources of Arizona by Sawyer et al (1992). In it, they discussed and tabulated the occurrence and production history of 16 mineral commodities that are known to occur in 189 principal mineral deposits. They also compiled site-specific deposit abstracts for 138 of the most important deposits in Arizona, including the commodities that have been or could be, produced from the deposits. The Sawyer report is taken as the starting point for this current study, which will serve as an update of the mineral resources and infrastructure. The infrastructure has been updated with maps that were provided by agencies in the State of Arizona that have responsibility for regulating electrical service, natural gas service, transportation, and water resources.

Nonmetallic mineral resources and rock products, coal, oil and gas, and geothermal energy are also important to the economic development of the Arizona-Sonora region, therefore they are also discussed in this report. Information on these resources was compiled from publications by the Arizona Geological Survey; Oil and Gas Conservation Commission, Navajo Nation Minerals Department, U.S. Geological Survey, U.S. Bureau of Mines, and professional geological societies.

A similar approach was used to assess the status of the infrastructure that is necessary to support economic development of the industry. Information was provided by the: Arizona Department of Mines and Mineral Resources (ADMMR); Arizona Department of Transportation (ADOT); Arizona State Land Department (ASLD); Arizona Corporation Commission (ACC); Arizona Department of Revenue (ADR), and the trade associations Arizona's Mining Industry Gets Our Support (AMIGOS) and Arizona Rock Products Association (ARPA). For the sake of brevity, acronyms are used in the text to identify repeated citations of state agencies and other organizations, and are defined in the following list:

Arizona Department of Mines and Mineral Resources (ADMMR)
Arizona Department of Transportation (ADOT)
Arizona State Land Department (ASLD)
Arizona Corporation Commission (ACC)
Arizona Department of Revenue (ADR)
Arizona's Mining Industry Gets Our Support (AMIGOS)
Arizona Rock Products Association (ARPA)
Arizona Geological Survey (AGS)
Arizona Oil and Gas Conservation Commission (AOGCC)
Navajo Nation Minerals Department (NNMD)
U.S. Geological Survey (USGS)
U.S. Bureau of Mines (USBM)

A questionnaire was distributed to members of the Technical Advisory Committee members, who represent the industry, state agencies, and the state universities, in an attempt to identify: 1) opportunities for development; 2) the major problems that are facing the industry; 3) environmental concerns. The questionnaire with responses received is included in Appendix 5.4. Personal and telephone interviews were conducted with these and a variety of other interested persons to increase awareness of the present status of the industry. From these perspectives, we present some recommendations for the implementation of a strategy for economic development of the minerals and mining industry in Arizona.

2. CURRENT STATUS OF THE INDUSTRY IN ARIZONA

2.1 Mineral deposits

2.1.1 Overview

Arizona's mineral industry is highly diversified with 63 companies operating 113 active mines that produce 24 major metallic and industrial minerals. An additional 78 companies produce sand and gravel products. The total value of mineral production in Arizona in 1995 was 4.48 billion dollars, which made the state the leading producer in the United States of non-fuel minerals. The greatest proportion of this value was in the 1.3 million tons of copper, which was valued at 3.6 billion dollars. Gold and silver are produced primarily as a byproduct of copper, with values of $23.3 million and $33.1 million respectively in 1995 (figure 1, table 1). Other commodities of which Arizona is a leading producer of gemstones, molybdenum, silver, perlite, and sand and gravel (figures 2, 5, and 6; table 2). Coal is second to copper in economic importance of mineral commodities in Arizona, with a produced value of $300 million in 1996 (figures 7 and 8). Combined oil and gas production was valued at about $2.5 million in 1996 (figures 9 and 10). These energy resources are all located on the Navajo and Hopi Indian Reservations in northeastern Arizona (figures 7 and 9). Large reserves of uranium ore have been located, but there has been no production since 1991 (figure 4). A major producer has announced plans to resume production of uranium in the near future, from mines north of the Grand Canyon.

The infrastructure that is required to support the mineral industry is well developed in Arizona, and maps of facilities and services such as: electrical suppliers (figure 13); electrical lines (figure 14); gas suppliers (figure 15); gas lines (figure 16); water resources (figures 17, 18, 19, 20); transportation systems, including rail (figure 21) and highway (figures 22, 23 and 24) ; and land ownership (figure 25); have been acquired from state and federal agencies and are included in this report. Industrial and mining equipment, supplies and services are readily available, and access to the suppliers is facilitated by the AMIGOS Trade Association and the Arizona Rock Products Association. Forty-two mineral processing facilities that are currently active Arizona (figure 12), are described in ADMMR Circular 76.

The large size of Arizona's metal mining industry and the large reserve base of copper ore in Arizona (table 3) have encouraged the research and development of mining equipment, mining and processing methods, and related supplies in Arizona. The network of manufacturers, warehouses, distributors, repair parts inventories, and product support groups for metal mining is extensive and easily able to supply new mining operations.

Table 1. Mineral Production in Arizona.

Year	Copper		Gold		Silver		Other**
	short tons	value*	troy ounces	value*	troy ounces	value*	value*
1987	827,908	$1,365,994	57,580	$25,789	3,665,100	$25,666	$155,698
1988	928,939	2,238,875	146,250	64,106	4,886,800	31,974	272,793
1989	990,379	2,593,734	88,991	34,047	5,497,650	30,186	223,415
1990	1,078,895	2,657,649	160,750	62,191	5,561,950	26,836	209,689
1991	1,128,828	2,468,255	199,169	72,362	4,758,200	19,212	201,403
1992	1,270,817	2,730,015	213,990	73,818	5,304,750	20,873	189,749
1993	1,277,300	2,339,018	87,159	31,459	6,430,000	27,684	202,043
1994	1,234,000	2,750,000	65,910	25,300	6,325,700	33,700	274,000
1995	1,290,000	3,560,000	61,728	23,900	7,073,000	36,400	331,000
1996/p	1,355,000	2,930,000	67,515	26,300	7,716,000	40,900	274,000

/p indicates preliminary estimate
*Values in thousands of dollars
** Combined value of cement, diatomite, gypsum, iron ore, lead, lime, molybdenum, perlite, pumice, pyrites, salt, sand & gravel (industrial), stone (dimension), tin, and values indicated by W in Table 2.

Table 2. Industrial Mineral Production in Arizona

Year	Clays		Gemstones	Iron Oxide		Sand & Gravel		Crushed Stone	
	tons	value*	value*	tons	value*	tons	value*	tons	value*
1987	218,000	$1,905	$3,000	NA	NA	38,100,000	$141,300	7,712,000	$33,999
1988	186,000	1,590	3,300	NA	NA	32,399,000	123,854	7,400,000	33,000
1989	207,465	2,506	2,821	W	W	33,900,000	133,900	6,649,000	28,552
1990	154,501	2,318	2,098	W	W	27,915,000	92,166	5,300,000	13,500
1991	212,700	937	3,173	20	$22	22,500,000	79,400	7,060,000	32,842
1992	112,434	463	5,416	85	62	33,842,000	123,517	5,500,000	26,300
1993	106,923	451	5,626	85	62	38,600,000	138,300	7,088,000	36,823
1994	108,000	452	3,550	85	62	38,360,000	166,000	5,478,000	25,000
1995	131,000	449	3,230	85	62	44,202,000	210,000	5,520,000	32,600
1996/p	132,000	454	4,010	W	W	46,186,000	220,000	6,173,000	33,600

/p indicates preliminary estimate
*Values in thousands of dollars

Sources for Tables 1 & 2: 1985-87-Greeley, 1987; 1988-91- Greeley & Kissinger, 1990, Dupree & Kissinger, 1991; 1992-94- U.S. Dept. of the Interior, 1994, Phillips, Niemuth & Bain, 1995; 1995- Phillips, Niemuth & Bain, 1996.

Table 3. Copper reserve base in Arizona, 1992

[Reserve base is that part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). Definition from "Mineral Facts and Problems" 1985 edition, U.S. Bureau of Mines, Bulletin 675, page 3]

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Antler T17N R16W S. 4	Standard Metals Corp.	Sulfide	5.0	1.95	Annual report & form 10-K, 1987. With 4.13% Zn, 0.94% Pb, and 1.05 Ag oz/ton. An additional 2.5 million tons reported in 1979 annual report.
Atlas T11S R8E S. 32	Asarco Inc.	Sulfide	5.4	0.64	"Report on the BS&K Project" by Buchella, F.
		Acid Soluble	4.9	0.37	Sulfide cutoff 0.40%. Acid Soluble cutoff 0.20%.
		Sulfide	18.9	0.66	Asarco property adjacent to Atlas.
		Acid Soluble	12.1	0.38	Asarco property adjacent to Atlas.
Bagdad T14N R9W S. 4	Cyprus Copper Co.	Sulfide	1231.0	0.37	Cyprus Minerals form 10-K, 1992. Includes proven and probable. With 0.022% Mo.
Buckeye East T3S R12E S. 26	Asarco Inc.	Acid Soluble	20.0	0.65	"Arizona Wilderness 1988", Arizona Mining Association, Report A-23. 40 million possible.
Carlota T1N R13E S. 36	Cambior USA Inc.	Acid Soluble	106.0	0.45	Cambior's Carlota fact sheet August, 1993. Includes Cactus and Eder deposits.
Casa Grande T6S R5E S. 18	Asarco & Freeport McMoran JV.	Mixed	352.0	1.00	Getty Oil Co. annual report, 1980. With 0.01% Mo. Cutoff at 0.5% Cu.
Casa Grande (Lakeshore) T10S R4E S. 25	Cyprus Copper Co.	Sulfide	41.0	0.71	Porphyry - Noranda annual report, 1984.
		Sulfide	9.0	1.35	Tactite - Noranda annual report, 1984.
		Acid Soluble	15.5	0.76	Cyprus Minerals form 10-K, 1992.

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Chilito T4S R15E S. 22	Asarco Inc.	Mixed	74.7	0.51	Chilito Mines Report. With 0.01% Mo and 0.04 oz/ton Ag.
Christmas T4S R16E S. 30	Cyprus Copper Co.	Sulfide Sulfide	7.0 20.0	0.63 1.82	Inspiration Resources form 10-K, 1983. Open pit. Underground.
Cochise T23S R24E S. 9	Phelps Dodge Corp.	Acid Soluble	210.0	0.40	Phelps Dodge annual report,1992.
Copper Basin T13N R3W S. 20	Phelps Dodge Corp.	Sulfide	70.0	0.53	Phelps Dodge annual report,1992. With 0.021% Mo.
Copper Butte T3S R13E S. 30	Asarco Inc.	Acid Soluble	22.0	1.09	"Arizona Wilderness 1988," Arizona Mining Association, Report A-23.
Copper Creek T8S R18E S. 11	Magma Copper Co.	Sulfide	80.0	0.55	Unpublished estimate.
Copper Queen T23S R24E S. 9	Phelps Dodge Corp.	Mixed	1.0	5.50	Phelps Dodge prospectus, May 8, 1975. Underground, contains significant gold resource.
Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Dos Pobres T5S R26E S. 27	Phelps Dodge Corp.	Sulfide UG Mixed OP	230.0 270.0	0.89 0.46	Phelps Dodge annual report,1992. Open pit reserves are recoverable by leaching.
Dragoon T16S R22E S. 25	Sullivan, James	Acid Soluble	25.0	0.50	Unpublished estimate.
Dynamite T17S R13E S. 30	Smith, Addison	Mixed	100.0	0.53	Unpublished estimate.
Emerald Isle T23N R18W S. 22	Arimetco International Inc.	Acid Soluble	1.8	0.72	Arimetco International annual report, 1991.

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Esperanza T18S R12E S. 16	Cyprus Copper Co.	Sulfide	48.0	0.27	Pennzoil form 10-K, 1981. With 0.034% Mo.
Four Metals T23S R16E S. 29	Duerr & Prochnav	Sulfide	14.0	0.7	Personal communication.
Gibson T1S R14E S. 21	Lodestar Minerals Inc.	Acid Soluble	10.8	0.7	Fletcher, J.B. et al report August, 1984. Geologic potential.
Helvetia T18S R15E S. 36	Asarco Inc.	Sulfide	362.0	0.61	SME Preprint 92-61 by Anzalone and Brown.
		Acid Soluble	66.0	0.53	Sulfide includes 0.25 oz/ton Ag and 0.016% Mo.
I-10 T15S R23E S. 31	Sullivan, James	Mixed	100.0	0.52	Unpublished estimate; with 0.02% Mo.
Iron Door T13S R25E S. 17	Unknown	Sulfide	63.0	0.38	Spike-E Hills Report. Cutoff at 0.20% Cu.
Johnson T15S R22E S. 26	Arimetco International Inc.	Acid Soluble	4.0	0.40	Arimetco International annual report,1992.
		Acid Soluble	12.0	0.23	Burro Chief deposit. Copper Chief deposit.
Kalamazoo T9S R16E S. 9	Magma Copper Co.	Sulfide	17.0	0.72	Magma Copper form 10-K, 1992.
		Sulfide	143.0	0.71	Resource below 2950 level of deposit.
Kay Copper T8N, R2E, S. 4	Rayrock Mines, Inc.	Sulfide	6.0	2.20	Northern Mines Handbook 1990-1. With 3% Zn, 1.6 oz/ton Ag and 0.08 oz/ton Au.
Korn Kob T12S R17E S. 14	Keystone Minerals Inc.	Acid Soluble	18.0	0.40	Reported by Keystone Minerals from 1990 drilling by A. F. Budge.
Lone Star T6S R27E S. 5	Phelps Dodge Corp.	Acid Soluble	1600.0	0.38	Phelps Dodge annual report,1992.
Lonesome Pine T1S R14E S. 14	Corn, Russ	Mixed	20.0	0.4	Geologic potential based on partially tested chalcocite/oxide zone.

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Mame T19S R25E S. 20	Hope Mining & Milling Co.	Acid Soluble	1.4	1.10	Unpublished estimate.
Miami T1N R14E S. 25	Cyprus Copper Co.	Acid Soluble	320.0	0.44	Cyprus Minerals form 10-K, 1992. Includes proven and probable reserves.
Miami East/Miami	Magma Copper	Sulfide	6.0	3.14	Newmont Mining annual report, 1985.
T1N R15E S. 19	Co.	Sulfide	50.0	1.95	USBM Minerals Yearbook 1973, Area Reports.
		Mixed			Unquantified. In situ production 10MM lb.annually.
Miami Tailings T1N R15E S. 30	Magma Copper Co.	Acid Soluble	25.2	0.36	Magma form 10-K, 1992. 54% recovery expected.
Mineral Butte T4S R7E S. 1	U.S. Government	Mixed	14.6	0.42	Withdrawn from mineral entry.
Mineral Park T23N R17W S. 19	Cyprus Copper Co.	Acid Soluble	14.4	0.24	Cyprus Minerals form 10-K, 1992.
Mission T16S R12E S. 31	Asarco Inc.	Sulfide	564.9	0.67	Asarco annual report, 1992. With 0.14 oz/ton silver.
Morenci T4S R29E S. 16	Phelps Dodge (85%) and Sumitomo (15%)	Sulfide	583.0	0.76	Phelps Dodge annual report, 1992. Milling reserves.
		Acid Soluble	861.2	0.34	Leaching reserves.
		Sulfide	150.0	0.72	Western Copper.
		Sulfide	180.0	0.71	Coronado deposit.
		Acid Soluble	300.0	0.29	Coronado deposit.
New Cornelia T12S R6W S. 27	Phelps Dodge Corp.	Sulfide	160.0	0.56	Phelps Dodge annual report, 1992.
Oracle Ridge T11S R16E S. 16	Oracle Ridge Mining Partners	Mixed	4.0	2.23	South Atlantic Ventures annual report,1990. With 0.67 oz/ton Ag. Additional 4.4 million tons poss.

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Peach Elgin T18S R15E S. 15	Asarco Inc.	Mixed	46.0	0.58	SME Preprint 92-61 by Anzalone and Brown. With 0.3% cutoff. Mineralization is 60% sulfides.
Pinto Valley T1N R14E S. 2	Magma Copper Co.	Sulfide	154.5	0.37	Magma form 10-K, 1992. Milling reserve.
		Sulfide	445.0	0.12	Dump leach reserve.
		Sulfide	146.4	0.42	Magma form 10-K, 1991. Milling resource.
		Sulfide	48.8	0.20	Magma form 10-K, 1991. Dump leach resource.
Poston Butte T4S R9E S. 33	Magma Copper Co.	Sulfide	500.0	0.39	Magma "Copper Sense," August, 1992.
		Acid Soluble	300.0	0.37	
Ray T3S R13E S. 10	Asarco Inc.	Sulfide	1120.0	0.63	Asarco annual report, 1992.
Red Mountain T22S R16E S. 20	Kerr McGee Corp.	Sulfide	100.0	0.71	Tucson Daily Citizen, Sept. 23, 1970.
Sacaton East T5S R5E S. 26	Asarco Inc.	Sulfide	15.0	1.25	Asarco form 10-K, 1979. Underground.
San Juan T5S R26E S. 35	Clardige, Alf et al	Acid Soluble	15.5	0.52	Producers Minerals Corp. Report June, 1975. At 0.35% Cu cutoff.
San Manuel OP T8S R16E S. 35	Magma Copper Co.	Acid Soluble	22.1	0.44	Magma Copper form 10-K, 1992.
		Acid Soluble	2.9	0.16	Open pit marginal.
		Sulfide	0.3	0.96	
San Manuel UG T8S R16E S. 34	Magma Copper Co.	Sulfide	63.0	0.69	Magma Copper form 10-K, 1992.
		Acid Soluble	196.8	0.35	In-situ. 50% recovery anticipated.
		Sulfide	142.0	0.64	Magma Copper form 10-K, 1990. Additional mineralization in shaft pillar.
Sanchez T6S R27E S. 25	AZCO Mining Inc.	Acid Soluble	168.0	0.34	AZCO report, 1992. Reseve and low grade suitable for leaching.
		Acid Soluble	23.0	0.18	

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Santa Cruz T6S R4E S. 13	Asarco & Freeport McMoran	Acid Soluble	800.0	0.43	U.S. Bureau of Mines data, 1985.
Sheep Mtn. T8N R1W S. 15	Orcana Resources Ltd.	Sulfide	39.0	1.27	"Preliminary economic evaluation ..." by Watts Griffis and McOuat, 1992. Supergene only.
Sierrita T18S R12E S. 7	Cyprus Copper Co.	Sulfide	980.6	0.29	With 0.032% Mo. Cyprus Minerals form 10-K, 1992. Reserve includes Twin Buttes deposit.
Silver Bell T12S R8E S. 11	Asarco Inc.	Sulfide	101.0	0.47	Asarco annual report, 1992.
Squaw Peak T13N R5E S. 29	Squaw Peak Copper Co.	Sulfide	20.0	0.36	Roe, Robert R., 1976 report.
Superior T1S R12E S. 35	Magma Copper Co.	Sulfide Sulfide	1.3 2.6	4.97 5.70	Magma Copper form 10-K,1992. Current reserve. Form 10-K,1991. Additional uneconomic tonnage.
Stray Elephant T4N R20W S. 31	Heinrichs GEO Exploraton Co.	Mixed	2.0	0.6	Reported by James Loughry. Additional 5M tons of 0.5% possible.
Strong & Harris T15S R22E S. 13	AZCO Mining Inc.	Mixed	60.0	0.60	Unpublished estimate with 0.70 Zn.
Swansea T10N R15W S. 32		Mixed	5.5	0.81	Wilkins, J., 1990, private report.
Turquoise T19S R25E S. 17	Santa Fe Pacific Mining Inc.	Acid Soluble Mixed	15.0 1.0	0.50 3.10	Santa Fe property synopsis 1992. With 0.05 oz/ton Au. Underground.
Two Peaks T19S R19E S. 20	Dugan Production	Sulfide	32.0	0.28	U.S. Geological Survey Professional Paper 1300, page 128.
United Verde T16N R2E S. 22	Phelps Dodge Corp.	Sulfide	21.0	0.52	U.S. Geological Survey Bulletin 1857D. With 6.6% Zn. 0.61 oz/ton Ag and 0.02 oz/ton Au.

Table 3. Copper reserve base in Arizona, 1992 (continued)

Deposit Location	Company	Mineral type	Million tons	% Cu	Source/comments
Van Dyke T1N R15E S. 30	Arimetco International Inc.	Acid Soluble	100.0	0.53	Arimetco International annual report, 1992.
Vekol hills T10S R3E S. 4	Tohono O'odham Tribe	Sulfide	105.0	0.56	Vekol Hills Project EIS, U.S. Interior Dept. 1988. With 0.014% Mo, 16 million tons acid soluble.
Ventura T23S R15E S. 1	Cyprus Copper Co.	Sulfide	6.0	0.26	Iso Mines Ltd. annual report, 1965. With 0.28% MoS2, 6 million additional tons possible.
White Mesa T38N R9E S. 29	Mesa Mining	Acid Soluble	25.0	0.25	Unpublished geologic estimate. Additional tonnage likely.
Zonia T11N R4W S. 12	Arimetco International Inc.	Acid Soluble	30.0	0.38	Arimetco International annual report, 1992.
Total copper reserve base in Arizona,1992					
		Sulfide	8,107.7	0.53	contains 43.034 million tons of copper
		Acid Soluble	5,348.6	0.39	contains 20.790 million tons of copper
		Mixed	1,050.8	0.68	contains 7.193 million tons of copper
Total			14,507.1	0.49	contains 71.017 million tons of copper

Table 3. Copper reserve base in Arizona, 1992 (concluded)

Company index to copper reserve base in Arizona, 1992

Company	Deposit
Arimetco International	Emerald Isle
Arimetco International	Johnson
Arimetco International	Van Dyke
Arimetco International	Zonia
Asarco & Freeport	Casa Grande
Asarco & Freeport	Santa Cruz
Asarco Inc.	Atlas
Asarco Inc.	Buckeye East
Asarco Inc.	Chilito
Asarco Inc.	Copper Butte
Asarco Inc.	Helvetia
Asarco Inc.	Mission
Asarco Inc.	Peach Elgin
Asarco Inc.	Ray
Asarco Inc.	Sacaton East
Asarco Inc.	Silver Bell
AZCO Mining Inc.	Sanchez
AZCO Mining Inc.	Strong & Harris
Cambior USA Inc.	Carlota
Challinor, John	Swansea
Claridge, Alf, et al	San Juan
Corn, Russ	Lonesome Pine
Cyprus Copper	Bagdad
Cyprus Copper	Casa Grande
Cyprus Copper	Christmas
Cyprus Copper	Esperanza
Cyprus Copper	Miami
Cyprus Copper	Mineral Park
Cyprus Copper	Sierrita
Cyprus Copper	Ventura
Duerr & Prochnav	Four Metals
Dugan Production	Two Peaks
Heinrichs GEO	Stray Elephant
Hope Mining	Mame
Kerr McGee Corp.	Red Mountain
Keystone Minerals	Korn Kob
Lodestar Minerals	Gibson
Magma Copper	Copper Creek
Magma Copper	Kalamazoo
Magma Copper	Miami East
Magma Copper	Miami Tailings
Magma Copper	Pinto Valley
Magma Copper	Poston Butte
Magma Copper	San Manuel OP
Magma Copper	San Manuel UG
Magma Copper	Superior
Mesa Mining	White Mesa
Oracle Ridge	Oracle Ridge
Orcana Resources	Sheep Mtn.
Phelps Dodge	Cochise
Phelps Dodge	Copper Basin
Phelps Dodge	Copper Queen
Phelps Dodge	Dos Pobres
Phelps Dodge	Lone Star
Phelps Dodge	Morenci
Phelps Dodge	New Cornelia
Phelps Dodge	United Verde
Rayrock Mines	Kay Copper
Santa Fe Pacific	Turquoise
Smith, Addison	Dynamite
Squaw Peak	Squaw Peak
Standard Metals	Antler
Sullivan, James	Dragoon
Sullivan, James	I-10
Tohono O'odham	Vekol hills
U.S. Government	Mineral Butte
Unknown	Iron Door

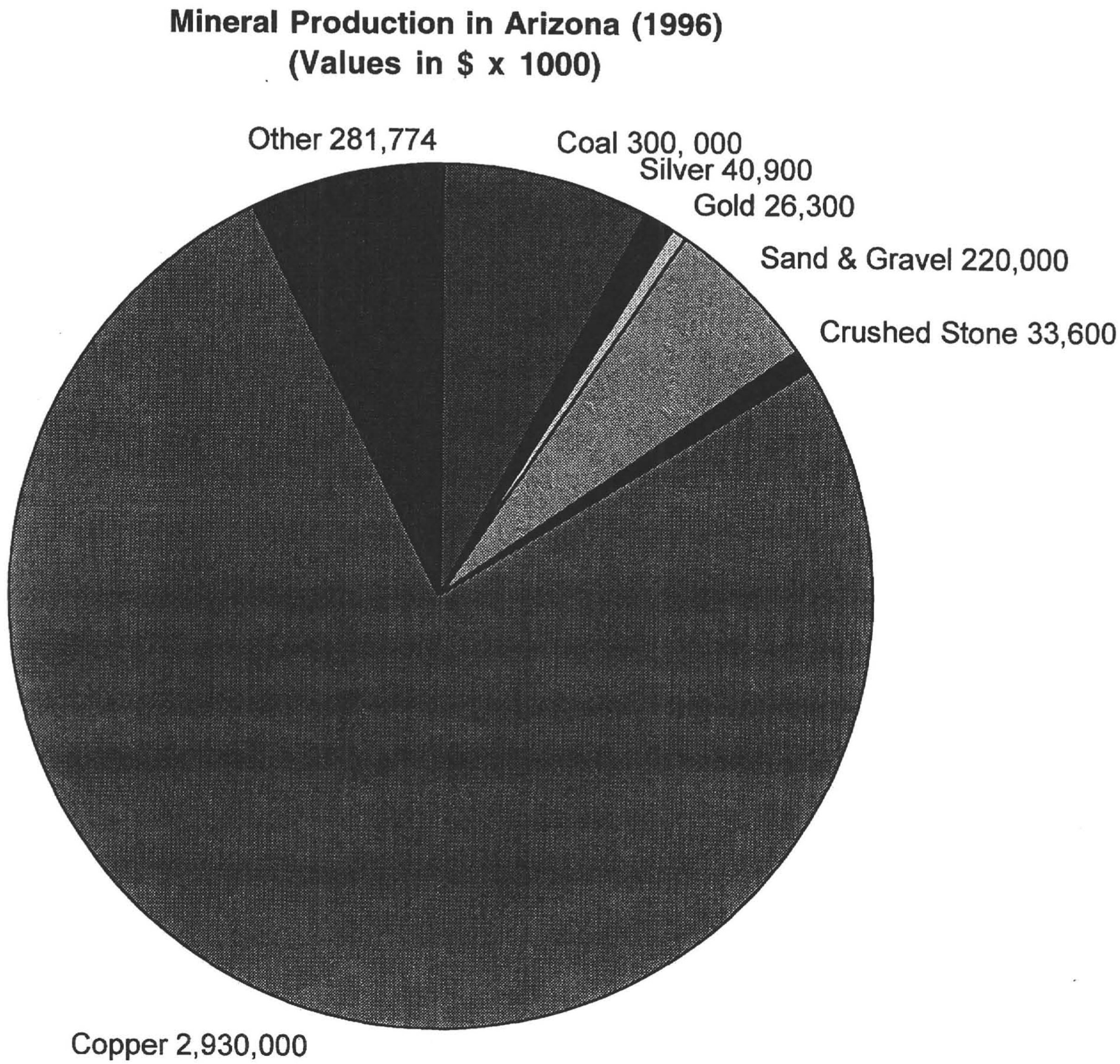


Figure 1: Relative values of minerals produced in Arizona, 1996

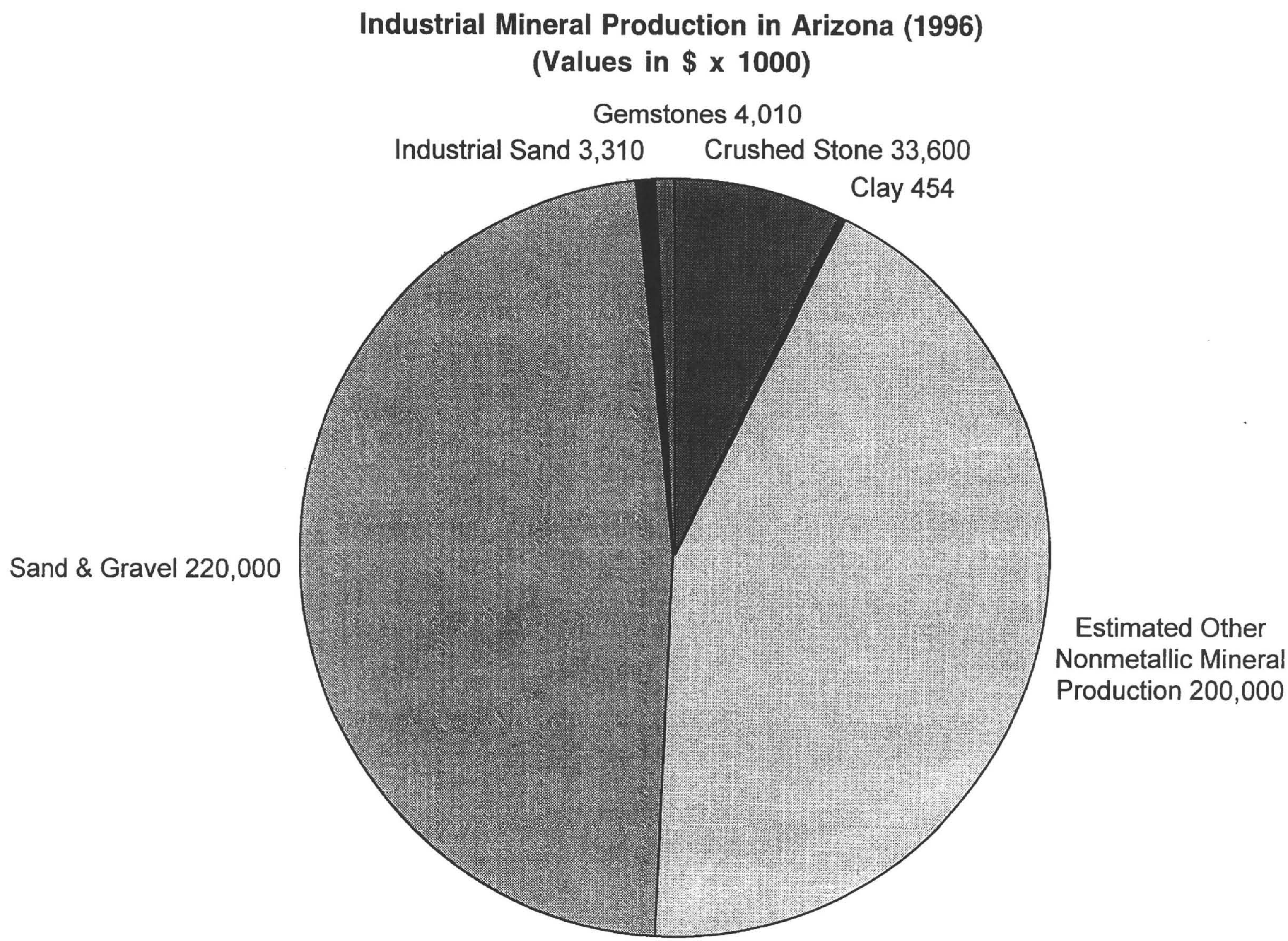


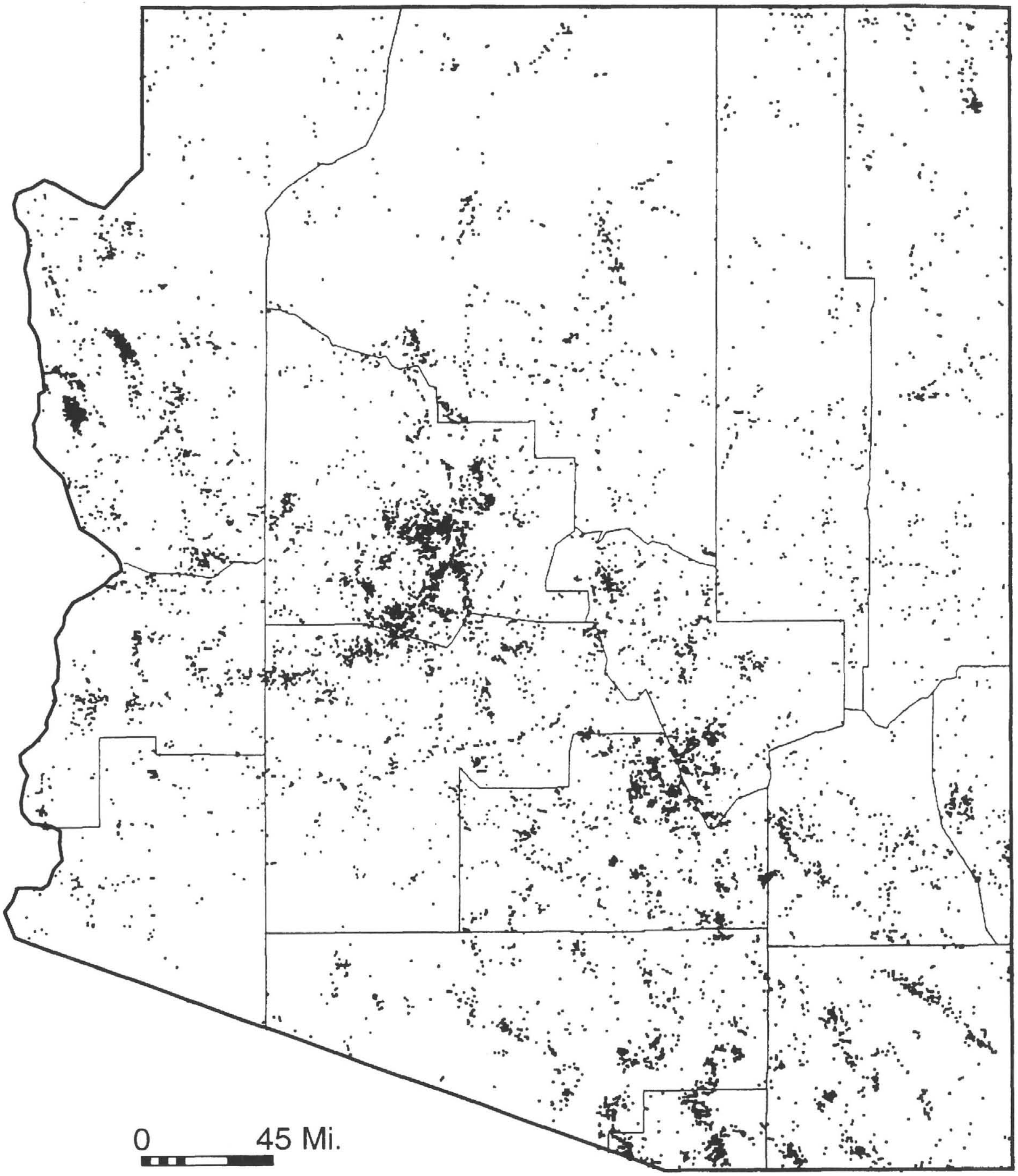
Figure 2: Relative values of industrial minerals produced in Arizona, 1996

2.1.2 Metallic Minerals

The occurrence and production history of 16 metallic and non metallic minerals was discussed in considerable detail by Sawyer et al (1992). Production statistics were compiled annually by the U.S. Bureau of Mines until 1996. In 1996 some of the Bureau of Mines responsibility for mineral data was transferred to the U.S. Geological Survey. The U.S. Geological Survey maintains the computerized Mineral Resource Data System (MRDS) in the Tucson office. This MRDS data base is available on CD ROM from the U.S. Geological Survey, Denver. A former U.S. Bureau of Mines' computerized Minerals Availability System / Minerals Industry Location System (MAS/MILS) database contains some similar information, but with greater emphasis on economic factors. It is available on CD ROM from Superintendent of Documents, P.O. Box 371954, Pittsburg, PA 1520-7954.

The Arizona Department of Mines and Mineral Resources maintains an AZMILS computerized database of mines, prospects, quarries, and processing mills and plants. The database includes primary names, alternate names, pertinent topographic map name, location by both latitude and longitude and by legal description, current status, pertinent commodities, and a reference bibliography for each of over 10,400 locations in Arizona. The data in this series was initially compiled from a study in cooperation with the U.S. Bureau of Mines to create the MAS/MILS data for Arizona. It is updated on a continuous basis by the Arizona Department of Mines and Mineral Resources.

Figure 3. Distribution of mineral occurrences in Arizona
(from ADMMR, June 25, 1997)



The 16 mineral commodities described in the Sawyer report were chosen because of their significance to the economy, critical and/or strategic nature, and environmental effects. The commodities are aluminum, asbestos, barite, columbium, tantalum, copper, fluorspar, gold, iron, lead, manganese, mercury, molybdenum, silver, tungsten, and zinc. Many other metallic mineral commodities are known in the State, but did not meet the criteria for that report.

Current Activity of Major Arizona Copper Producers

Copper mining represented about 88 percent of Arizona's nonfuel mineral value in 1996. The producer cathode price averaged $1.08 per pound, significantly lower than the 1995 average of $1.38. Record output of 2.7 billion pounds, gave the copper industry good operating earnings. The price at this time (June 24, 1997) is $1.13 per pound.

Arimetco Incorporated

Arimetco produces cathode copper from the Johnson Camp mine and holds additional reserves at their Van Dyke, Zonia, and Emerald Isle copper properties. Arimetco has recently filed for reorganization under Chapter 11 of the U.S. Bankruptcy Code.

Johnson Camp, located 65 miles east of Tucson, produced 6.3 million pounds of copper in 1995, up from 5.6 million pounds in 1994, as crushing of ore was implemented to improve leaching. Reserves at Johnson Camp's producing Burro Pit are estimated at 10 million tons, while the undeveloped Copper Chief orebody contains reserves estimated at 17.8 million tons. Mining of new ore has ceased as of June 1997, but leaching of heaped ore and recovery of copper continues.

The Emerald Isle open-pit mine and solution extraction/electrowinning (SX-EW) plant located near Kingman has been on care and maintenance, but may reopen in 1997. Ore reserves are estimated at 0.87 million tons of 0.57 percent copper.

Asarco Incorporated

Asarco's Arizona operations consist of the Hayden copper smelter, two major open-pit mines, Mission and Ray, and a dump leaching/cementation operation at the Silver Bell mine. The mines' production was 556 million pounds of copper in 1995.

Mission complex, 18 miles south of Tucson, consists of two pits, Mission and the smaller, but separate, San Xavier North. Sulfide ore is treated at two mills, Mission and South. They have the capacity to process 63,000 tons of ore daily, resulting in an annual capacity of 124,000 tons of copper in concentrates. Mission produced 228 million pounds of copper in 1995.

In 1994 Asarco began developing a 5-million-ton underground deposit located 400 feet lower and outside of the open-pit limits at Mission. Access to the orebody is through declines driven from the base level of the Mission pit. The underground operation will add about 28 million pounds of copper per year.

The Ray mine, the second largest in Arizona, produced 329 million pounds in 1995. It consists of an open-pit mine, dump and heap leach operations, a 40,000-ton-per-year SX-EW plant at Ray, and two mills - a concentrator at Hayden and a 30,000 ton per day concentrator at Ray. The Ray mine is in an elite group of a few deposits in the U.S. with reserves in excess of 1 billion tons. The Hayden smelter consists of an INCO flash furnace rated at 720,000 tons of charge per year for an estimated production of 175,000 tons of blister copper. A surplus of concentrates at the Hayden smelter has Ray reducing concentrate output from October, 1996 through March, 1997.

Asarco's Silver Bell mine continues to produce copper by dump leach precipitation while construction of a new $70 million SX-EW plant is underway. The project is being developed with Mitsui and Co. Ltd. as a 25 percent partner. Production is expected to commence in mid- to late 1997 with a capacity of 18,000 tons of refined cathode copper annually. Oxide ore for the project will come from a new area of the property known as Silver Bell North that contains nearly 200 million tons of reserves.

Asarco, along with joint venture partner Freeport McMoran Copper and Gold, continues the in-situ leach research project at the Santa Cruz property in cooperation with the U.S. Bureau of Reclamation who took over this function from the eliminated Bureau of Mines. In early 1996, construction of the test well site and SX-EW recovery plant was finished and injection of sulfuric acid into the undisturbed copper-bearing formation begun. This technology, if successful, has the potential of extracting copper from deep deposits with very little impact on the environment.

BHP Copper

Magma Copper was acquired by Broken Hill Proprietary Company Ltd. (BHP) of Australia effective January, 1996. The merger made the BHP Copper the second largest copper producer in the world with 9 percent of mine production. San Manuel and Pinto Valley are the company's two active mining divisions in Arizona. The Magma mine at Superior closed in June of 1996. It produced 38 million pounds of copper in 1995. BHP has begun engineering and permitting for an in-situ leach SX-EW for the Poston Butte deposit.

San Manuel is the largest underground mining operation in the United States and one of the largest underground copper mines in the world. The San Manuel Division consists of a block-caving underground copper mine, a 62,000 ton per day concentrator, heap leach, in-situ leach, SX-EW plant, a 1,300,000 ton per-year smelter with a 3,000 ton per-day acid plant and a 345,000 ton per-year electrolytic refinery, and a 180,000 ton per-year rod plant. It produced 282 million pounds of copper in 1995. Heap leach SX-EW production declined dramatically from 98 million pounds in 1994 to 48 million pounds in 1995 as no ore has been placed on the heap since the January, 1995 depletion of the open-pit.

Development of, and production from, the Lower Kalamazoo ore body at San Manuel is continuing. Its estimated ore reserves of 2.1 billion pounds of contained copper will add a number of years to the San Manuel underground mine. Production is being phased in with the depletion of the San Manuel orebody over the period from 1997 through 1999.

Magma's San Manuel smelter accounts for about 25 percent of U.S. copper smelting capacity. The Outokumpu flash smelting furnace is the largest single furnace smelter in the industry and a 20 percent expansion of its capacity was completed in March, 1994.

The Pinto Valley division includes the Pinto Valley mine and the Miami in-situ and Miami No. 2 tailings leach operations. The Pinto Valley mine consists of an open-pit mine, a 63,000 ton per-day concentrator, dump leach and 8,000 ton per-year SX-EW plant. Miami's leach operations recover copper from in-situ leaching of the old Miami mine block cave area and by hydraulic mining and leaching of the old Miami tailings. The resulting pregnant leach solutions are processed through Miami's 10,000 ton per-year SX-EW plant. Pinto Valley produced 189 million pounds of copper, and the two Miami leach units 23 million pounds in 1995.

Cambior U.S.A.

Construction of the Carlota mine of Carlota Copper Company, a subsidiary of Cambior U.S.A., continues to be delayed by the permitting process. Permits from the U.S. Forest Service had not been received as of June, 1997. Completion of the Final Environmental Impact Statement from the Tonto National Forest had been expected in late 1996 and permitting to have been completed so that construction could begin in early 1997. A media advertising campaign against issuing permits for the mine's development has recently begun by organizations opposed to mining. The property consists of four oxide ore bodies, Charlotte, Cactus, and North and South Elder. Mineable reserves total 96 million tons grading 0.44 percent copper. Production is planned at a rate of 30,000 tons of copper per year for the first ten years via open-pit mining, heap leaching, and SX-EW.

Cyprus Climax Metals Company

Cyprus is Arizona's second largest producer of copper and the world's largest producer of molybdenum. Copper totals for 1995 were 621 million pounds of copper.

Cyprus Climax Minerals Company maintains corporate headquarters in Tempe, Arizona and operates five copper mines in the State: Bagdad, Tohono, Miami, Mineral Park, and Sierrita.

The Sierrita property consists of three open-pit copper-molybdenum mines, a 110,000 ton per-day concentrator, two molybdenum roasting plants, a ferromolybdenum plant, a rhenium plant, a dump leaching operation, and an SX-EW plant. More than three quarters of Cyprus' molybdenum concentrate from Thompson Creek (Idaho), Bagdad, and Sierrita is processed at Sierrita through roasters to produce molybdenum oxide and ferromolybdenum. Sierrita is recognized as one of the most efficient mines in the world as it operates with the lowest average copper grade, 0.27 percent, of any milling operation. Sierrita contains proven and probable reserves to last 20 years at its present mining rate of almost 50 million tons per year.

The Bagdad operation consists of an open-pit copper-molybdenum mine, an 85,000 ton per day concentrator, a dump leach operation, and a SX-EW plant. In 1995 Bagdad produced 31 million pounds, or 15 percent of its total copper production, as electrowon copper cathode. Cyprus reported in 1995 that Bagdad has over a billion ton proven and probable ore reserve of 0.38 percent copper and 0.021 percent molybdenum.

Cyprus' Tohono operations consists of an SX-EW plant fed by a newly developed test open-pit and heap leach. In 1995 Tohono produced 34 million pounds of copper, an increase of over 10 million pounds. Cyprus mined 8.4 million tons in 1995 despite reporting only 12 million tons of reserves. A 600 million ton resource could become reserves if heap leaching operations continue to be successful.

The Miami mine consists of an open-pit copper mine, an SX-EW plant, a 650,000 ton per-year capacity smelter, an acid plant, a 380 million-pound electrolytic refinery, and a 135,000 ton per-year rod plant. Miami produced 129 million pounds of copper in 1995 and has increased the capacity of its SX-EW plant to increase production in 1995. The investments in the smelter and refinery at Miami have made Cyprus more efficient and self sufficient in domestic copper smelting and refining.

At the Mineral Park open-pit copper-molybdenum mine in Mohave County, Cyprus converted the in-place leach and precipitate operation to an SX-EW operation capable of producing 6 to 8 million pounds of copper per year. Production resumed in November 1994, and during 1995 produced over 3 million pounds of copper. A letter of intent has been signed to sell the operation. The final sale is dependent on the buyers confirmation of the operation and the deposit's value.

Phelps Dodge Corporation

Phelps Dodge Corporation, with headquarters in Phoenix, is the nation's largest copper producer and the world's largest producer of SX-EW cathode copper. Its mining division, Phelps Dodge Mining Company, produces about one-third of the US's mined copper at its properties in southeastern Arizona and southwestern New Mexico. The company broke all production and financial records in 1995. In Arizona, Phelps Dodge operates the Morenci mine complex in Greenlee County and the Copper Queen in Bisbee, and holds significant undeveloped copper resources throughout the state. Phelps Dodge owns an 85 percent interest in the Morenci mine; the remaining 15 percent is owned by Sumitomo Metal Mining Company, Ltd. The mine employs approximately 2,700 people.

Morenci is the largest copper producer in North America and the third largest copper mine in the world. In 1996, Morenci produced a record 1.02 billion pounds of copper from 297.7 million tons of ore. This copper production is 25 percent more than the record set in 1994. For the first time ever, copper recovered by leaching SX-EW exceeded that from flotation concentrates. The Morenci operation consists of the Morenci, Metcalf, Northwest Extension, and the Southside Expansion open-pit copper mines, and the 9/10 stockpile, the 75,000-ton-per-day Morenci concentrator with a molybdenum circuit, the 60,000-ton-per-day Metcalf concentrator, four leach stockpile systems with SX plants, the new Southside EW plant with a 130 million pound capacity, and, at a capacity of 370 million pounds annually, the world's largest EW plant. Morenci's milling and leaching reserves total over 1.5 billion tons.

The Coronado deposit hosts 480 million tons of sulfide and oxide ores. The nearby Western Copper deposit is estimated to contain 530 million tons of milling material at a grade of 0.55 percent copper, and 500 million tons of leach material at a grade of 0.31 percent copper. In 1994-95, a large resource of leachable material called Garfield, containing one billion tons grading 0.27 percent copper, was outlined north of the Metcalf mine. It is anticipated that continued drilling will result in a doubling of this resource.

The company's Copper Queen mine consists of a small dump leaching and precipitation operation at the depleted Lavender pit. No decision has been made as to when to bring the adjacent Cochise deposit, containing 210 million tons of 0.4 percent leach material, to production.

Phelps Dodge has a district office in Safford where evaluation and permitting of the Lone Star, Dos Pobres, and San Juan deposits continues. In late 1995, the Sanchez deposit was acquired from AZCO Mining. This increases the company's open-pit, leachable copper resources in the district to nearly 2.4 billion tons. Dos Pobres also contains 330 million tons of sulfide reserves. Work is underway on an EIS to facilitate development in the district.

Phelps Dodge has recently announced plans to reopen the New Cornelia mine at Ajo that was closed in the early 1980's. It will spend approximately $238 million to update and reopen the mine. Plans include the construction of a new concentrator and employment of approximately 380 workers. During the last couple years the obsolete recovery plant and smelter have been dismantled and scrapped. The copper resource there is 160 million tons grading 0.56 percent copper. When the mine reaches planned full production it will add 135 million pounds of copper to Arizona's annual total. The precious metal content of copper ore in the New Cornelia deposit is one of the highest in Arizona's bulk low grade copper deposits. Approximately 25,000 tr. ounces of gold will be added to Arizona's annual byproduct gold production

Phelps Dodge and Cominco announced a joint venture agreement for the United Verde massive sulfide deposit at Jerome. The property contains a 21-million-ton resource at 6.6 percent zinc, plus copper and precious metals. This deposit is believed to contain the second largest undeveloped zinc reserve and the largest zinc reserve that can be developed in the United States.

Table 4. 1995 Copper Mine Production

Mine/Company	Production (lbs)	Percent of Total
Morenci/Phelps Dodge	874,523,599	33.5
Ray/Asarco Inc.	329,106,694	12.6
San Manuel/BHP Copper	282,971,000	10.8
Sierrita/Cyprus Copper Co.	240,214,000	9.2
Mission/Asarco Inc.	227,762,115	8.7
Bagdad/Cyprus Copper Co.	214,931,000	8.2
Pinto Valley/BHP Copper	188,930,171	7.2
Miami/Cyprus Copper Co.	129,046,000	4.9
All others	125,840,837	4.9
Total	2,609,986,416	

Gold Production in Arizona

Gold production in Arizona over the last 30 years has fluctuated considerably. Byproduct production from copper mining has constituted at least 50 percent of the gold recovered in Arizona, sometimes as high as 99 percent. Current reported production is relatively low because of lack of data from one producer and the closing of Cyprus-Amax's Copperstone operations in 1993. Byproduct production from copper mines has not kept pace with increases in copper production due to the inability of leaching processes to recover precious metals and semi-precious metals contained in the ores. The start-up of the New Cornelia mine at Ajo will add about 25,000 ounces to Arizona's annual gold production.

Addwest Minerals Inc. was sold by Addington Resources in December, 1995, to a group of private investors. The company continues to operate the Gold Road mine and mill at Oatman. The

Gold Road mine, which is the only producing primary gold mine in Arizona, produced 40,000 oz of gold in 1995. Due to statistical data-handling difficulties, this production is not included in the totals for Arizona's production.

BEMA Gold, doing business in Arizona as Yarnell Mining Company, continued permitting efforts for its Yarnell deposit that contains 7.3 million tons of 0.037 oz per-ton Au. The planned open-pit heap leach hopes to receive the final EIS in September, 1997 and to begin construction immediately thereafter.

Gold continues to be produced as a by-product of the copper industry in Arizona. In 1995, the major copper mines produced approximately 50,000 ounces of gold from the following mines: San Manuel, Magma, Morenci, Ray, Mission, Sierrita, Pinto Valley, and Oracle Ridge. Both the Magma and the Oracle Ridge mines have since closed. There is no basis to the long-standing rumor that sufficient amounts of gold and silver are recovered from copper mining "to pay the costs and have all the copper be profit".

Nevada Pacific has obtained permits for an open-pit, heap leach, gold mine operation at the Cyclopic Mine in Mohave County at the rate of 750,000 tons of ore per year. The company is awaiting the completion of financing arrangements to begin construction.

Royal Oak has been exploring a deep portion of the Copperstone ore body. They have announced completion of a second phase drilling program and budgeted $250,000 for drilling in 1997 with the objective of outlining 1,000,000 ounces of gold in mineable reserves. Currently the property contains a resource of approximately 500,000 ounces.

Gold and the platinum group metals have a very high unit value (greater than $100 per troy ounce) compared to base metals (about $1.00 per pound) and many of the industrial minerals (as little as $3.00 per short ton). High unit values, along with the fact that ores containing as little as one part per million (ppm) may have economic potential, allow these metals to be subject to many kinds of questionable promotional schemes. Claims of the economic presence of these metals in rocks that cannot be verified by standard industry practice or that require secret metallurgical processes for recovery are suspect.

Other Metals

Molybdenum is recovered as a byproduct or coproduct at some copper mines. When it occurs in economically recoverable quantities, the molybdenum mineral molybdenite, can be recovered by selective flotation during the copper ore concentration process.

Zinc and lead minerals are contained in the flotation concentrates from at least one copper mine. These metals are recovered from the waste dusts generated in the process of smelting the copper concentrate.

Very small quantities of tellurium, selenium, palladium, and platinum are recovered from impurities released during the electrolytic refining of anode copper produced at copper smelters.

2.1.3 Metallic Fuel Minerals (uranium)

Economic History

Carnotite was discovered in Monument Valley in 1911 and in the Carrizo Mountains in 1918. The first production of uranium in Arizona was a small ore shipment in 1920 from the Carrizo Mountains. The vanadium content of the carnotite ores became important in the early 1940s for use by the steel industry in the manufacture of armaments. From 1942-46 mines in Monument Valley and the Carrizo Mountains produced 15,070 tons of vanadium ore from which 64,000 pounds of uranium oxide were recovered. Stimulated by the uranium procurement program of the Atomic Energy Commission, which began in 1947, exploration for and development of uranium mines in Arizona boomed and by 1955 most of the presently-known surface and subsurface deposits had been discovered. Production peaked in 1958 when 257,756 tons of ore, averaging 0.32 percent U_3O_8, and containing 18,000,886 pounds of U_3O_8 and 42,186,661 pounds of vanadium oxide (V_2O_5) was produced. Production continued into 1969. There was no uranium mining in Arizona in the early

1970s but exploration increased in 1975, and a major discovery in Yavapai County was announced in 1977 in the immediate area of the Anderson mine, but has yet to be developed. Nearly 1,000 tons of ore were mined in Gila, Navajo and Pima counties. In 1980, uranium began to be recovered as a by-product from copper leach solutions at Anamax's Twin Buttes operation in Pima County, which produced about 200,000 pounds of U_3O_8 by 1985 when the operation closed down.

The Grand Canyon region became the focus of uranium exploration in 1980 when Energy Fuels Nuclear began production from breccia pipe deposits. From 1980 to 1991, the company mined more than 13,000,000 pounds of uranium at an average grade of 0.65 percent U_3O_8. The high grade of the breccia pipe deposits has made them attractive exploration targets and will continue to be of interest to the industry in the future.

Occurrence

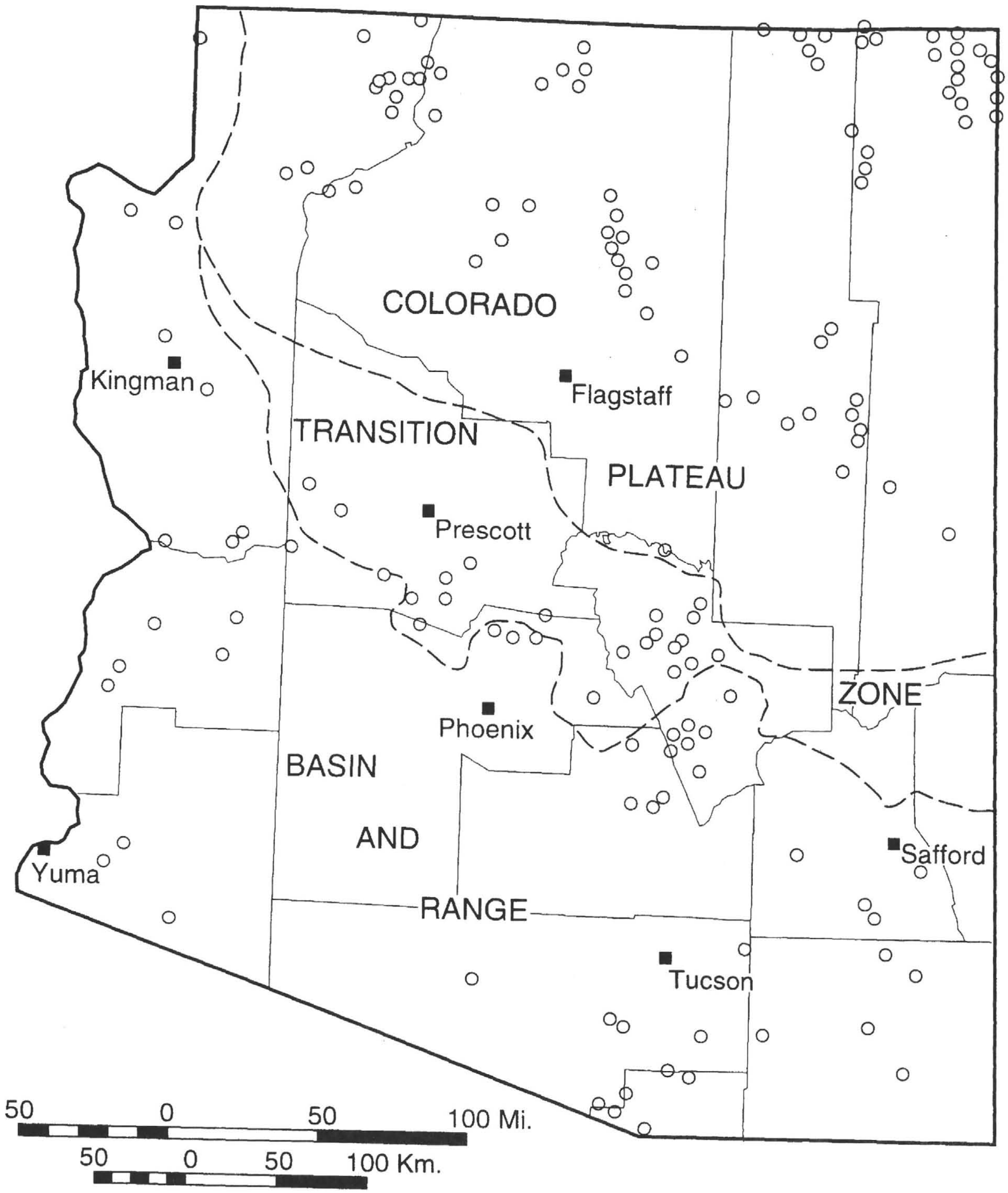
Numerous occurrences of uranium are known throughout Arizona, with past production primarily from Triassic and Jurassic strata and in breccia pipe deposits in Permian strata on the Colorado Plateau (figure 4). Arizona produced approximately 32 million pounds of uranium oxide (U_3O_8) between 1947 and 1987, approximately three percent of the total United States production. Domestic uranium production began to decline in 1980, while the production from Arizona increased, with the result that Arizona and New Mexico became the leading uranium-producing states between 1984 and 1988. As indicated in table 5, uranium ore has been mined from several rock units, all of which still offer potential for future production.

Table 5: Uranium production in Arizona, 1947-1991

Host Rock	Tons of Ore	% U_3O_8	Pounds U_3O_8
Toreva Formation	16,781	0.17	55,730
Morrison Formation	810,999	0.24	3,852,021
Chinle Formation	1,607,336	0.24	9,657,931
Breccia Pipes	1,497,006	0.50	20,575,144
Miocene sediments	10,759	0.16	33,593
Dripping Spring Quartzite	25,671	0.22	115,305
Other	2,288	0.15	6,707
Total (mined ore)	3,970,840	0.43	34,246,271
By-product production (est.)			1,100,000
Total U production			35,346,271

(Source: Wenrich et al, 1989, ADMMR)

Figure 4: Uranium occurrences in Arizona



2.1.4 Industrial Minerals

Introduction

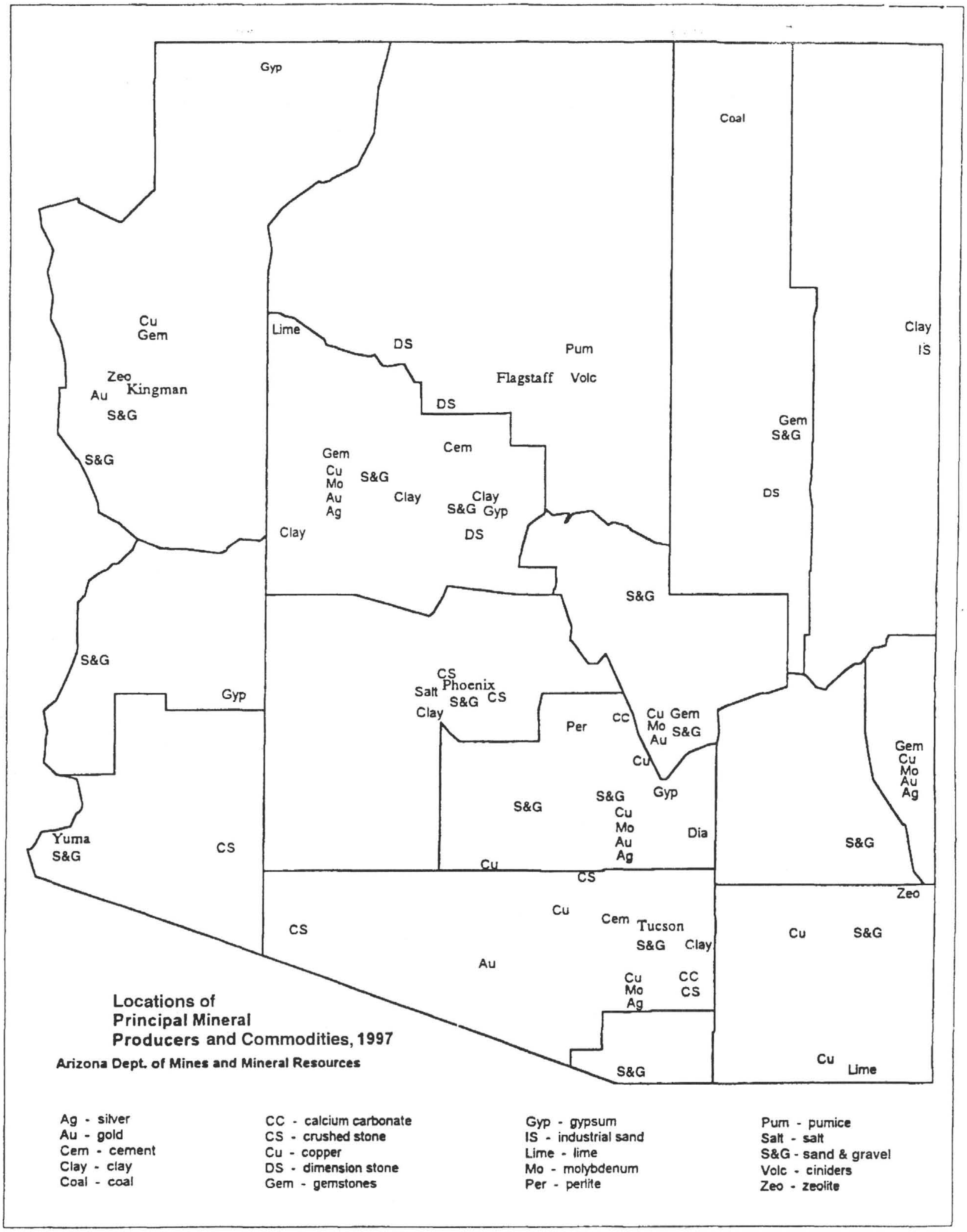
Industrial minerals are mineral commodities other than the metals. Ores of metals are mined and processed to produce refined metals. All other mined ores, minerals, and inorganic earth substances are industrial minerals. The division between the two commodity groups appears simple, but there are some points best explained by example. The metals gold, silver, copper, lead, zinc, iron, chrome, beryllium, etc. are recovered from metal ores. The industrial minerals, often referred to as nonmetallic mineral commodities, include sand, aggregate, quartz, feldspar, fluorite, clays, gemstones, salt, barite, etc. They are recovered from mining and processing industrial mineral ores and rocks. Some examples are not as straightforward. Mining zinc ore, a metal, processing it to produce zinc metal is metal mining. Mining the same zinc ore, processing it to produce white zinc oxide pigment and pharmaceuticals is industrial mineral mining. The zinc ore example is applicable to other ores as well. Iron ore for iron versus iron ore for ochre pigments; beryl ore for beryllium metal versus beryl ore for beryllia ceramics; and copper ore for copper metal versus copper ore for copper sulfate livestock feed additives are additional examples.

Arizona per capita consumption of basic nonmetallic materials is approximately 12 tons per year. These mineral commodities are used to build infrastructure (homes, schools, roads, etc.), to support society, and to aid in the disposal of waste. Arizona continues to be one of the fastest growing states in population. An increasing population requires more than the average quantity of industrial mineral materials to provide for that population's needs. As incremental growth is supported on an ever increasing base, the incremental demand for many forms of infrastructure decreases and thus does the per capita consumption of industrial minerals. Although the expanding population of Arizona will require an ever increasing supply of industrial minerals, the rate of production growth of many industrial mineral commodities may decrease.

The value of nonfuel-mineral production in Arizona in 1996 exceeded $3.53 billion , about 88 percent of which was derived from metal ore production and about 12 percent from industrial minerals. The value of the industrial mineral component of this production is estimated at about $435 million. This amount would rank Arizona between 15th and 20th by value in the United States. In terms of all nonfuel mineral production in Arizona, the value of sand and gravel is second only to copper. Within the nonmetallic mineral group itself, sand and gravel, cement, and lime made up more than 86 percent of the dollar value in 1996. The remaining $61 million is attributed mainly to crushed stone, gypsum, calcium carbonate, dimension stone, perlite, clays, salt, zeolites, cinders, pumice, iron oxide pigment, diatomite, and gemstones. The locations of the principal mineral producers and commodities in Arizona during 1997 are shown in figure 5.

Industrial mineral commodities exported from Arizona range from basic raw materials, such as industrial sands, clays, zeolites, pyrites, lime, calcium carbonate, diatomite, iron oxides, perlite, and dimension stone, to fabricated or processed materials, such as vitrified sewer pipe and salt and ingredients in manufactured products such as calcium carbonate and copper in insulated electric wire, gypsum and perlite in horticultural planting mixes, and calcium carbonate and salt in pet foods.

Figure 5. Locations of principal mineral producers and commodities in Arizona, 1997



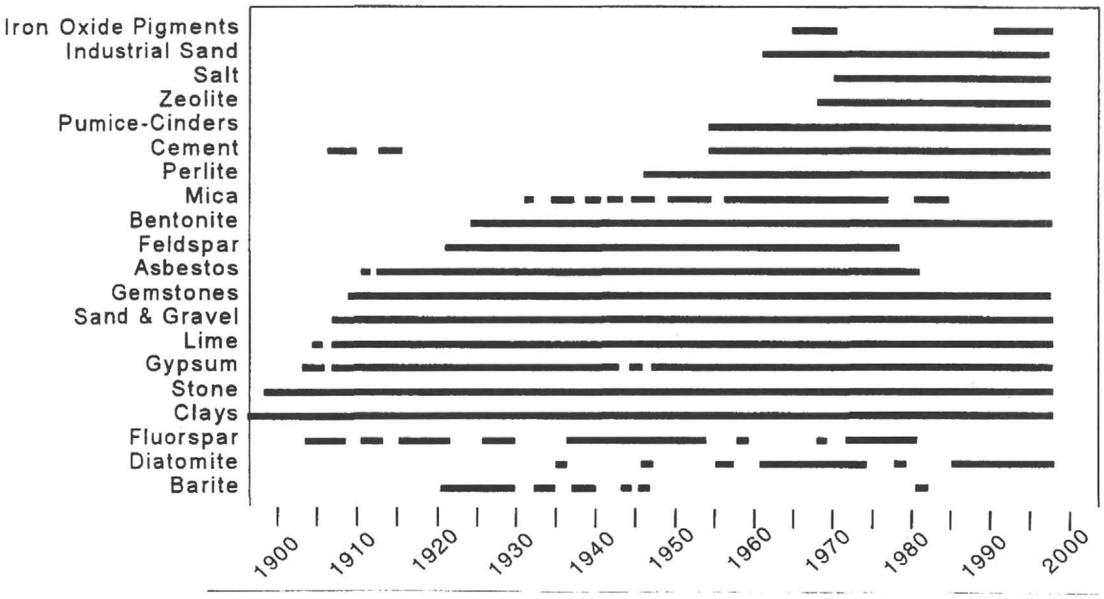


Figure 6. Production history of nonmetallic minerals in Arizona, 1895-1997
(modified from Peirce, 1988)

Markets and Market Stability

Production of industrial minerals is much more sensitive to market factors than production of metals. Quantity, location, variety, and quality are parameters of significance. Further, the duration and continuity of production of an industrial mineral mine in Arizona is dependent on markets, ore deposits, mine management, and governmental regulation. The continuity, or discontinuity, in the production of several nonmetallic-mineral commodities is shown in figure 6.

Most industrial mineral commodities are sold as bulk commodities and priced in dollars per ton whereas most metallic mineral commodities are sold and priced in dollars per pound or troy ounce. The industrial minerals are thus often considered to have a high place value as opposed to a high unit value. In general, high place value minerals and mineral deposits are only valuable when produced very close to their consuming markets. However, this consideration varies extensively. Some examples will be helpful in explaining this characteristic

Concrete ingredients are a good example to explain the variation in place value versus unit value considerations. Concrete may be made up of about 85 percent aggregate, about 15 percent Portland cement, and a small amount of admixtures. Aggregate is the main component of concrete and has a very small unit value, ($4.00 - $6.00 per ton). Aggregate cannot economically withstand much transportation cost and thus the source must be very close to where the concrete is mixed. Commodity sources that must be close to their point of use are said to have high place value. Portland cement makes up only 15 percent of concrete, has a higher unit value, ($50.00 - $70.00 per ton), thus can with stand some transportation cost, but is generally still manufactured within 100 - 200 miles of where it will be used. Admixtures form a very small part of the concrete mix, but are very important in adjusting parameters of the final set concrete. Admixtures have a very high unit value ($750.00 - $3500.00 per ton) and can withstand the cost of global transportation.

A related example is the manufacture of Portland cement made from limestone, quartz, high alumina clay, iron ore, and gypsum. Limestone makes up the largest portion of the feed to a cement plant. Availability of a nearby, large limestone deposit amenable to cement manufacture is one of the most important considerations in locating a cement plant. Additionally, if given the choice of more than one limestone deposit, the cement plant will most likely be located near the deposit that allows the plant to be closest to the market area for the cement.

An example of production longevity is the special bentonite clay that occurs in southern Apache County in the Plateau Province of northeastern Arizona. The raw clay is stripped of its overburden and shipped out of state for processing into desiccants, thickeners, and other industrial uses.

Arizona Industrial Minerals, Arizona Department of Mines and Mineral Resources Mineral Report MR-1, (1987) by Ken A. Phillips contains extensive listings of industrial mineral occurrences in Arizona. Gem stones, aggregates, and dimension stone are excluded from that report.

Locations of Raw Materials and Processing Plants

Most nonmetallic minerals and rocks undergo some type of processing, somewhere. In certain cases the processing is done close to the deposit and in others the raw materials are delivered to plants either in or out of Arizona. Processing techniques for industrial minerals that are produced in Arizona, are discussed by Phillips (1996) in ADMMR Circular 65.

Industrial Mineral Commodities

Sand and Gravel (Construction Aggregates)

Sand and gravel are the most common and most important industrial rock products used. They exceed in total tonnage, the production and use of any other rock material in the United States. The annual tonnage used in Arizona outranks that of any other mineral resource. The value of Arizona sand and gravel production ranks below only copper and coal. In 1996, Arizona produced 46,190,000 short tons of construction sand and gravel worth $220 million at an average mine value of $5.25 per ton. The urban centers of Maricopa and Pima Counties were the largest producers and consumers of construction sand and gravel. Arizona ranks among the top five states in sand and gravel production.

The value of sand and gravel varies, and commercial competition in Arizona is strong. Contrary to the normal economic trend, prices generally are lower in times of high demand since many small producers only operate during such periods and thus provide increased competition in the available markets.

A factor in Arizona's high rank is the State's relative abundance of natural aggregate available from alluvium deposits. In many states a large portion of construction aggregates are produced from quarried hard rock deposits. Costs to produce and the selling price of aggregate obtained from quarried hard rock deposits are about 33 percent higher than that from sand and gravel deposits.

There are four major steps to sand and gravel mining: 1) site acquisition and clearing; 2) open-pit mining, sometimes under water in flooded pits; 3) processing, consisting of crushing, screening, washing, and blending materials, and; 4) site reclamation.

Sand and gravel consist of unconsolidated detritus ranging from the finest powdery silt and clay to large boulders. In normal commercial usage sand is commonly classified as "granular particles almost entirely passing the No. 4 (4.76 millimeter or approximately 3/16-inch) sieve but predominantly retained on the No. 200 (0.074 millimeter or 74 micron) sieve." Gravel is "granular material predominantly retained on the No. 4 sieve" (Am. Soc. Testing Materials, 1967, pt. 10, p. 83). Material over 2 inches in diameter is usually crushed to a smaller size. Stone that is crushed and pulverized is not normally called sand and gravel, but is used in nearly all of the same applications. Aggregate is a term commonly used for sand, gravel, and crushed and broken stone, particularly when mixed with cement, lime, or bituminous material to make concrete, mortar, or asphaltic concrete.

Sand and gravel particles may be angular to rounded, and elongated to spherical in shape, depending on the characteristics of the parent materials and the amount of disintegration and abrasion that has taken place in their formation. The sand grains and rock particles may consist of one or more minerals but crystalline quartz, one of the most common minerals, usually predominates and is the most desirable constituent. Other common minerals in sand and gravel are feldspar and mica. The presence of more than minor amounts of silt and clay or other soft, friable, unsound, and chemically active materials such as mica, kaolinized feldspar, amorphous silica, carbonaceous matter, iron oxides, and salts normally are undesirable. The specifications for sand and gravel for construction use have become increasingly strict in recent years and careful field checks and laboratory testing often are required to determine the suitability of a deposit for exploitation. Industrial sand is sand used for specialized purposes other than construction. Its specifications are even more stringent.

Sand and gravel deposits result from the natural disintegration and abrasion of rock through the combined action of weathering and erosion. The character of the deposits depends on the original rock constituents, the type and duration of the disintegration and abrasion processes, the manner and distance of transportation, and the form and manner in which the products are deposited and, or, reworked. Most rocks can yield sand and/or gravel, but the products from different rocks vary greatly in quality and size and shape of particles.

In Arizona the most important sand and gravel deposits are the ones formed by the transportation, deposition, and reworking of detritus by stream action. Such deposits occur in basin and valley fills, in stream terraces, in buried and active stream channels, and in alluvial fans.

Sand and gravel deposits occur in all counties of Arizona, but the amount and quality of the deposits vary greatly between localities because of the different geologic, topographic, and climatic conditions.

General areas or locations of known significant commercial sand and gravel operations in Arizona include the Phoenix area in Maricopa County which accounts for a major share of the production followed by:

Tucson area, Pima County
Casa Grande area, Pinal County
Verde Valley area, Yavapai County
Bullhead City and Lake Havasu City areas, Mohave County
Sierra Vista area, Cochise County
Yuma area, Yuma County

Other commercial production areas and localities include industrial sand production at Houck in Apache County. Other sand and gravel production areas are:

Bisbee and Wilcox areas, Cochise County
Flagstaff area, Coconino County
Globe area, Gila County
Safford area, Graham County
Kingman area, Mohave County
Taylor and Holbrook areas, Navajo County
Mammoth, Kearney, and Apache Junction areas, Pinal County
Nogales area, Santa Cruz County
Prescott and Clarkdale areas, Yavapai County
Parker area, La Paz County

Some industrial quality sand occurs mainly in the Bidahochi Formation, of Pliocene age, on the Navajo Indian Reservation, Apache and Navajo Counties. Currently, a sand deposit a few miles northwest of Houck is being mined and processed for hydrafrac and sand-blasting purposes. The sand is unconsolidated, fairly coarse-grained, well-rounded and well-sorted, and is nearly pure quartz. Local dune and terrace deposits of Quaternary age also are known. Although too impure for glass manufacture, many of these sands may be acceptable for other industrial uses .

Arizona has ample reserves and resources of sand and gravel for constructional purposes but the remoteness from markets and the limited accessibility of many deposits limits their exploitation.

In the northeastern Plateau region good sand is plentiful and some of it is of industrial quality, but good gravel is scarce, particularly near population centers or along main transportation routes. Fortunately, volcanic cinders and scoria are available and more accessible and, thus, are used extensively as a substitute for gravel. The production of industrial sand in Arizona presently is small but the resources are large and could supply a greatly expanded market.

Fairly abundant local resources of sand and gravel occur in the mountainous regions of central Arizona, but the deposits are generally inaccessible and too far from the major markets.

In the central, southern, and western basins, particularly in the Phoenix and Tucson areas where the principal markets exist, the best and most accessible alluvial deposits have been or are being exploited. These deposits generally are thin but are frequently recharged with new material by intermittent stream action. The sand content greatly predominates and gravel generally occurs only in local lenses and bars. Processing almost always is required and a large amount of material is rejected as waste. Another serious problem for producers is conflict with urban growth. As the cities expand, sources of sand and gravel are eliminated by restrictive zoning and increased land values. Thus, sand and gravel producers are forced to find deposits that are less satisfactory in quality or quantity, or are more distant from the markets. Such problems are common in urban and the related large suburban areas. Generally, however, Arizona has great resources of sand, but coarser aggregate is quite limited. With the large and increasing demand in the State for coarse aggregate, crushed and broken stone will likely become a major substitute for gravel in the near future.

Portland Cement

Cement ranks second in value to sand and gravel production in the State's nonmetallic mining industry and is estimated to rank fourth in nonfuel mineral production behind copper, sand and gravel, and molybdenum.

Arizona's cement production capacity of 1.73 million short tons ranks fifth among states west of the Mississippi. Arizona has two Portland cement plants. One plant is operated by Arizona Portland Cement Company at Rillito, the other is operated by Phoenix Cement Company at Clarkdale. Arizona's combined production of Portland cement and masonry cement is estimated at 1.6 million short tons worth $105 million; an estimated per-ton value of $61. These cement plants often operate well below capacity. They are impacted by both the slumps in the construction economy and the practice of southern California and Mexico cement plants shipping excess production to Arizona. Limestone for each plant is mined from company-owned quarries near their plants. Other raw materials are supplied by independent mines and secondary industrial sources.

Arizona Portland Cement Company's plant with an annual capacity of 1,100,000 tons produces Portland cement from quarried and purchased raw materials. Phoenix Cement Company is owned by the Salt River Pima-Maricopa Indian Community. Their plant, located at Clarkdale approximately 100 miles north of Phoenix, has an annual capacity of 630,000 tons.

Raw materials consist of siliceous limestone, high calcium limestone, high alumina clay, "aluminum catalyst waste," low grade bauxite, floated hematite from Magma Copper Company's Magma Mine at Superior, iron ore (hematite) from Eagle Mountain in California, gypsum, and the fuels; natural gas, fuel oil, coal, coke, and shredded automobile tires. These materials supply the necessary calcium oxide, silica, alumina, iron oxide, and energy to make cement clinker and the calcium sulfate to control setting and curing properties of the final product.

Arizona Portland's plant is supplied largely with limestone from their Twin Peaks deposit about 4 miles southwest of the plant. The limestone formations utilized come from a fault block in the Basin and Range Province and include the Devonian Martin Formation, Mississippian Escabrosa Limestone and Pennsylvanian Horquilla Limestone. These limestones are fine grained and interbedded with silty to sandy limestone. Limestone for Phoenix Cement comes largely from the Mississippian Redwall Limestone in an outcrop belt in the Transition Zone. The Redwall Limestone is a massively bedded, often cherty, gray and coarsely crystalline rock with few limited impurities. At both plants the limestone usually contains sufficient silica such that only limited additional sources are needed.

Lime

Chemical Lime operates the two lime plants in Arizona. Their Nelson plant is located between Flagstaff and Kingman north of Interstate 40. Here the company quarries a pure high-calcium limestone from the Mooney Falls Member of the Redwall Limestone. The limestone is crushed and sold directly and used as feed to the plant's two rotary lime kilns. The two kilns, one with a capacity of 1000 tons per day and the other rated at 750 tons per day, produce a soft burn, low density, highly reactive quicklime. Coal and coke are used for fuel. The plant serves Arizona customers and the company's bulk distribution terminals in Stockton, California, Denver, Colorado, Gallup, New Mexico, and Belen, New Mexico.

Their Douglas plant is located at Paul Spur west of Douglas and 1.5 miles from the Mexico border. Here the company quarries feed for their plant from the Cretaceous Mural Limestone. This limestone is crushed and sold directly and used to feed the company's two rotary and one vertical lime kilns. The three kilns provide the plant with a total capacity of 1000 tons per day. The plant serves Arizona's copper industry and water treatment plants in southern Arizona and west Texas, as well as some gold mines in southern California.

Chemical Lime reports a growing use of lime in the extension of sand and gravel reserves by reducing the deleterious effect of clay particles in concrete aggregate.

Crushed Rock

Crushed rock in Arizona is a term used to cover everything from rip-rap and fill to value-added, finely ground, controlled-particle-size calcium carbonate for functional filler uses. Crushed and ground calcium carbonate, decorative or landscape rock, and volcanic cinders are the important crushed rock industries in Arizona. Also important is crushed rock for construction aggregate in regions with no local sand and gravel and railroad ballast.

There are at least four Arizona producers of crushed and/or milled limestone and marble for non-cement and non-lime uses. In 1989, the last year for which production data is available, they produced 62,500 tons valued at $865,700 for an average mine value of $13.85 per ton. High-calcium marble is the ingredient in the manufacture of these ground products; whereas high-calcium limestone is fundamental ingredient in the manufacture of cement and lime

With the acquisitions of small Arizona operations by Pfizer (now called Specialty Minerals) and Georgia Marble and the startup of Minerals Development a number of specialty coarse-sized and finely milled calcium carbonate and marble products have become available to Arizona and southwestern United States consumers and manufacturers from a local source.

Operations to produce these products consist of open-pit mines, crushing and screening plants, mills, and ancillary packaging and handling facilities. In the quarry, the coarsely crystalline marble is drilled, shot, and loaded into mine trucks for haul to the crushing and mill plant. At the plant, mine run material is crushed and screened to produce landscape rock, and finely crushed and screened to make poultry grit and marble sand. The crushing and screening plant also produces minus 7/8" material to feed the Raymond roller mills. The Raymond roller mills with their internal wizzers in closed circuit with air cyclone classifiers are used to produce the finely ground marble filler grades. The various products are either conveyed to stockpiles for the coarse materials or blown or lifted to silos for fine products. A bagging plant is fed from the silos and bulk trucks are also loaded from the silos. The coarse landscape material is loaded into trucks with a front end loader.

Volcanic cinders, or scoria, are quarried from geologically young cinder cones in a belt extending from Williams east to the New Mexico border in north central Arizona and in the southeast corner of the state. Cinders are used for some types of aggregate, horticulture mixes, road deicing, light weight aggregate, leach fields, and decorative rocks.

The range of sized products listed at the end of this paragraph illustrates the variety of products produced by Arizona's crushed stone industry. Production from quarries is typically drilling, blasting and loading, or by dozer and front end loader. Screening plants produce many size gradations for multiple markets:

Decorative boulders
Powdered marble
Plus 2" decorative rocks
Plus 3/4" minus 2" leach field rock
Plus 3/8" minus 1/2" precast surface rock
Plus 1/4" minus 3/8" cinder block aggregate and snow removal rock
Decorative plus 7/8" minus 1.25"
Decorative plus 1.25" minus 2"
Decorative plus 1/2" minus 7/8"
Decorative plus 7/8" minus 1"
ABC 3/4" minus
ABC 1" minus

Decorative and landscape rock can be described as any crushed, broken, or quarried blocks of rock, and natural boulders used outdoors for ground cover and decorative purposes. Included is naturally crystalline rock that has weathered to produce a "decomposed granite" type material.

The major market for crushed and decomposed granite produced in Arizona is the urban and suburban areas of Tucson, Phoenix, and Las Vegas. Material for the Tucson market is produced at San Manual; that for Phoenix is produced from outcrops and pediments surrounding the Salt River Valley; and that for Las Vegas is from the Mineral Park area of Mohave County.

Clay

A variety of types of clay are produced in Arizona. Commercial clays may be classified by mineralogy, chemistry, uses, or consuming industries. The U.S. Bureau of Mines reports Arizona as producing non-swelling bentonite, swelling bentonite, and common clay. By use classification, these clays are reported as bentonite clays for oil refining catalysts and clay desiccants, and common clays for floor and wall tile, bricks, Portland cement, structural tile, and miscellaneous clay products. The clays of the Pantano Wash are classified as common clay for bricks, common clay for structural tile, and common clay for cement. However, high alumina clay suitable for structural clay products is not a common occurrence.

Arizona structural clay is used for a variety of products including bricks, tile, and vitrified sewer pipe. Kaolinitic shales from the Upper Cretaceous strata along the edge of the Colorado Plateau in east-central Arizona (figure 5), along with clay from a deposit near Dewey, is trucked to the plant near Phoenix to produce a vitrified sewer pipe. These clays, blended with refractory schist, fuse at a low temperature, forming an impervious glasslike binder to make the pipe.

Relatively pure calcium montmorillonite clay from the Cheto bentonite deposit is exported for processing into high value-added desiccants, acid-activated bentonites, thickeners, and gellants. These Arizona bentonites are produced principally in the northeastern corner of the State. Bentonites are also used as acid-activated bleaching clays to clarify nearly all edible oils, including olive oil, safflower oil, and corn oil.

A deposit of hectorite near Kirkland Junction has produced about 150 tons per year. This specialty clay product is used to produce thickeners and viscosifiers in a whole range of products, such as paints, greases, cream rinses, shampoos, rouge, eye shadow, mascara, and lipstick, in which they form a stable gel. Such specialty clays command a high price on the market.

Gypsum

Gypsum has been produced commercially in Arizona since about 1880, but has been an important mineral commodity only since the mid-1950s when demand for its use in agriculture and construction increased substantially. Current production is from the Camp Verde area of Yavapai County, the Littlefield area of Mohave County, the Harquahala Mountains near Salome, and the Winkleman-Mammoth area of Pinal County.

The quantitative production and value details of Arizona's gypsum mining industry are kept proprietary to protect individual company data. The Arizona Department of Mines and Mineral Resources estimates total gypsum production for Arizona at 500,000 short tons with a mine value of $6 million. At least six companies produce gypsum in Arizona. They are, in decreasing order of production: National Gypsum Company, Superior Company, Western Gypsum Company, Pinal Gypsum Company, Western Organics Incorporated, and Kinder Ag Chemicals. These six companies operate seven mines.

Production by National Gypsum from the Winkleman-Mammoth area of Pinal County is for their Gold Bond Building Products wallboard manufacturing plant in Phoenix. National Gypsum is the only operation calcining gypsum in the State. Superior Company's production from both the Winkleman-Mammoth area and the Camp Verde area is primarily for the cement plants at Rillito and Clarkdale respectively. They also supply a small quantity for local agricultural use. Shipments to horticultural material packagers and to out-of-state fertilizer companies has been increasing. Western Gypsum's production from the Littlefield area is shipped to Nevada and California for cement additives, agriculture, functional fillers, and water treatment. Pinal Gypsum Company's production from the Winkleman-Mammoth area is sold for agricultural use. Western Organic's production is used for agriculture and the manufacture of horticultural supplement and premixed packaged potting soils. Kinder Ag Chemicals production in Cochise County supplies local agricultural markets.

At Superior Companies' Larson Gypsum Quarry mining is done selectively with a paddle wheel scraper-loader with specially adapted teeth added to the scraper blade. Overburden and low grade gypsite is removed and stockpiled for reclamation. Mined material is loaded through a grizzly to a 24" X 36" jaw crusher and then through a set of twin 40" X 30" rolls. Roll crusher discharge is conveyed to a coarse ore stockpile. Stockpiled material is feed to a 36" X 20' log washer that discharges to a sand screw that in turn discharges to a twin 6' X 20' vibrating screen. The log washer, sand screw, and vibrating screen remove sufficient gypsite, clay, and dirt to produce a sufficiently beneficiated gypsum, which when sufficiently drained and blended with rotary dryer processed gypsum, meet market requirements for cement additive and agricultural use. Additional screening is done to produce sized products required by various agricultural customers. A unique property of this deposit's gypsum is its occurrence as the variety selenite. The selenite crystals move through the crushing, washing and screening process such that a pellet-shaped final product 3/16" X 1/8" is produced.

The gypsum calcining plant at National Gypsum's Gold Bond facility is the only one in Arizona. All plaster of Paris, casting plaster, and stucco is imported from other states. Northern Mexico supplies gypsum to meet much of the demand for gypsum raw materials along the west coast of California.

Salt (Saline Deposits)

Morton Salt operates the Southwest Salt Mine west of Phoenix in Glendale. Salt is recovered as brine from solution-mining and concentrated in solar evaporation ponds. Harvesters remove suspended halite crystals from the solution as they form through saturation. The halite is dried, crushed, sized, and packaged for industrial uses, metallurgical use, livestock feed, and commercial food processing. Some is blended with synthetic zeolites and pelletized before packaging for use in water softeners. An adjacent operation stores propane and butane liquids in solution cavities in the halite. Presently, solution cavities in the nearly horizontal salt beds near Sanders in Apache County, are being utilized to store propane and butane along the Burlington Northern Santa Fe Railroad.

Large deposits of bedded salt are widely distributed in Arizona's subsurface strata. Anhydrite and halite sequences are thousands of feet thick beneath several of the Cenozoic basins of southern and western Arizona. The Luke salt body west of Phoenix contains a thickness of about 9,000 feet.

The search for cheap underground gas storage in halite, as well as the possible occurrence of rarer evaporite minerals, should stimulate ongoing interest in Arizona's closed basins of Cenozoic age. The presently known deposits may represent the thickest, youngest bedded evaporite deposits in the world.

Zeolites

Chabazite and mordenite are the two zeolite group minerals currently mined in Arizona. Deposits of many other minerals of the zeolite mineral group occur in Arizona. Deposits of clinoptilolite, phillipsite, analcite, and erionite have been described in the literature but have not been developed.

GSA Resources and UOP mine chabazite from the Bowie Chabazite deposit in southeast Arizona and UOP mines mordenite near Kingman in northeast Arizona. UOP's production is shipped out of state for processing. GSA Resources processes their production in their plant in Tucson.

The Bowie chabazite deposit has yielded the most mined tonnage of any natural zeolite deposit in the United States. GSA Resources mines high purity, crude lump chabazite by stripping and selectively mining the lower, massive, half-foot-thick, "high grade" bed.

At the GSA plant in Tucson the mined chabazite is crushed to minus 1" in a jaw crusher, then heat activated at 400^{o}F in a kiln. Kiln discharge is further crushed with rolls and screened to make five sized products; -4 mesh; -4+8 mesh; -8+20 mesh; -20+60 mesh; and -60 mesh. The products are bagged for use as activated desiccants, odor control material, and RAD waste treatment for adsorbing Cs^{137} and Sr^{90}.

Diatomaceous Earth

Diatomite, or diatomaceous earth, is a sedimentary rock composed of a high proportion of the microscopic-sized shells of minute, water-dwelling plants or algae called diatoms. It is also known as infusorial earth, kieselguhr, and fossil flour.

The White Cliffs Mine has been Arizona's important producer. Its output has been used for filter aids, fillers, cement additives, and metallurgical insulation. Deposits in the San Pedro Valley area of Pinal County are extensive and have only been exploited to a small extent. Other deposits have also been described in Arizona.

Current processing methods consist of crushing crude material, drying to about 1 percent moisture, sizing in dust collectors, grinding of dust collector over size, and resizing with dust collectors in closed circuit with grinding to produce a -325 mesh product. At various times coarser size products have also been produced such as - 0.125" for agricultural applications.

Iron Oxides

Swansea Minerals and Arizona Oxides produce hematite for pigment markets. The production of the two companies serves entirely different markets.

Arizona Oxides mines earthy red hematite from the Iron Chancellor iron deposit in Mohave County. Crude ore is shipped to a sizing and grinding plant in Phoenix for size reduction using crushing, grinding, impact mills, and micronizers with air classification. The finished product is packaged for color pigments for use in paints, plastics, and concrete products and for mold release agents in iron and steel foundries.

Swansea Minerals produces micaceous iron oxide in the form of specular hematite. Production is from the dumps and tailings of the Swansea copper deposits mined before 1950. The specular hematite occurred as a gangue mineral in the copper deposits.

Silica

Silica in the form of quartz is mined in Arizona for use as metallurgical flux in the copper smelting industry. The primary constituent of metallurgical flux is the SiO_2 content. Gold, silver, or copper contained with the silica is recovered and is a financial bonus. Any other constituent is deleterious. Most metallurgical flux mined in Arizona is barren of copper and precious metals and has a low unit value of $5.00 to $20.00 per ton. It is therefore mined as near the copper smelter as possible.

The sale of silica for copper smelter flux can be an avenue to market low grade copper, gold and silver ores. Numerous copper, gold, and silver deposits are too low in metal content to pay for their processing and in too small deposits to justify the capital investment in a beneficiation plant. If the silica content is high enough and deleterious constituents are absent, the need for silica may provide a market for these ores.

Gemstones

Arizona is a leading state in the value of mined gemstones in the United States. Approximately $4.01 million worth of commercial gemstone production is reported for Arizona annually. Turquoise, peridot, and petrified wood account for most of the value. Significant value is added to turquoise and petrified wood by commercial lapidaries in Arizona. Cut and polished turquoise is used by Native Americans in the southwest to make traditional southwestern Indian jewelry. Petrified wood is cut, polished, or tumbled and polished to make jewelry and decorative items.

The gemstones quartz, garnet, aquamarine, specularite, Apache Tears, siliceous copper minerals, opal, , onyx, amethyst, chrysocolla, azurite, malachite, fire agate, and many varieties of cryptocrystaline quartz are also commercially mined in Arizona.

It is likely that rockhounds and mineral hobbyists collect as much or more than the $4 million in official production. It would take only 4,000 rockhounds to collect 1,000 pounds of material each worth only $1.00 per pound to exceed the reported production. Although much of the rockhound production does not enter commerce directly, the rock hound-lapidary-mineral collecting hobbies do have a multimillion dollar impact on Arizona's retail trade and hospitality industries.

Pumice

Pumice is mined and processed by Tufflite north of Flagstaff for laundry uses and light-weight aggregate. It is screened and used directly or with adsorbed oxidants and bleaches for fabric treatment for the production of "stone washed jeans." It is also for use as light weight aggregate.

Dimension Stone

Arizona is possibly the sandstone/flagstone production capital of the world. Unfortunately, official statistics do not substantiate such an assertion. The industry is dominated by operators best described as rugged individualists. Only one of many production companies, who operates only a handful of the hundreds of source quarries, bothers to provide production data to industry censuses.

Arizona sandstone is quarried by at least 12 companies operating over 100 quarries. Quarrying and processing of sandstone is centered in the Drake-Ashfork region of Yavapai and Coconino Counties. Production is shipped throughout the world.

Bedded sandstone is the major type of dimension stone produced in Arizona. It is typically split along bedding planes to produce slabs for facing, flooring, and tiles. It is sometimes cut into structural shapes and ornamental objects. Other stone quarried in Arizona includes schist, marble, rhyolite, and granite.

Perlite

Perlite is mined in Arizona by the Harborlite Corporation at Superior, Arizona. The perlite is mined from company-owned pits and hauled up to 2 miles to the company's preparation plant. At the plant, run-of-mine material is crushed in a 10" X 24" jaw crusher to minus 1 inch. The perlite is then feed to a 5' X 60' rotary dryer. The high end temperature of the dryer is 1000°F, high enough to completely dry the perlite, but below the temperature at which it pops. The dryer discharges at 260°F to a two-screen scalper. The plus 16 mesh scalper product feeds a turbo impact crusher. A minus 16 mesh - plus 30 mesh product and a minus 30 mesh product are produced for bulk shipment to the company's popping plants in California, Florida, North Carolina, Michigan, and Wyoming.

The primary use of popped Arizona perlite is as a filter aid. The popped kernels of perlite commonly seen in potting soils are large and hard. They are produced from perlite mined in New Mexico.

Arizona Industrial Mineral Future

The future of industrial mineral production in Arizona is positive. Population growth in Arizona and the southwestern US market areas will demand more higher quality industrial minerals that Arizona can supply. In addition to the currently-produced industrial minerals, a number of other types have been produced previously and might be produced again. They are listed in table 6.

Table 6. Industrial Minerals Previously Produced in Arizona

Chrysotile Asbestos	Diopside	Granite dimension stone
Muscovite mica	Quartz crystals	Tufa dimension stone
Barite	Feldspar	Kaolin
Pozzalon	Sericite mica	Silica
Diatomite	Fluorspar	Tuff dimension stone
Beryl	Lithium minerals	Manganese minerals
Quartz cobbles	Sodium sulfate	Marble dimension stone

Other industrial minerals known to occur in Arizona that might be produced in the future are listed in table 7.

Table 7. Other Industrial Minerals Known to Occur in Arizona

Alunite	Biotite mica	Garnet
Potash	Rutile	Wollastonite
Anhydrite	Brucite	Ilmenite
Pyrophyllite	Vermiculite	Zircon

2.2 Energy Resources

2.2.1 Coal

History of Coal Mining in Arizona

Black Mesa coal was first exploited by prehistoric inhabitants of the area. Coal ash from kivas, primitive stone stoves, and pottery firing pits date back at least to the year 1300 A.D., which was before coal was in general use in Europe. The first mining may have begun as early as 900 A.D. More recent underground mining on Black Mesa was carried on to supply local fuel requirements. Although no official records exist between 1600 and 1925, small amounts were mined. From 1926 to 1946, recorded coal production was 88,730 tons valued at $358,800. From 1943 to 1970, production has been less than 10,000 tons annually, most of which was mined for local use at schools on the reservations and for limited shipment to Holbrook, Winslow, and Flagstaff. Arizona's total production from 1926 to 1970 is estimated to have been less than 300,000 tons.

Large scale mining began in 1970 when Peabody Coal Company started production on a 64,000 acre lease (4.5% of Black Mesa's total area) on tribal lands at the north side of Black Mesa. Annual production increased steadily until 1977 when it exceeded 10 million tons, and has averaged 11-12 million tons per year since then.

Introduction and economic significance

Coal is a distant second to copper in economic importance of mineral commodities produced in the State. It is Arizona's most abundant fuel energy resource today and will probably continue to be well into the future. In 1996, Arizona's coal production was 13,192,000 short tons, having an estimated value of $300 million. All commercial production is from land on Black Mesa in northeastern Arizona that is leased from the Navajo and Hopi tribes by Peabody Western Coal Company, the nation's largest coal producer. Royalties from coal production amount to approximately $40 million annually.

High-quality coal is strip-mined from the Kayenta and Black Mesa mines in central Navajo County. It is ranked as subbituminous, with an average quality of 11,000 Btu/pound, 0.5 percent sulfur, and 10 percent ash. Both mines are now using 300-ton capacity tractor-trailer, bottom-dump, trucks to transport coal from the mine to the conveyor belt and pipeline feed plants.

The Peabody mines provide coal to two generating plants, the Mohave Power Plant near Bullhead City, Nevada via a 273-mile slurry pipeline; and the Navajo Generating Station near Page, Arizona via an 83-mile long railroad. The projected production from the Peabody lease is 12-13 million tons/year until the year 2005. The Navajo Minerals Department estimates that the remaining coal reserves on the lease will last until the year 2027, at the current rate of production.

The Kayenta mine's production capacity is approximately 7 million tons annually. The coal from the mine is carried by a conveyer system 17 miles to storage silos. From there it is transported by the electric-powered trains of the Black Mesa & Lake Powell Railroad to the Salt River Project Navajo Generating Plant 83 miles away.

The Black Mesa mine's annual capacity is approximately 5 million tons. The coal from this mine is ground to a powder consistency and mixed with water for transport by coal-slurry pipeline to the Mohave Generating Station at Laughlin, Nevada. The 273-mile journey takes about three days.

Occurrence and reserves

Coal is found only in Cretaceous age rocks in Arizona, with the largest deposits in Black Mesa, and smaller deposits in the east-central and southeastern parts of the State (figure 7). The most extensive coal reserves are in the Black Mesa field in northeastern Arizona. Several smaller deposits occur at scattered locations in eastern Arizona. These include the Pinedale field, and the Deer Creek field. Smaller deposits are found in extreme north central Arizona, in the northeast corner , and in the extreme east central part of the State.

Black Mesa Field

Coal-bearing rocks occur throughout Black Mesa, a 3,200 square-mile area covering parts of Apache, Navajo, and Coconino counties. Coal seams crop out in cliffs around the periphery as well as on the eroded top of the mesa. Total coal reserves beneath Black Mesa have been estimated at 21.25 billion short tons, with strippable coal within 130 feet of the surface at about one billion tons. The application of subsurface mining techniques below the economic stripping depth would increase the recoverable coal from the area to approximately 8 billion tons.

The total thickness of the Cretaceous rocks of Black Mesa is about 1,700 feet and include, in ascending order, the Dakota Formation, Mancos Shale, Toreva Formation, Wepo Formation, and Yale Point Sandstone. Mineable coal seams occur in the Dakota, the Toreva, and the Wepo formations.

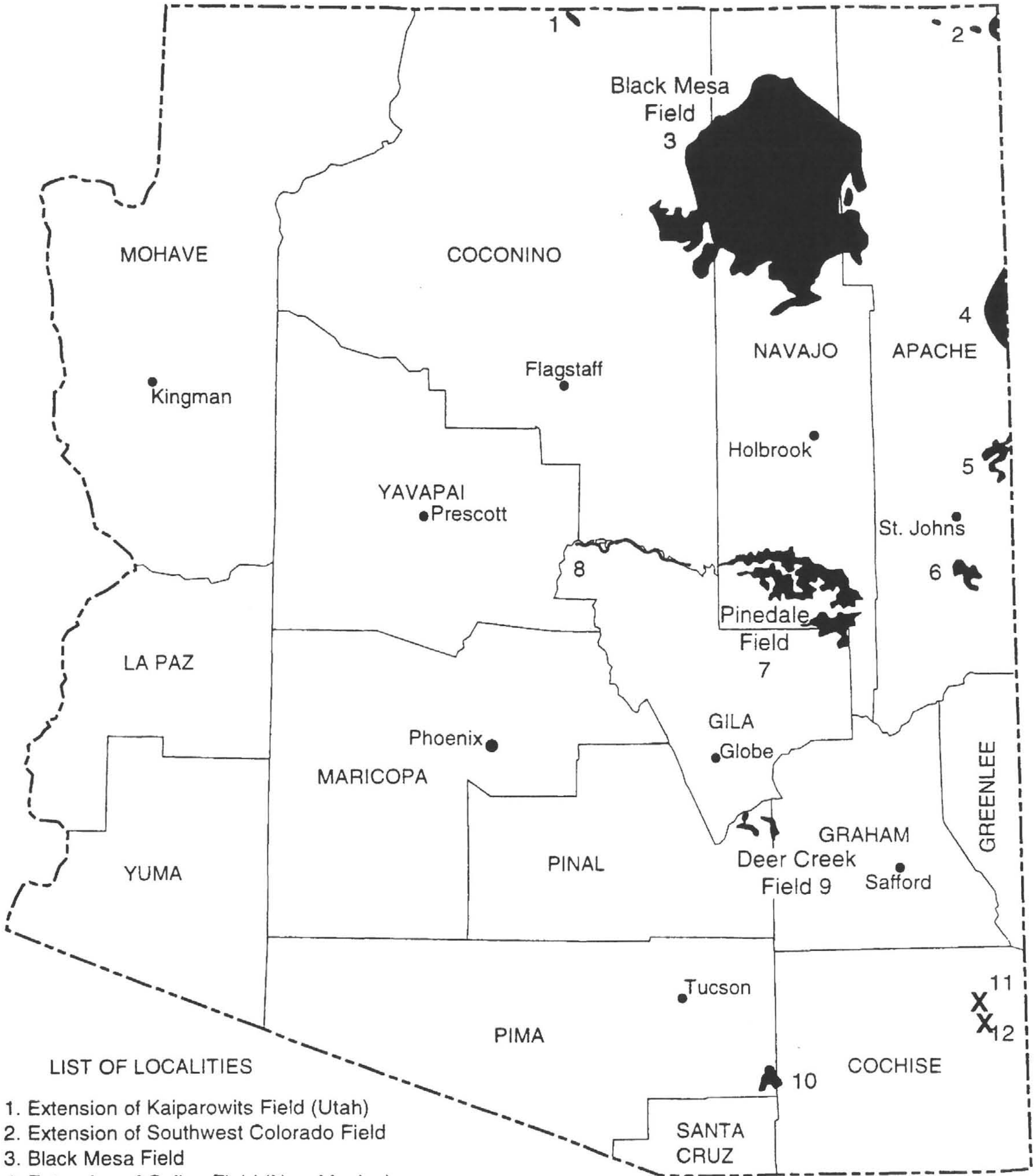
The Wepo Formation contains the best quality coal (subbituminous rank) in the mesa and is exposed at the surface over a large portion of the mesa. It contains at least seven coal horizons in which individual seams may exceed 3-9 ft in thickness The coal seams vary in thickness and number laterally, but up to 25 different coal seams may be mined. An estimated 0.424 billion tons of coal has been blocked out for stripping by the Peabody Western Coal Company This formation is currently being strip-mined from depths as great as 200 ft near the northern margin of Black Mesa, where the total coal thickness is as much as 36 ft. The coal from the Wepo Formation is generally considered to be the highest rank and highest quality coal available in the Four Corners coal-bearing area. The relatively high Btu and low sulfur content makes it very desirable for fuel in power plants (table 8).

Table 8. Quality and reserves of coal in the Black Mesa coal field, Arizona

	Dakota	Toreva	Wepo
Average Ash %	11.9	13.8	5.20
Average Sulfur %	1.62	1.09	0.58
Average Btu/lb.	11,125	12,338	12,382
Estimated Resources (billions of tons)	9.60	6.00	5.65

Coal in both the Toreva Formation and the Dakota Formation, is widespread beneath Black Mesa, however it is of generally lower quality, and is buried too deeply beneath most of the mesa to be recovered economically by strip mining techniques. The thickest coal in the Toreva Formation is 6-7 feet in the northwestern portion of the mesa. Coal seams in the Dakota Formation average 2-4 feet thick with an observed maximum of 9 feet along the southwestern margin of the mesa. Both of these coal-bearing formations have been mined for local use in the past, and could be strip-mined, or subsurface-mined in some areas near their outcrops.

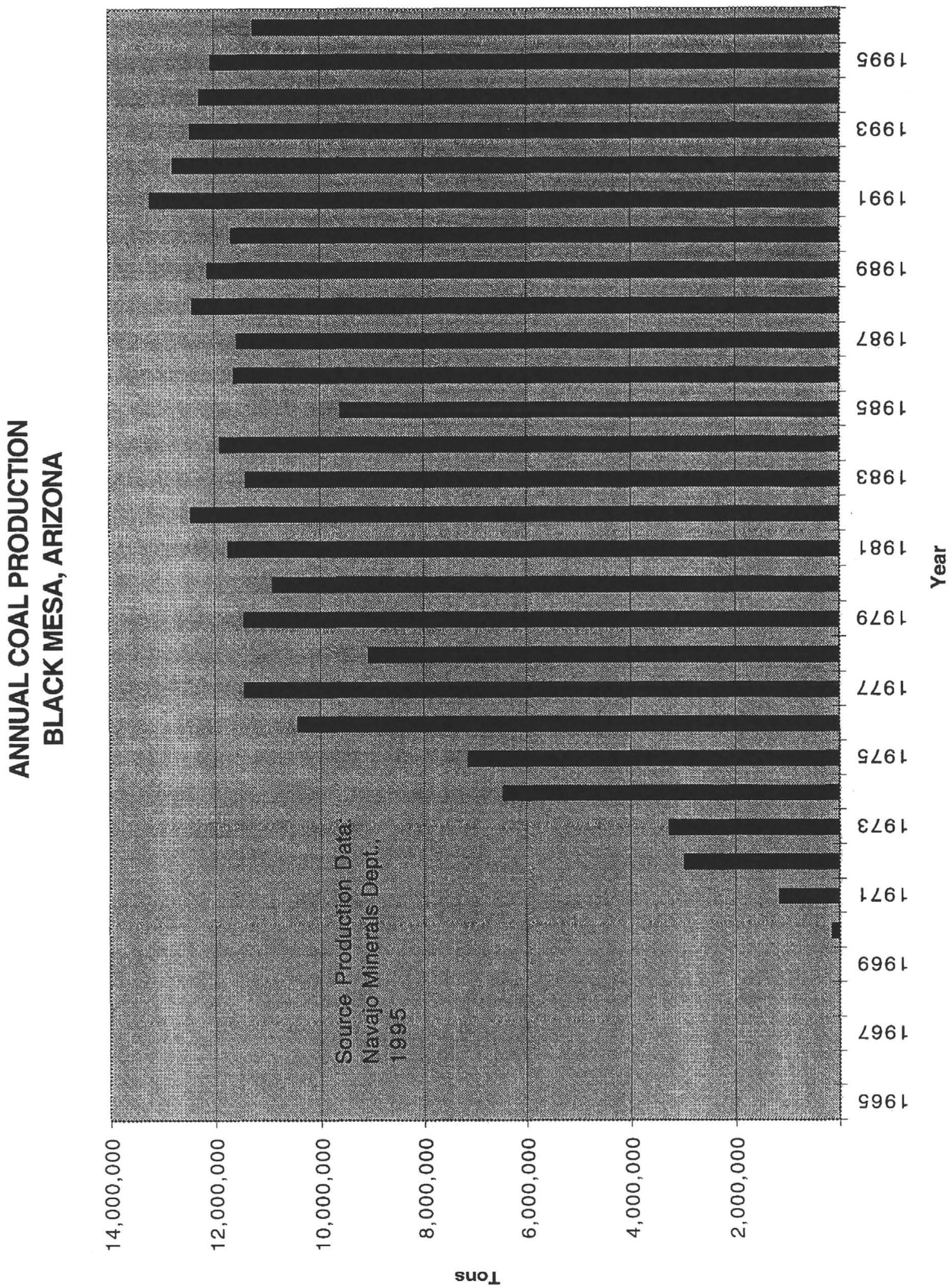
Figure 7: Coal fields in Arizona (modified from Peirce and Wilt, 1970)



LIST OF LOCALITIES

1. Extension of Kaiparowits Field (Utah)
2. Extension of Southwest Colorado Field
3. Black Mesa Field
4. Extension of Gallup Field (New Mexico)
5. Extension of Zuni Field (New Mexico)
6. Coyote Creek
7. Pinedale Field
8. Mogollon Rim
9. Deer Creek Field
10. Western Whetstone Mountains
11. Blake's (1898) Anthracite coal
12. Dumble's (1902) Carboniferous coal

Figure 8: Black Mesa Annual coal production , 1971-96 (Navajo Minerals Department)



Pinedale Field

A remnant of coal-bearing Cretaceous strata, up to 500 feet in thickness and covering about 175 square miles, crops out along the southeastern portion of the Mogollon Rim (figure 7). The general area of outcrop is in southern Navajo County west and south of Show Low and extends into the northern portion of the Ft. Apache Indian Reservation. Coal analyses from this field indicate that the coal is low-quality, high-volatile C bituminous, with a high ash and sulfur content (table 9).

Table 9: Coal analyses from the Pinedale coal field

	Ref. No.	Mois-ture	Volatile Matter	Fixed Carbon	Ash	Sulphur	BTU	BTU Ash-Free Basis
Top 16"	1	6.8	37.8	38.8	16.6	3.1	10,430	12,800
Mid 28"	2	3.7	29.6	25.6	41.1	2.2	7,100	12,900
Low 28"	3	5.9	34.2	37.3	22.6	3.3	9,630	12,800

(Source: Peirce & Wilt, 1970)

This coal has been used locally, but the limited reserves and low quality make it unfavorable for major commercial development as a fuel. However, unlike the Deer Creek field, it is readily accessible from Highway 260 (figure 22). No estimate of the amount of the coal resource has been published. In the past there has been interest shown for its use as a soil conditioner for farmland in the Salt River Valley.

Deer Creek Field

The Deer Creek field contains an estimated 10 million tons of low grade coal, similar to that of the Pinedale Field, however this coal will probably not be developed except for local use because of the thinness of the beds, the high ash content, and the relative inaccessibility of the area.

Environmental Impacts of Coal Mining

The adverse effects of strip-mining are well known, and have generated considerable controversy in the communities on and around Black Mesa. Not only is the land disturbed by the strip-mining, but the use of large volumes of potable water from deep water wells for the coal-slurry pipeline has been the subject of considerable opposition among the local people. This opposition to mining on Black Mesa has persisted, even though Peabody 's operations there are model reclamation programs. Mining and reclamation proceed at the same rate of approximately 500 acres annually. As an area is mined, the topsoil is removed and stored. After mining is completed, the topsoil is returned and the surface is contoured and re-seeded. The resultant reclaimed land, used for sheep and cattle grazing, is 2-3 times more productive than the original land.

Future Potential

Considering the increasing worldwide demand for coal, coupled with the reserves of good coal available in the Black Mesa field, there is an opportunity for additional energy-based economic development of the Black Mesa area. In spite of the large reserves there, more coal is imported into Arizona than is produced here. It is used primarily for electrical power generation, but may also be used as fuel for cement plants and other industrial uses. There is an on-going program of coal assessment for Black Mesa, both of volume and quality, that is being developed currently through a cooperative effort between Northern Arizona University, the U.S. Geological Survey, the Arizona Geological Survey, and the Navajo and Hopi tribal governments.

The Black Mesa reserves are on the Hopi and Navajo Indian reservations and are subject to their management.The currently-producing commercial coal mines on Black Mesa are on leases that cover only a small part of the potentially strippable area. Although most of the coal reserves of Black Mesa are below currently economic stripping range it is probable that large additional stripping reserves could be developed, especially to the northwest of the current lease area, and around the margin of the mesa. The development of mineable reserves on other parts of Black Mesa or in other fields is largely dependent on future energy prices, but reasonable potential exists in both the Black Mesa and Pinedale fields.

There is potential for the occurrence and production of coalbed methane, a commercially valuable natural gas, from all of the formations in the interior of the Black Mesa, where the coal is buried below depths of 500 feet. There are many other possible future uses of coal, including the manufacture of other hydrocarbon fuel forms including gasoline products and gas. Existing natural gas pipelines are in close proximity to Black Mesa so that a major distribution system is already present, should coalbed methane be discovered, or the conversion of Black Mesa coal to gas become a practical reality.

Black Mesa coal is sold by long term contracts to utility companies for generating electricity. The Black Mesa mine supplies coal via an 18 inch-diameter coal slurry pipeline to the Mohave Power Plant in southeastern Nevada. Production from the Kayenta mine goes to the Navajo Generating Station near Page via the Black Mesa and Lake Powell Railroad, a dedicated electrified railway.

2.2.2 Oil, Natural Gas and Carbon Dioxide/ Helium in Arizona

Oil and Natural Gas

Occurrence and Production

All oil and natural gas production and known reserves in Arizona are in the Paradox Basin located in Apache County in the northeastern corner of the state (figure 9). Seventy-four wells have produced oil in 13 fields or producing areas from reservoir rocks of Devonian, Mississippian, Pennsylvanian, and Tertiary ages. The monthly production for March,1997 from 4 currently producing fields was 6,102 barrels of oil (BO) and 42 million cubic feet of gas from 22 oil and 7 gas wells. The value of oil and gas produced in 1996 was approximately $2.5 million. Cumulative production from all these fields from 1954 through 1996 was 20,240,586 BO and 27,006,494 MCFG (figure 10).

Figure 9: Location of oil and gas fields in Arizona

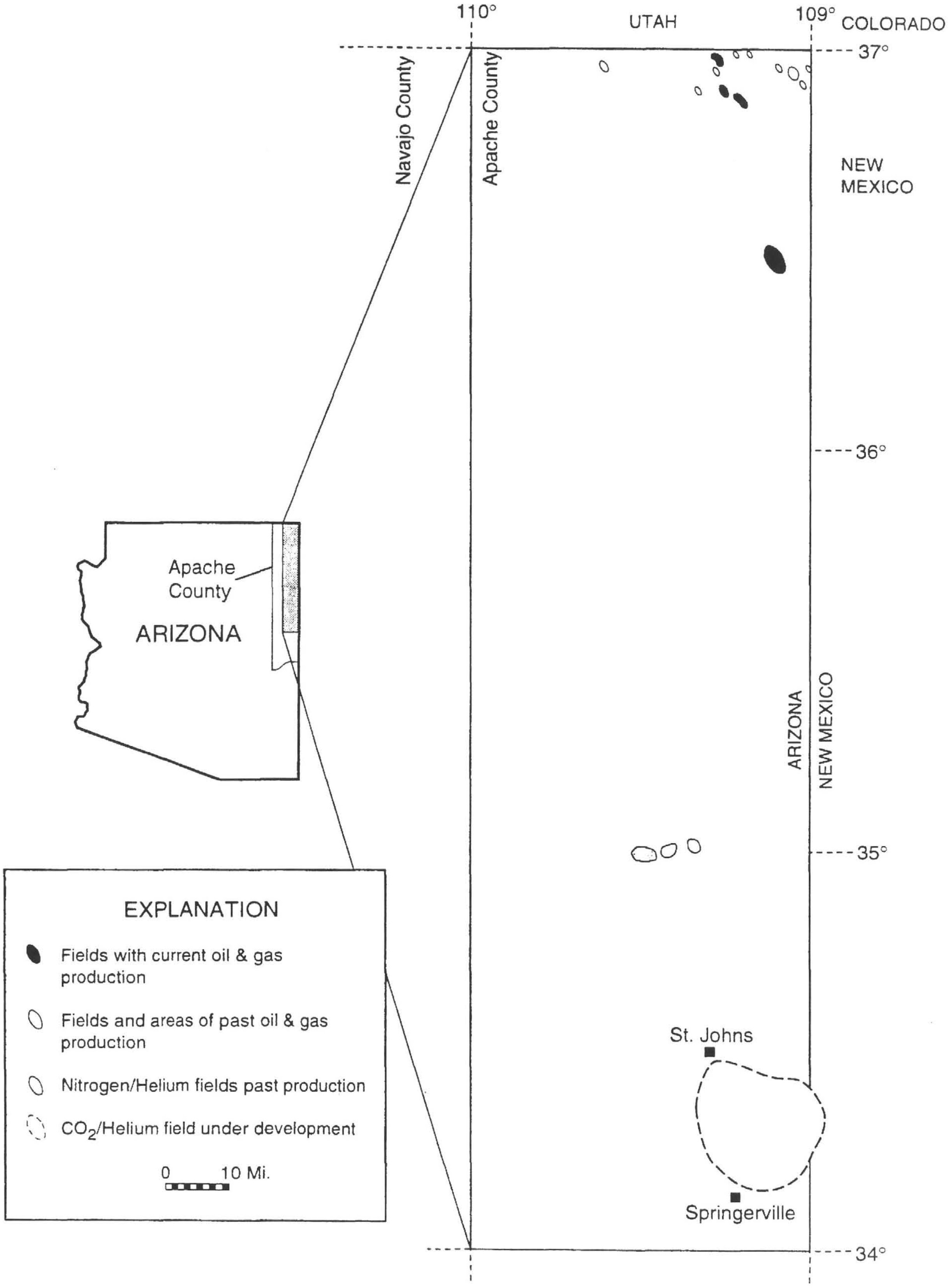
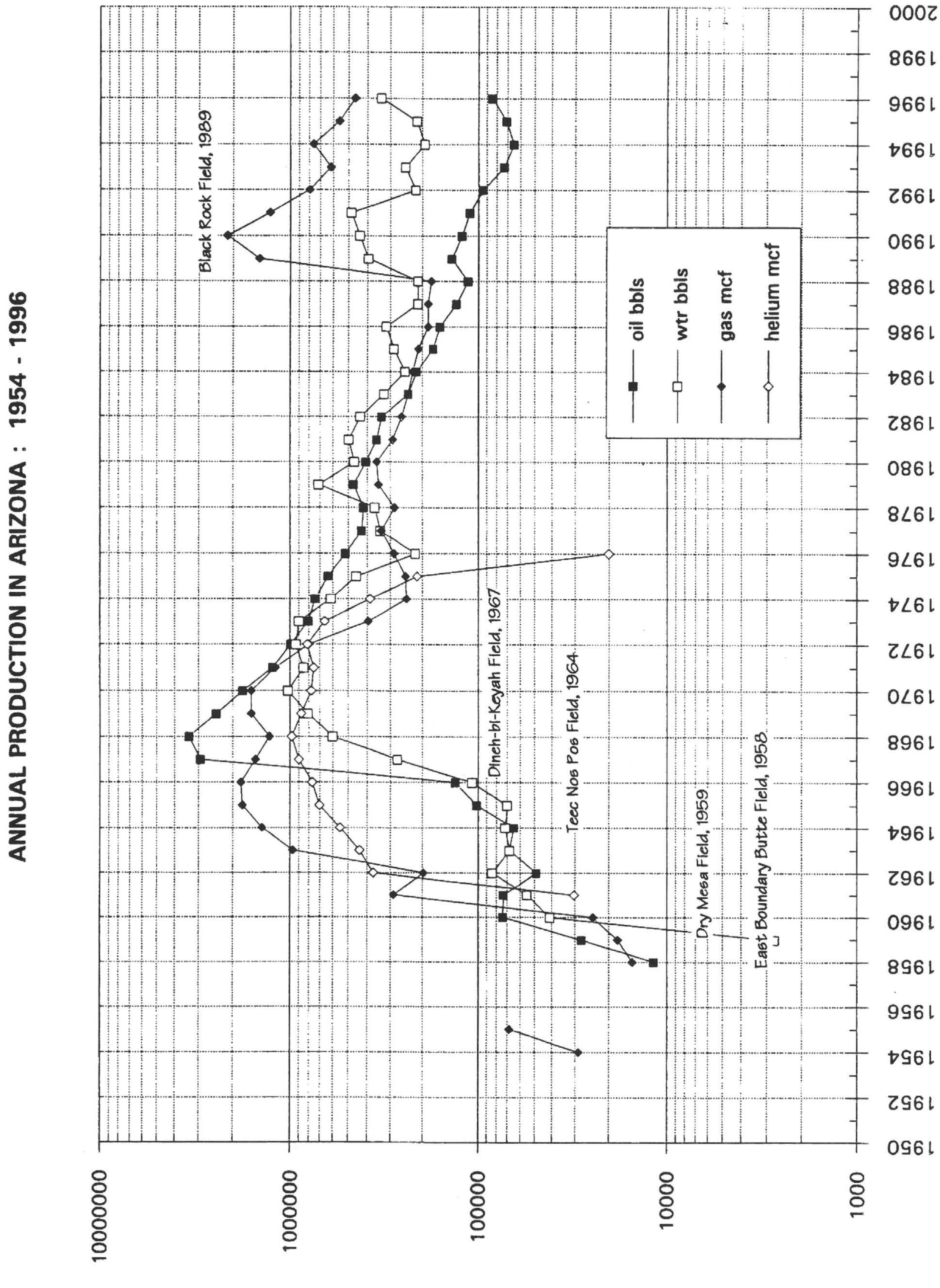


Figure 10: Annual production of oil and gas in Arizona, 1954-1996



Future Potential

Approximately 1,000 exploratory and development wells have been drilled in Arizona. The areas that are considered to have potential for future discoveries are the Paradox Basin, Black Mesa Basin, Holbrook Basin, Pedregosa Basin, San Luis-Fortuna Basin, the "Arizona Strip" north of the Grand Canyon, and Tertiary basins of southern Arizona. Although potential exists in all these areas, whether they will yield oil and gas is unknown. Additional drilling will be needed to evaluate the potential. Exploration in Arizona has probably been limited by the relative thinness and limited areal extent of marine sedimentary rocks that have been the major source and reservoir rocks in other states. Also, the complex Cenozoic tectonic history of most of the state has made exploration difficult and uncertain.

However, the exploitation of more favorable exploration areas and depletion of domestic reserves have stimulated interest in frontier exploration areas such as Arizona. The successful exploration in the Rocky Mountain overthrust belt in Utah and Wyoming, and in the Basin and Range Province of Nevada has proved that there is great potential for additional discoveries of oil and gas in unconventional geologic settings. Production history in Arizona suggests that the highest probability of future discoveries is in the Colorado Plateau Province, but possibly the greatest potential is in the Pedregosa Basin and the Basin and Range Province. Stratigraphic and structural complexity in all sedimentary basins of Arizona leads to both challenge and opportunity for future discoveries of oil and gas. These difficulties are offset, in part, by the favorable leasing policies of federal and state governments and the availability of large areas of leasable land. Technical information on geology and production and exploration history is available at the Arizona Geological Survey, 416 W. Congress, Suite 100, Tucson, AZ 85701. The Arizona Oil and Gas Conservation Commission, which regulates the drilling for and production of oil, gas, helium, and geothermal resources, is attached to the Arizona Geological Survey. The AZGS provides administrative and staff support. Leasing information is available from the U.S. Bureau of Land Management and the Arizona State Land Department in Phoenix.

Carbon Dioxide/Helium

Helium production in Arizona between 1959 to 1975 was 9,238,739 MCF from three fields near Holbrook, with a value of about $27,000,000. The discovery by Ridgeway Arizona Oil Corporation, of carbon dioxide and helium in two exploration wells drilled in 1994 and 1995 in the St. Johns area has stimulated an ongoing 11-well drilling program to determine the extent and potential of the gas field (figure 9). Carbon dioxide is a valuable commodity that is used in enhanced recovery of oil from reservoirs in mature oil fields. Helium is even more valuable, primarily for use in medical equipment.

Environmental Impacts of Oil and Natural Gas Production

Other than the initial preparation and active drilling of a well location, there is minimal environmental impact associated with oil, gas and geothermal development. Depending on the location of the well, unimproved roads may have to be graded into the area, and pipeline systems or above-ground oil-storage tanks have to be provided for collecting the produced oil. However, these impacts can be minimized with careful design of the production facilities.

Oil and Gas Leasing Policy and Activity

State Trust Land under lease for oil and gas drilling increased to 246,000 acres in December, 1996 from 105,000 acres the year before. State Trust Land is leased for a primary 5-year term with an annual rental of $1.00 per acre. State leases may be renewed for a second 5-year term at $2 per acre. The State Land Department administers leasing, which is noncompetetive.

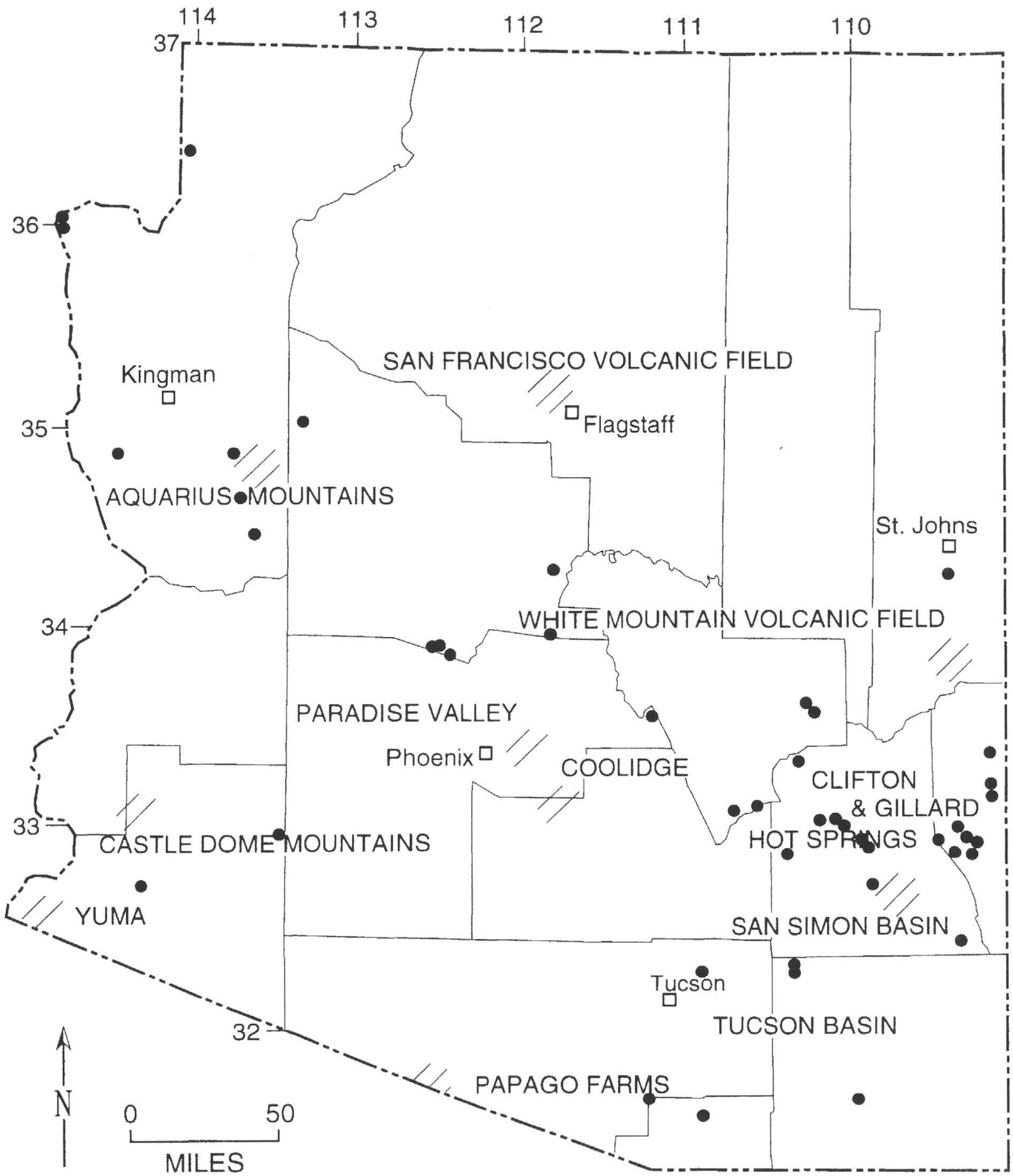
Leases on Federal land decreased to 80,000 acres from 130,000 acres for the same period in 1995. Leasing of Federal land is competetive and is for a 10-year primary term. The annual rental is $1.50 per acre for the duration of the 10-year primary term. The U.S. Bureau of Land Management within the Department of the Interior administers Federal leases. The last Arizona lease sale was held in June, 1995, but another is scheduled for September, 1997.

2.2.3 Geothermal Energy in Arizona

Investigation of Arizona geothermal resources began in 1971 when state and federal agencies, utility companies and private interests began geological and geophysical exploration for resources. Twelve areas of potential geothermal resources in Arizona were identified, as indicated by thermal springs with temperatures ranging from 85°C to 40°C. The thermal waters in the Basin and Range Province are closely associated with deep-seated faults. The occurrence of thermal water in areas of relatively recent volcanism such as the White Mountains and San Francisco Peaks volcanic fields, both of which have numerous faults, indicates a potential for the occurrence of geothermal energy in those areas (figure 11).

Low- to moderate-temperature (less than 100^{o} C) geothermal resources are abundant in Arizona, however no high-temperature resources have been identified. Numerous thermal springs are known in southern and western Arizona, many of which have been used as mineral baths and spas for recreational or health purposes. Figure 11 indicates the locations of thermal springs and geothermal areas that are considered to have potential as heat sources.

Figure 11: Locations of thermal springs and geothermal areas in Arizona (modified from Stone,1989)



Most of these are in the Gila and San Simon valleys of southeastern Arizona, where water temperatures as high as 83° C, and commonly 50° C, have been measured in springs and wells. In the Tucson area, deep wells have encountered water temperatures of 57° C at depths below 425 meters. Geochemical and geophysical characteristics suggest that these water temperatures indicate significantly higher temperatures at depth, ranging from 100 to 125° C. Wells in the Coolidge and Phoenix areas produce water at temperatures from 50 to 72° C.

Geothermal potential in western Arizona is considered high because of its proximity to the tectonically active Salton Trough, Gulf of California fault system, and several geophysical indications of elevated temperatures in the crust. Studies in the Yuma and Castle Dome areas indicate that temperatures at depth may be as high as 200° C at 3,000 to 10,000 foot depths.

The San Francisco and White Mountains volcanic fields are areas of recent volcanic activity, which, along with favorable geophysical indicators, make those areas potentially favorable for geothermal energy sources. The Alpine to Springerville area has been identified as apotential source of geothermal energy, based on an anomalously high geothermal gradient and geochemical indicators of 110° C at depth.

Additional information on geothermal resources in Arizona is available through the Arizona Geological Survey, and includes several reports and maps of geothermal investigations. A state-wide map published with Open File Report-79-5 is a compilation of existing data printed on a USGS 1:1,000,000 scale base map. It depicts the locations of hot springs (greater than 30°C), cinder cones and extrusive volcanic rocks younger than 3,000,000 years, state and federally designated known geothermal resource areas, regions of high chemical geothermometers, high heat flow, and moderate (36° C/km) and high (150° C/km) geothermal gradients. A concise discussion was published by Claudia Stone (1989), which includes a complete reference list, and from which figure 11 was modified. Another summary of geothermal energy resources was published by Duncan and Mancini (1991), which includes a 1:1,000,000 scale map of all types of energy resources, oil and gas pipelines, and 345 and 500 Kv powerlines in Arizona.

Sixty-three test holes have been drilled in Arizona to explore for geothermal energy resources. None of these have resulted in commercial development, but future exploration of the numerous geothermal anomalies will be necessary to evaluate the potential. The absence of any known high-temperature resources probably precludes the generation of electricity, however low-temperature resources are suitable for direct-use applications such as heating buildings and greenhouses, food processing and aquaculture. The future of geothermal energy in Arizona is uncertain. Discovery of high-temperature geothermal systems is unlikely, but continuing development of the State's low-temperature geothermal resources is probable. The speed and extent of development largely depend on future energy prices and new technological developments, both of which could make the low- temperature resources more attractive as energy sources.

Permits for geothermal drilling operations are issued by the Arizona Oil and Gas Conservation Commission, Arizona Geological Survey.

2.3 Processing of Minerals

2.3.1 Types of Processed Products

Metals

Copper is sold by mines, or shipped to the mining companies' out-of-state facilities for further processing or sold to others for further processing. Copper is sold by Arizona mines in the form of rod, cathodes, anodes, and concentrates. Some portion of Arizona-produced copper rod is sold to wire mills in Phoenix and Kingman where it is manufactured into copper building wire and copper communications wire. A small portion of Arizona-produced copper cathodes are sold to copper foundries in Arizona.

The electrolytic refining of copper anodes, either in Arizona or out-of-state allows for the recovery of precious metals and semimetals contained in the the anodes. These precious metals and semimetals are part of the anode impurities that are collected as anode slimes when the anodes are refined. All anode slimes produced in Arizona's two anode refineries are processed out-of-state. Recovery of copper by leaching, solvent extraction, and electro winning does not recover any molybdenum, precious metals, or semi metals.

Molybdenum is sold by copper mines in the form of molybdenum sulfide concentrate and molybdenum oxide. It is shipped out-of-state for further processing and manufacture into molybdenum chemicals and alloys.

Industrial Minerals

Table 10 lists the industrial minerals produced in Arizona and the significant related processed products. Table 11 lists Arizona industrial minerals and their processing methods.

Table 10. Arizona Industrial Minerals and Processed Products

Industrial Mineral	Processed in state	Processed out-of-state	Processed products
Sand and Gravel	X		Concrete, base, fill, mortar
Portland Cement	X		Concrete, mortars, asphalt fillers
Lime	X	X	Chemicals, water treatment, cementitious materials
Crushed Rock			
Rip Rap	X		Road and imbankment stablization
Decorative rock	X	X	Landscape materials, decomposed granite
Calcium carbonate	X	X	Functional fillers, feed supplements, chemicals , decorative rock
Aggregate	X		Concrete, mortars, asphalt fillers
Scoria and cinders	X	X	Light weight aggregate, road deicing, fill
Clay	X	X	Bricks, sewer pipe, dessicants, viscosifiers, functional fillers, filters
Gypsum	X	X	Portland cement, gypsum board (dry wall), fertilizer, horticulture mixes
Salt (Saline Deposits)	X	X	Food processing, chemicals, de icing, water treatment
Zeolites	X	X	RAD control, adsorbants
Diatomaceous Earth		X	Insulation, functional filler
Iron Oxides		X	Color pigments, barrier pigments
Silica	X		Copper smelter flux
Gemstones	X	X	Jewelry, decorative items, display specimens
Pumice	X		Light weight aggregate, abrassives, fabric finishing
Dimension Stone	X		Tile, facia, decorative items, building stone
Perlite		X	Filter aid

Table 11. Arizona Industrial Minerals and Their Processing Methods

Industrial Mineral	Applicable Processing done in Arizona
Calcium carbonate as limestone and marble for mineral filler as well as for raw material for lime and cement plants	1) Filler uses; fine dry grinding 2) Lime; grinding and calcining 3) Cement; grinding and blending with silica,, alumina,, and iron sources,, kilning to produce clinker,, regrinding with added gypsum; may be blended with admixture chemicals at concrete producers
Bentonite for desiccants and for bleaching and clarifying of edible oils	Processed out-of-state for use as desiccants, and as acid activated clay for use in clarifying edible oils and removal of organic contaminates from leach solutions
Sand and gravel for construction aggregate	Processed by crushing, screening,, and washing; some flocculation chemicals may be used in reclaiming wash water
Diatomite for metallurgical process insulation	Processed by crushing, gas fired drying, and sizing by cyclones and bag houses
Tile and brick clay	Blended with other clays, grog, and slate, extruded and fired into structural clay products such as bricks, sewer pipe, and roof tile
Salt	Recovered as brine from solution mining and harvested from solar evaporation ponds; synthetic zeolites are added to some final products for use in water softeners
Cinders	Screened for use as specialty aggregate
Pumice for laundry uses and light-weight aggregate	Screened and used directly or with adsorbed oxidants and bleaches for fabric treatment as in stone-washed denim; screened for use as light-weight aggregate
Zeolites	Selectively mined, crushed, heat activated at 400°F, rolled, and screened to produce sized products; also processed out-of-state; used for RAD control, adsorbents, and molecular sieves
Stone	Quarried and shaped
Perlite for filters	Selectively mined, crushed, and dried; shipped out-of-state for popping and manufacture into filters
Gypsum for wall board and agriculture	1) For wall board, selectively mined,, crushed,, roasted to produce plaster-of-Paris, rehydrated and fabricated into wall board 2) For agriculture, selectively mined and crushed 3) For cement additive - selectively mined, crushed, washed, dried, and screened
Silica flux	Selectively mined and crushed
Micaceous hematite for pigment	Selectively mined (reclaimed) from dumps and tailings, screened and fine sized
Quarried flagstone	Quarried, split, and shaped
Hydrafrac sand	Selectively mined, screened, and dried

Coal

Coal is crushed to two-inch particles at the mine for transport to the Navajo Generating Station at Page, via conveyor belt and the Black Mesa and Lake Powell Railroad. It is ground to a powder by the Black Mesa Pipeline Company for transport to the Mohave Power Plant at Bullhead City via the coal/water slurry pipeline.

2.3.2 Mineral Processing Facilities

Mineral processing facilities in Arizona are shown in figure 12 and listed in table 12. Mill capacities and types and operational data were compiled from the ADMMR publication, *Directory of Active Mines in Arizona, 1997* in conjunction with individual personal cornmunications with vendors, owners, and operators. The information in neither the figure nor the tables is intended to be exhaustive, but does show the versitility and variety of minerals processing in Arizona.

Figure 12: Location of selected mineral processing facilities in Arizona

Table 12. Selected mineral processing facilities in Arizona (see figure 12 for locations)

Selected Mineral Processing Facilities in Arizona 1997

Mine/Company	Map #	County	Commodity; Type of Mine	Processing Plant and Capacity	Notes
GSA Bagging Plant, GSA RESOURCES	1	Pima	Chabazite - strip mine	Crushing, grinding, heat activation, and bagging - capacity 25 tons per 10 hour day.	
Kayenta Mine, PEABODY WESTERN COAL CO.	2	Navajo	Coal - strip mine	Crushing plant - 8,000,000 TPY.	
Black Mesa Mine, PEABODY WESTERN COAL CO.	3	Navajo	Coal - strip mine	Crushing plant - feeds slurry pipeline - 5,000,000 TPY.	
Bagdad, CYPRUS BAGDAD COPPER CORP.	4	Mohave	Copper-molybdenum - open pit	Concentrator - 85,000 TPD - dump leach - SX/EW plant.	
Carlota, CARLOTA COPPER CO.	5	Gila	Copper - heap leach	Heap leach - SX/EW plant - capacity 50,000,000 lb. copper per year.	Permitting and engineering phase - construction anticipated to begin early 1997.
Emerald Isle, ARIMETCO INTERNATIONAL INC.	6	Mohave	Copper - open pit	Heap leach, SX/EW plant - capacity 10,000 lb. copper per day - on standby.	
Johnson Camp, ARIMETCO INTERNATIONAL INC.	7	Cochise	Copper - open pit	Heap leach - SX/EW plant - capacity 45,000 lb. copper per day.	
Miami, BHP COPPER	8	Gila	Copper - in-situ leach and tailings reclaim leach	SX/EW plant.	
Miami, CYPRUS MIAMI MINING CORP.	9	Gila	Copper oxide - open pit	Dump leach - SX/EW plant - smelter with acid plant - 120,000 TPY - electrolytic refinery - 100,000 TPY - continuous cast rod plant.	Concentrator - 24,000 TPD - inactive.
Mineral Park, CYPRUS MINERAL PARK CORP.	10	Mohave	Copper - dump and bench leach	SX/EW plant - in situ research project underway.	
Mission Mine, ASARCO INCORPORATED	11	Pima	Copper - open pit	Two concentrators - combined rated capacity of 63,000 TPD.	Mission and South concentrators used together.

Mine/Company	Map #	County	Commodity; Type of Mine	Processing Plant and Capacity	Notes
Morenci, PHELPS DODGE, INC.	12	Greenlee	Copper - open pit	Two concentrators (one with molybdenum circuit) - total capacity 125,000 TPD - SX/EW plant - 500,000,000 million lb. per year copper.	Morenci smelter dismantled.
New Cornelia, PHELPS DODGE INC.	13	Pima	Copper - open pit (in active).		New Cornelia concentrator and smelter have been dismantled.
Oracle Ridge Mine, ORACLE RIDGE MINING PARTNERS	14	Pima	Copper, gold, and silver - underground - idle	Idle column flotation mill - 1020 TPD.	
Pinto Valley Operations, BHP COPPER	15	Gila	Copper-molybdenum - open pit	Concentrator - 63,000 TPD - dump leach - SX/EW plant.	
Ray - Hayden Operations & Smelter, ASARCO INCORPORATED	16	Gila & Pinal	Copper - open pit	Two concentrators - dump leach - heap leach - SX/EW plant. Combined concentrator capacity - 60,000 TPD. Ssmelter capacity 720,000 TPY with 1,600 TPD acid plant.	Ray concentrator - 32,000 TPD - Hayden - concentrater - 28,000 TPD
San Manuel Operations, BHP COPPER.	17	Pinal	Copper-molybdenum - under ground	62,000 TPD concentrator - in-situ leach - heap leach - SX/EW plant - capacity 120,000,000 lb. copper per year.	
San Manuel Smelter, BHP COPPER METALS	18	Pinal	Copper smelter	Flash smelter - 1,300,000 TPY - acid plant 1,150,000 TPY - electrolytic refinery - 345,000 TPY - continuous cast rod plant - 180,000 TPY.	
Santa Cruz, ASARCO INCORPORATED, FREEPORT McMORAN, & US BUREAU OF RECLAIMATION	19	Pinal	Copper - insitu leach	Experimental in-situ leach research project. Copper recovery by SX-EW plant.	Managed by ASARCO with joint venture partners Freeport McMoran and U.S. Bureau of Reclamation.
Sierrita, CYPRUS SIERRITA CORP.	20	Pima	Copper-molybdenum - open pit	Concentrator - 110,000 TPD - concentrator - 17,500 TPD.	Also has ferromolybdenum plant - rhenium plant - dump leach - SX/EW plant.

Mine/Company	Map #	County	Commodity; Type of Mine	Processing Plant and Capacity	Notes
Silver Bell, ASARCO INCORPORATED	21	Pima	Copper - mine	Leach - new SX/EW plant under final construction and scheduled to be operating at capacity mid July 1997 - capacity 18,000 TPY copper.	Precipitation plant being phased out.
Tohono, CYPRUS TOHONO CORP.	22	Pima	Copper - open pit	Heap leach - SX/EW plant.	
Zonia, ARIMETCO INTERNATIONAL INC	23	Yavapai	Copper - open pit	Heap leach - SX/EW plant. Permitting and engineering stage.	Designed capacity - 60,000 lb. copper per day
Sun Chief Mill, JEFF BROWNMILLER	24	Gila	Custom floatation mill	Crushing, grinding, and floatation - ball mill rated at 200 tons per day - 6 floatation cells.	
Black Canyon Mill, BLACK CANYON MILLING	25	Maricopa	Custom gravity mill	Crushing, grinding, magnetic separation, table, and cone concentration - capacity 3 tons per hour.	
White Cliffs, ARIMETCO	26	Pinal	Diatomite - open pit	Crushing, drying, air classification, and bagging - capacity 100 tons per day.	
Yarnell Mine, YARNELL MINING CO., INC.	27	Yavapai	Gold - open pit under development	Heap leach - cyanide disolution - activated carbon recovery.	Permitting and predevelopment construction. Plan fall 1997 startup.
Gold Road, ADDWEST MINERALS INC.	28	Mohave	Gold - underground	500 TPD carbon in pulp mill.	
Congress Gold Mine,	29	Yavapai	Gold - underground	Carbon in leach mill - 450 tons per day	Idle
Gladiator Mine, NEW WESTWIN	30	Yavapai	Gold, silver, copper, zinc - under ground	Floatation, capacity 100 tons per day.	
Franconia Steel Mill NORTH STAR STEEL	31	Mohave	Iron and steel foundry using secondary materials	Electric furnace melting of scrap iron	
M E West Castings, M E INTERNATIONAL	32	Maricopa	Iron and steel foundry using 100% secondary feed.	Electric furnace melting and alloying of scrap steel and white iron - capacity 18,000 TPY	Formerly Capitol Castings Kyrene plant.
Clarkdale Quarry & Plant, PHOENIX CEMENT CO.	33	Yavapai	Limestone - quarry and cement plant	Cement plant - 630,000 TPY	

Mine/Company	Map #	County	Commodity; Type of Mine	Processing Plant and Capacity	Notes
Rillito Plant & Quarry, ARIZONA PORTLAND CEMENT COMPANY	34	Pima	Limestone - quarry Cement plant	Cement plant - capacity 1,100,000 TPY.	
Nelson Quarries & Plant, CHEMICAL LIME	35	Yavapai	Limestone - quarry Lime Plant	Lime plant with two rotary kilns rated at 1800 TPD lime.	
Douglas Quarry & Plant, CHEMICAL LIME	36	Cochise	Limestone - quarry Lime plant	Lime plant 3 lime kilns - rated at 1,000 TPD lime.	
Andrada and Davidson Marble Quarries, GEORGIA MARBLE CO. OF ARIZONA	37	Pima	Marble (calcium carbonate) - open pit	Crushing and Raymond mill grinding plant - 600 TPD.	
Queen Creek Marble Quarry, MINERAL DEVELOPMENT, INC.	38	Pinal & Maricopa	Marble (calcium carbonate) - open pit	Primary crushing and screening plant - fine sizing plant - 200,000 TPY.	
Santa Rita Quarry, SPECIALTY MINERALS INC.	39	Pima	Marble (calcium carbonate) - open pit	Raymond roller mills - sizing and bagging plant - 175,000 TPY	
Superior Perlite, HARBORLITE CORP.	40	Pinal	Perlite - open pit	Crushing, screening, and drying plant.	
Therm-O-Rock, THERM-O-ROCK INDUSTRIES	41	Maricopa	Perlite and vermiculite - processes crude perlite and crude vermiculite mined by others.	Perlite popping and vermiculite expansion.	
Zonolite, W.R. GRACE	42	Maricopa	Vermiculite - processes crude vermiculite from company's mines in other states.	Vertical expansion furnaces, screening, and bagging - capacity 17,500 TPY.	

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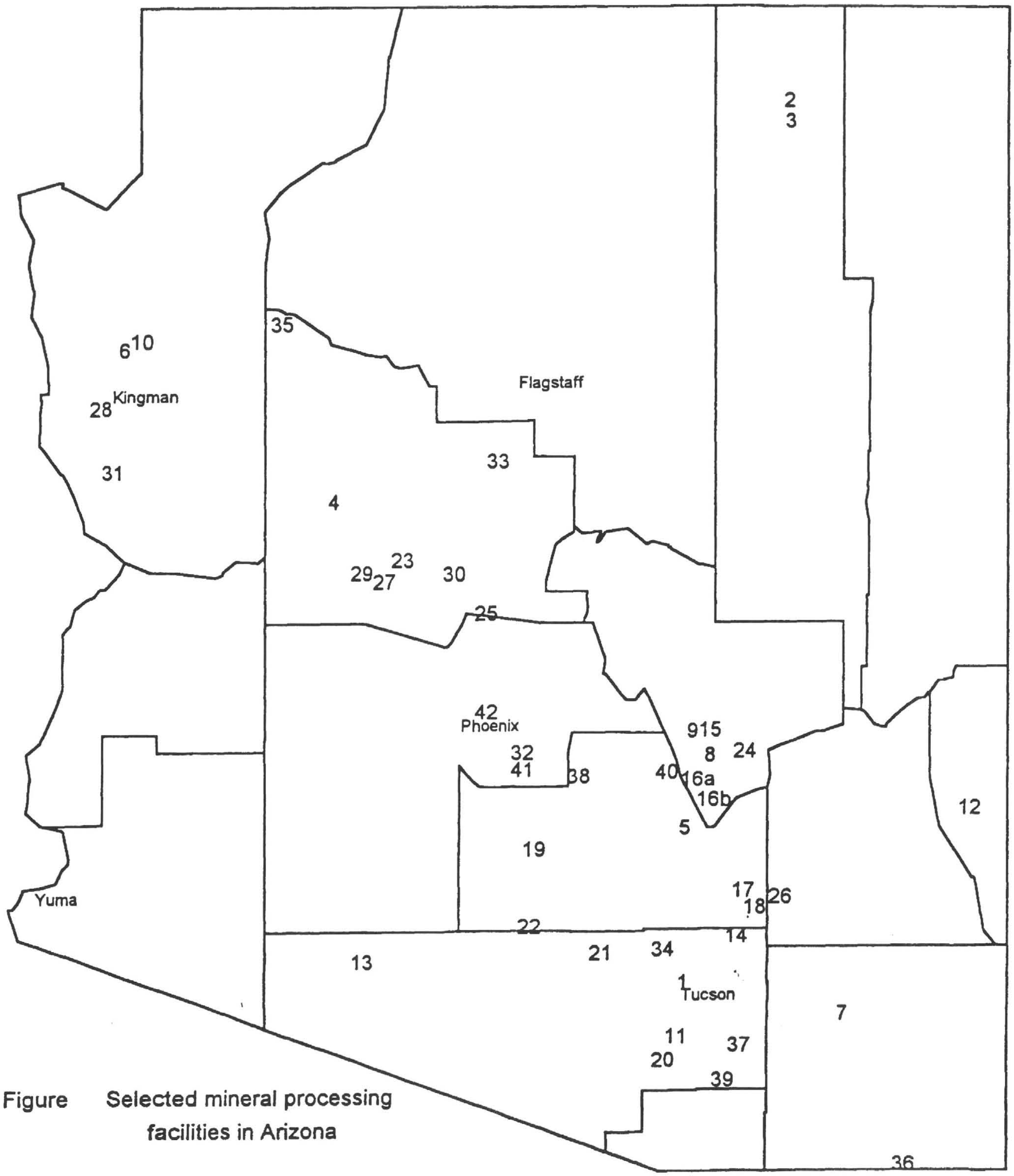
Figure 12. Location of selected mineral processing facilities in Arizona (ADMMR, 1997)
(see Table 12 for explanation of numbered locations)



2.4 Supporting Infrastructure

Infrastructural Factors

Because most mineral resource developments initially require large capital expenditures, second only to utilities, and have relatively low profit margins, existing infrastructure is very important to the economics of these operations. The infrastructural systems having the greatest impact are utilities and transportation. Availability of electrical power sources, natural gas pipelines, sources of water, highways, and rail lines is critical to most operations because of the high cost of creating these items when they do not already exist.

The infrastructural base must be capable of not only meeting the demands of today's mining industry for utilities and transportation, but also must be flexible enough to meet future demands. Arizona is fortunate in having a relatively well-developed infrastructural base, which is discussed in the following pages.

Instititutional Factors

In addition, institutional factors can have a significant economic impact. Federal, State, and local taxes certainly have an impact, and the costs of complying with environmental and safety regulations have drastically increased over the past several decades. Finally, the availability of post-mill processing facilities is vital to those operations that do not produce a product that is directly marketable.

Taxation and regulation must be considered to maintain the delicate balance between economic progress on the one hand and the demands of government and the environment on the other. The status of these infrastructural and institutional factors in Arizona is summarized in the following pages.

2.4.1 Utilities

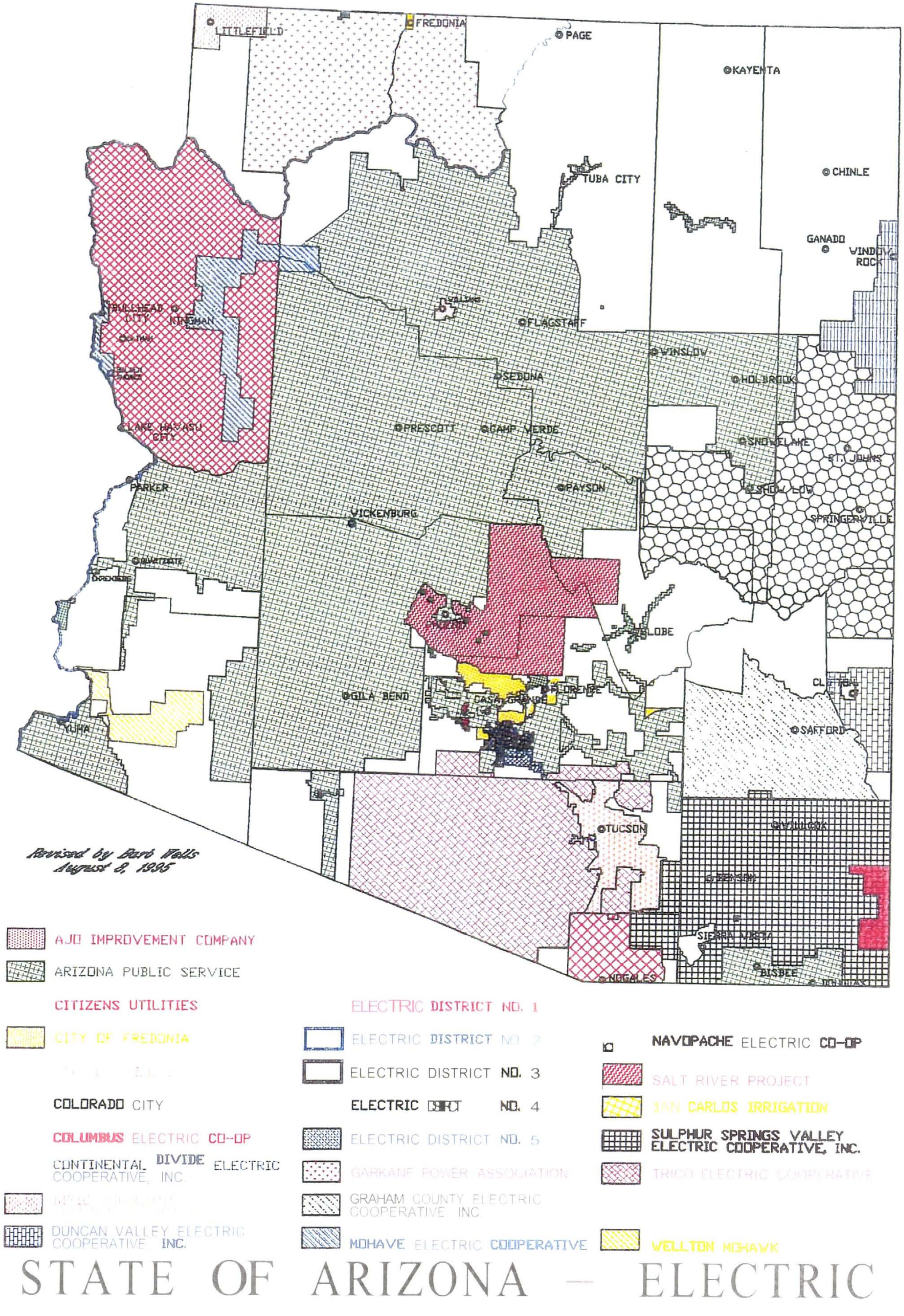
A. Power and Fuels (electricity, natural gas)

Electricity

Mining and milling are activities that tend to consume large amounts of energy, primarily in the form of electricity and natural gas. Energy usage varies widely from operation to operation because of differences in such factors as operation size, mining method, and milling method. These variations make it impossible to generalize about a typical mining operation, but it is clear that mining is one of the largest energy-consuming industries in Arizona. Smelting of ore requires large volumes of natural gas. In a typical copper mine/mill operation, electricity amounts to about 20% of the variable operating costs. Each of the major electricity-generating companies in Arizona has a copper mine as its largest customer.

There has been a shift throughout the mining industry in recent years, from the labor- and energy-intensive technologies of the past toward more efficient methods. In Arizona, this change can best be seen in the copper industry in which conventional methods of underground or open-pit mining, flotation milling, and smelting-refining have frequently yielded to in situ, dump, or heap leaching and solvent extraction-electrowinning technologies. These newer methods have not only cut labor and energy requirements, but have also resulted in the ability to mine lower grade ores than in the past. In addition, leaching has become the method of choice for precious-metal operations because of its low cost and ability to treat very low-grade ores.

Arizona has several sources of electrical energy. Although there are 18 active vendors, the two largest provide almost 60% of the energy for public, industrial, agricultural, and mining needs (figure 13). These are the Arizona Public Service Company (APS), the largest utility operating in Arizona, and the Salt River Agricultural Improvement and Power District (SRP), the second largest utility. Both have multiple methods of supplying consumers:



STATE OF ARIZONA – ELECTRIC

Figure 13: Electrical suppliers in Arizona (ACC)

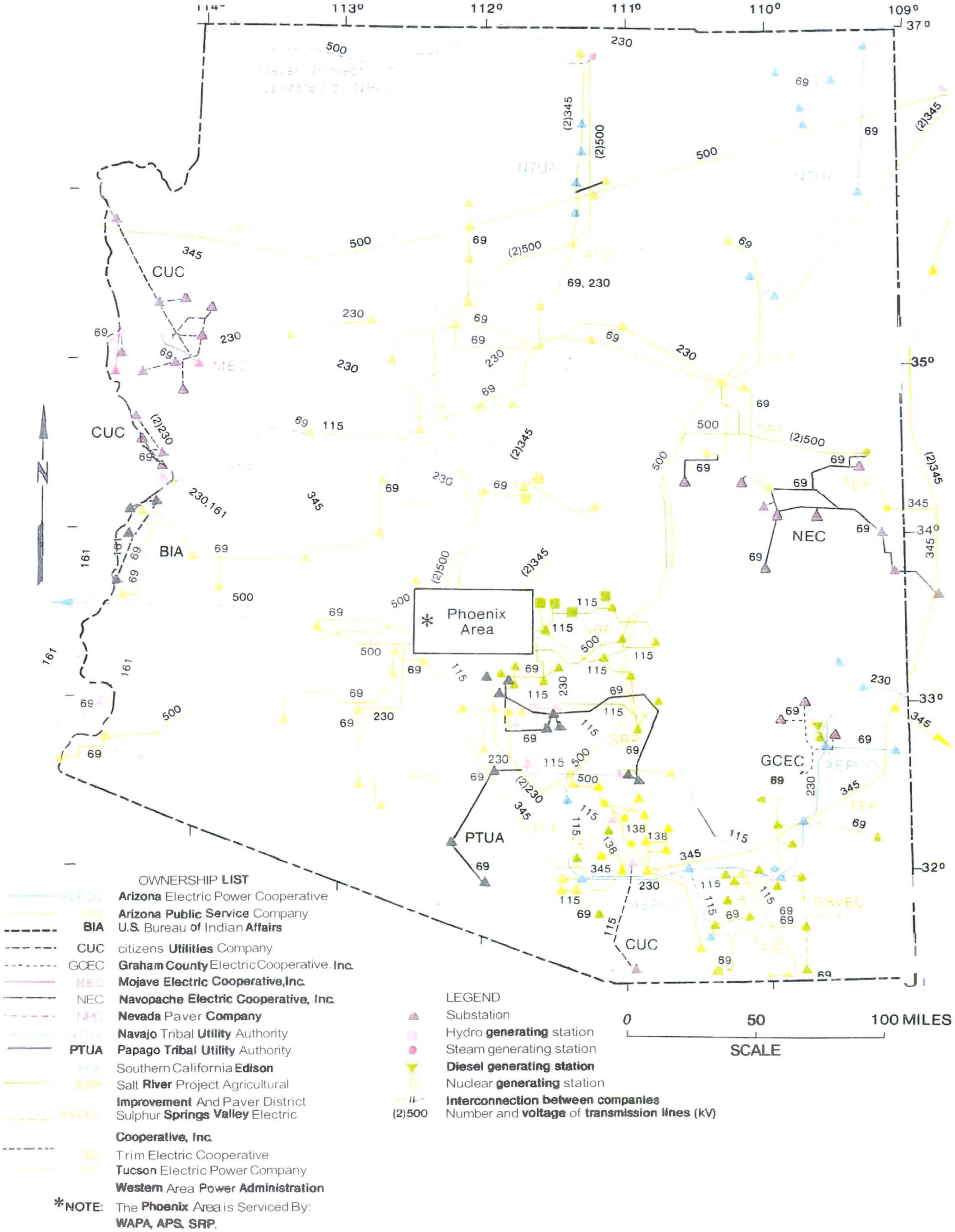


Figure 14: Electrical transmission lines in Arizona (from Sawyer et al, 1992)

The main sources of electricity are generating plants using coal, nuclear fuels, and gas-oil; however, future environmental concerns and regulations could cause the amount of power produced by hydroelectric plants to be increased at the expense of plants using other fuels.

The turbines at Hoover Dam generate and supply about 4.5 billion kW-h of energy annually, enough to support 500,000 homes in Nevada, Arizona, and California. The Arizona legislature created the Arizona Power Authority (APA) in 1944. As of May 1987, it received and marketed 165,000 kW-h of the Hoover power plant output . Effective June 1, 1987, the APA entered into a new 30-year power sales contract with the United States acting through the Western Area Power Administration (WAPA). The contract stipulates that 18.9% of the energy produced at the Hoover power plant be available to Arizona, and any amount in excess of 4.5 billion kW-h in any given year must first be offered to the authority for use in Arizona. The result is an increase in APA's allocation to about 1.1 billion kW-h of total energy per year delivered by the Federal System (Parker-Davis Project and the Pacific Northwest-Pacific Southwest Intertie) to WAPA's allottees.

Also, Arizona is provided with electricity by smaller, privately owned electric utility systems. Figure 14 depicts the distribution of major electrical transmission lines, principal substations, in-state generating facilities, and ownership. Figure 13 displays the major certificated electricity service areas as well as the areas now unassigned. Utilities having a certificated service area have exclusive rights to market electricity in the area and are obliged to provide power to all new consumers. Service in the uncertificated areas is competitive subject to the regulations of the Arizona Corporation Commission. After January 1, 1999, all electrical service will be unregulated. The electric companies regulated by the commission are listed in table 13. Industrial power availability and rates can be determined by contacting the utility system in the area of interest.

Table 13. Electricity suppliers in Arizona

Company	Address
Ajo Improvement Company - Electric Division	P.O. Drawer 9, Ajo, AZ 85321 520-387-7151
*Arizona Electric Power Cooperative, Inc.	P.O. Box 670, Benson, AZ 85602 520-586-3631
Arizona Power Authority	1810 W. Adams, Phoenix, AZ 85007 602-542-4263
*Arizona Public Service Company	P.O. Box 53999, Phoenix, AZ 85072-3999 602-250-1000
Citizens Utilities Company - Arizona Electric Division	P.O. Box 3801, High Ridge Pk. Stamford, CT 06905 203-329-8800
Citizens Utilities Company - Mojave County Division - Electric	P.O. Box 3801, P.O. Box 3099, Kingman, AZ 86402 520-753-2124
Citizens Utilities Company - Santa Cruz Division - Electric	P.O. Box 3801, P.O. Box 280, Nogales, AZ 85628 520-281-1212
Columbus Electric Cooperative, Inc.	P.O. Box 631, Deming, NM 88031 505-546-8838
Continental Divide Electric Coop., Inc.	P.O. Box 1087, Grants, NM 87020 505-285-6656
Dixie Escalante Rural Electric Association	HC 76 Box 95, Beryl, UT 84714 801-439-5311
Duncan Valley Electric Cooperative, Inc.	P.O. Box 440, Duncan, AZ 85534 520-359-2503
Garkane Power Association, Inc.	P.O. Box 790, 56 Center St., Richfield, UT 84701 801-896-5403
Graham County Electric Cooperative, Inc.	P.O. Box Drawer B, Pima, AZ 85543 520-485-2451
Mohave Electric Cooperative, Inc.	P.O. Box 1045, , Bullhead City, AZ 86430 520-763-4115
Morenci Water & Electric Company- Electric Division	Box 68, Morenci, AZ 85540 520-865-3681
Navopache Electric Cooperative, Inc.	P.O. Box 308, Lakeside, AZ 85929 520-368-5118
*Salt River Project	P.O. 52025, Phoenix AZ, 85072 602-236-5900
Sulphur Springs Valley Electric Coop., Inc.	P.O. Box 820, Willcox, AZ 85644 520-384-2221
Trico Electric Cooperative, Inc.	P.O. Box 35970, Tucson, AZ 85740 520-744-2944
*Tucson Electric Power Company	P.O. Box 711, , Tucson, AZ 85702 520-571-4000

Source: Arizona Corporation Commission and selected utilities
* Power-generating companies, coal, uranium, oil & gas

Natural Gas

Supplies of natural gas to Arizona are delivered by two interstate pipeline companies, Transwestern and El Paso Natural Gas, to Citizens Utilities Company, Southwest Gas Corporation, and several smaller distributors (figures 15 and 16; table 14). Figure 15 shows the certificated service areas for each of the gas companies serving Arizona; the white areas are presently unassigned.

The El Paso and Transwestern pipelines serve the northern portion of the State, crossing from east to west following the route of Interstate Highway 40, connecting the Window Rock, Navajo, Dilkon, Leupp, Flagstaff, Williams, Seligman, Hackberry, and Topock stations. This line has important laterals serving Holbrook, Winslow, Prescott, Bagdad, and Lake Havasu City (figure 16).

Another El Paso pipeline serves the southern portion of Arizona, crossing from east to west following Interstate Highway 10, connecting the San Simon, Willcox, Benson, Vail, Tucson, Casa Grande, Gila, and Wenden stations. This line has laterals supplying Bisbee, Sonoita, Nogales, Ajo, Phoenix, and Yuma (figure 16).

There are also two subsidiary El Paso Natural Gas pipelines that connect the interstate lines, the San Juan-Maricopa Cross-Over and the Havasu Cross-Over (figure 16). The first connects the two mainlines just described between the Williams and Casa Grande stations passing through Phoenix; the latter unites both mainlines between the Topock and Wenden stations.

Figure 16 also depicts pipelines owned by other smaller suppliers that supply gas to various other parts of the State. Table 14 lists the gas distributors in Arizona regulated for rates, by the Arizona Corporation Commission, Utilities Division, 1200 W. Washington, Phoenix, AZ 85007.

As of June, 1997, natural gas distribution and availability on demand is adequate; serving the mining industry in the future should not be a problem.

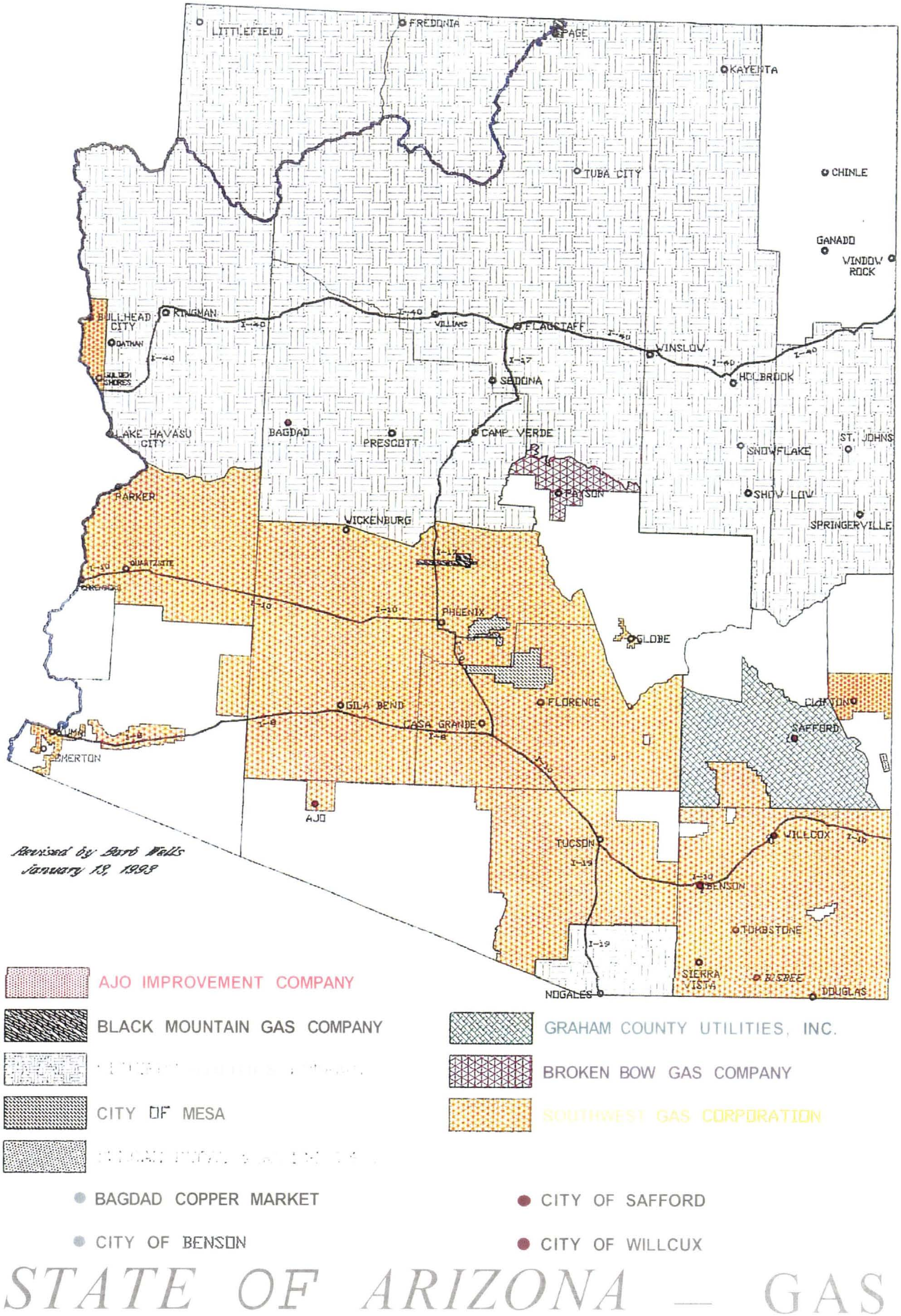


Figure 15: Natural gas suppliers in Arizona (ACC)

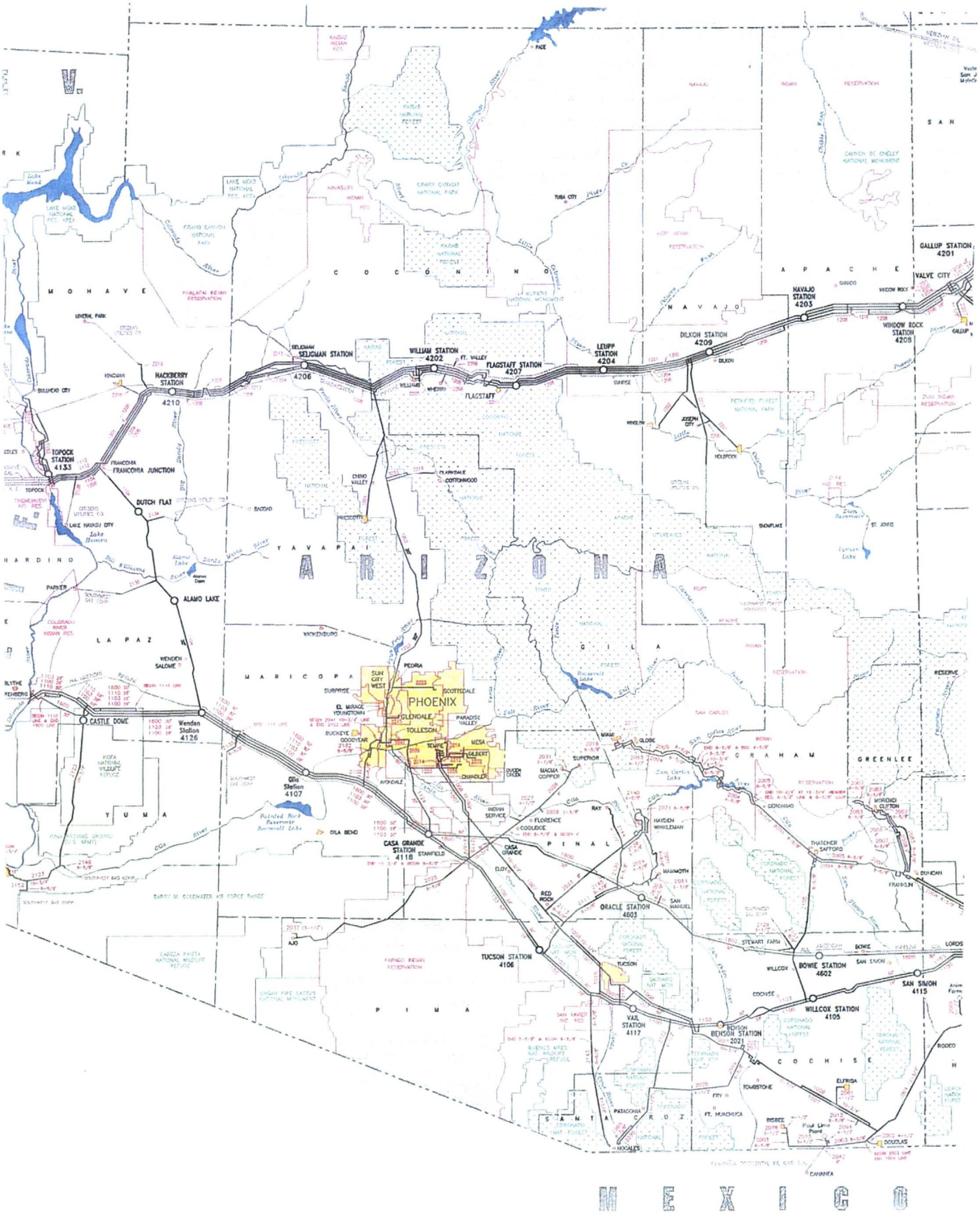


Figure 16: Natural gas pipelines in Arizona (from El Paso Natural Gas Company)

LEGEND

- 1101 — PIPELINE CODE AND AERIAL ALIGNMENT MAP NUMBERS – NUMBERS IN BLACK AR
- PARALLEL LINES WHICH ARE INCLUDED ON MAPS IDENTIFIED BY RED NUMBERS
- 1103 — PIPELINES OWNED BY OTHER COMPANIES
- 4106 — PLANT OR COMPRESSOR STATION CODE NUMBERS
- COMPRESSOR STATIONS AND PLANTS — FACILITIES SOLD OR RETIRED
- OTHER COMPANIES PLANT OR DELIVERY POINT
- UNDERGROUND STORAGE AREA
- 1000 — PIPELINES FORMERLY OWNED BY EL PASO NATURAL GAS COMPANY
- EL PASO FIELD SERVICES PIPELINES
- EL PASO FIELD SERVICES PLANTS

Table14. Natural gas suppliers in Arizona

Company	Address
Ajo Improvement Company - 7/1/97 Gas Division	Service transferred to Southwest Gas Corporation on (see below)
Black Mountain Gas Company	P.O. Box 427, Cave Creek, AZ 85327 602-488-3402
Black Mountain Gas Company - Cave Creek System	P.O. Box 427, Cave Creek, AZ 85327 602-488-3402
Black Mountain Gas Company - Page System	P.O. Box 427, Cave Creek, AZ 85327 602-488-3402
Broken Bow Gas Company	200 W. Longhorn, Payson, AZ 85541 520-474-2294
Citizens Utilities Company - Arizona Gas Division	P.O. Box 3801, High Ridge Pk., Stamford, CT 06905 203-329-8800
Copper Market, Inc.	P.O. Box 245, Bagdad, AZ 86321 520-633-3262
Duncan Rural Service Corporation	P.O. Box 440, Duncan, AZ 85534 520-359-2503
Graham County Utilities, Inc.- Gas Division	P.O. Box Drawer B, Pima, AZ 85543 520-485-2451
Southwest Gas Corporation	P.O. Box 98510, Las Vegas, NV 89193-8510 702-364-3104
Southwest Gas Corporation - Central Arizona Division	P.O. Box 52075, Phoenix, AZ 85072 602-395-4079
Southwest Gas Corporation - Southern Arizona Division	P.O. Box 26500, Tucson, AZ 85726 520-794-6500

Cities of Bagdad, Benson, Safford and Willcox have independent contracts with suppliers.

Source: Arizona Corporation Commission

B. Water

As with electricity and natural gas, water usage by mines varies greatly from one operation to another. Most of the water is consumed by leaching or milling processes but also is used in mining for such purposes as drilling and dust control. Both surface- and ground-water resources are used by mining operations, and, in some cases, water must be transported a significant distance to the mine-mill site. Although water should generally continue to be available for mining use in the future, the cost of obtaining it could be high in some areas. With expected increases in water usage by agriculture, industry, and municipalities, the competition for existing water supplies may have a significant economic impact on some mining operations. Also, the ground-water in many areas is highly over-exploited, resulting in lowering of the water table, increasing pumping costs and land subsidence. This has also affected surface water resources, for example the Santa Cruz River has been dry since the 1960s as a result of ground water table lowering by irrigation pumping. Figure 17 illustrates the major rivers and streams, and the major surface water reservoirs in Arizona.

The climate in most of Arizona is classified as arid or semiarid with annual precipitation varying from a low of about 4 in to a high of about 25 in. Of this precipitation, about 95% evaporates or is transpired by vegetation leaving only a limited amount to run off or enter the ground-water system. This high evaporation rate also has a marked effect on storage reservoirs in the area, Lake Mead, for example, lost 787,600 acre-ft to evaporation during 1982.

Arizona has three water provinces that are closely related to the State's physiography. These are the Plateau Uplands, Central Highlands, and Basin and Range Lowlands (figure 18). Water conditions in these three provinces differ markedly because of differences in geology and climate. Flat-lying sedimentary rocks and volcanic peaks rising to over 12,000 ft above sea level characterize the Plateau Uplands. Annual precipitation in this area varies from about 10 to 25 in. The Basin and Range Lowlands province is typified by mountain ranges that bound broad, alluvium-filled valleys and by annual precipitation of 4 to 12 in. The Central Highlands province, which is transitional between the other two provinces, is generally mountainous and consists of a mixture of igneous, metamorphic, and sedimentary rocks. Annual precipitation ranges from 15 to 25 in.

About 58% of Arizona's water supply comes from ground-water reservoirs with the remaining 42% from surface-water supplies. The geographic distribution of the principal aquifers is shown in figure 19, and the locations of the principal river basins and dams are shown in figure 18. Ground-water reservoirs are of great significance as a source of water because virtually all surface water has been appropriated. Any future increases in water demand will have to be met by ground water.

Surface Water

The USGS formally defines for the United States a number of water-resources regions, which are further divided into subregions and river basins. Most of Arizona falls within the Lower Colorado Region except for the northeastern corner of the State, which lies within the Upper Colorado Region. These regions and their subregions are shown in figure 17. The major rivers that drain these areas are the Colorado, Little Colorado, Bill Williams, Gila and Salt.

The Colorado River enters northern Arizona at Glen Canyon, flows through the Grand Canyon into Lake Mead, and then forms the western border of the State before entering Mexico (figure 17). All of the other rivers in the State eventually flow into the Colorado River. The Central Arizona Project Canal diverts approximately 1.6 million acre-feet to southern Arizona annually.

The Little Colorado River, which is mostly fed by ephemeral streams, drains most of the northeastern corner of the State and joins the Colorado River upstream from the Grand Canyon. The Bill Williams River drains the west-central portion of Arizona and joins the Colorado River on the western border of the State.

The Salt River and its major tributaries, the Black, White, and Verde Rivers, do not flow directly into the Colorado River, but rather join the Gila River near Phoenix. The area drained by these rivers includes the central and east-central portions of the State.

The Gila River drains most of the southern half of the State. In addition to the Salt River, tributaries to the Gila River include the Santa Cruz and San Pedro Rivers entering from the southeast and the Agua Fria River from the north. The Gila River joins the Colorado River in the southwestern corner of the State near Yuma.

Storage reservoirs are used both to regulate the flow of perennial streams and to store surface water for eventual use. Arizona has water rights to large amounts of water stored in major reservoirs located on the State's borders. These reservoirs include Lakes Mead, Mohave, Havasu, and Powell. In addition, significant quantities of water are stored in Roosevelt Lake (Roosevelt Dam in figure 17), San Carlos Lake (Coolidge Dam in figure 17), and other smaller reservoirs.

About 89% of the surface-water withdrawals in Arizona are for irrigation and about 9% are for public supply. Industrial withdrawals, including those for mining, only account for about 2% of total withdrawals. Mining, therefore, can be seen to have a fairly negligible effect on surface water supplies. However, because virtually all surface water in Arizona is appropriated, most, if not all, future mining activity will have to rely on supplies of ground water.

Rights to surface waters in Arizona are based upon prior appropriations that put the water to a beneficial use. State laws require that an application be filed to obtain a permit to apply such water to beneficial use. Strict compliance with these laws is mandatory to acquire surface-water rights.

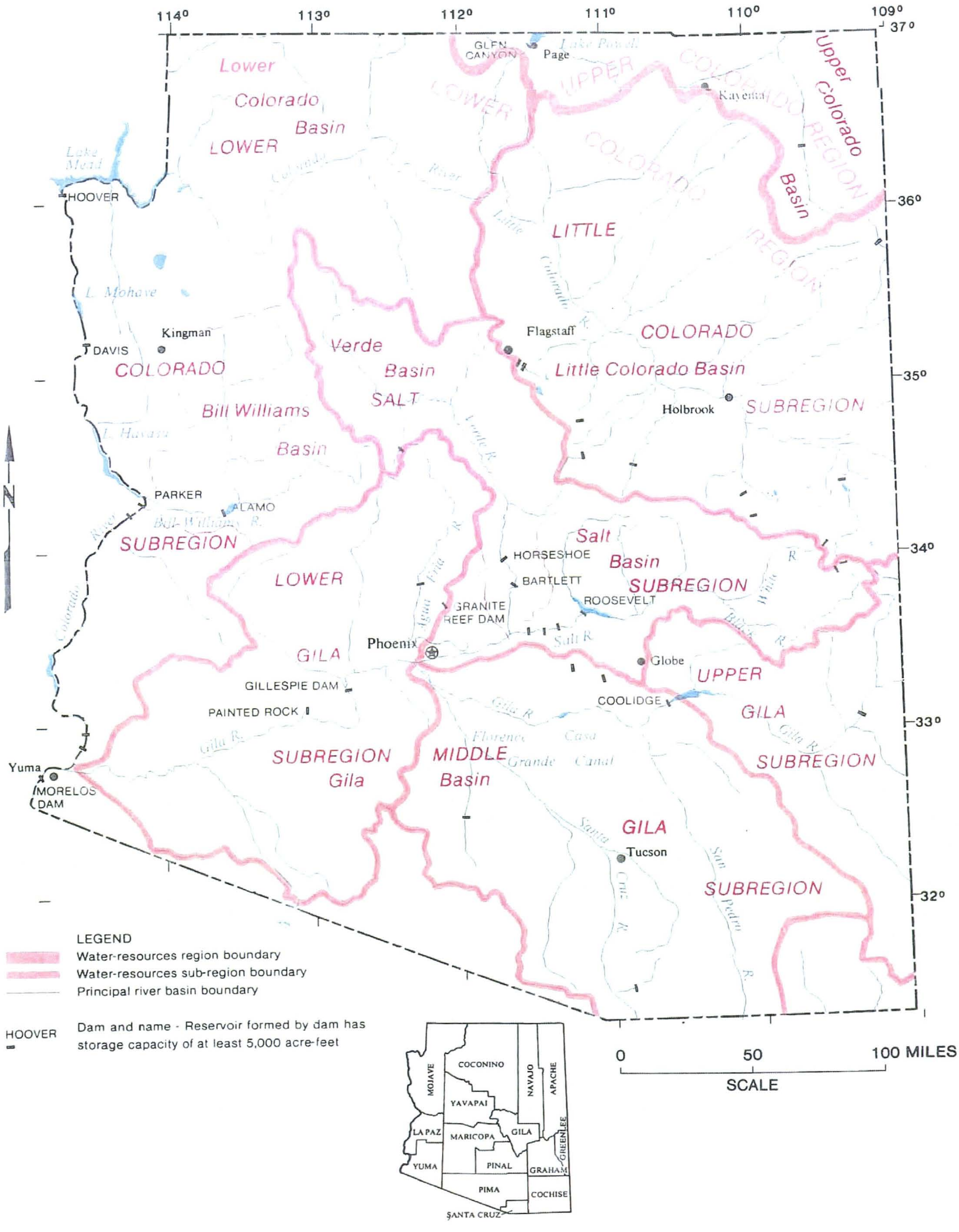


Figure 17: Surface water resources in Arizona)
(from Sawyer et al, 1992)

Ground Water

Ground water in Arizona is found in three types of aquifers: alluvial, sandstone, and low-yielding bedrock (figure 18). The alluvial aquifers are the most significant, consist mainly of unconsolidated sands and other sediments, and are found in the Basin and Range Lowlands and parts of the Central Highlands. These aquifers commonly are found at depths between 100 and 2,000 ft and have a typical yield of about 1,000 gpm but may exceed 2,500 gpm. The thickness of these units varies from a few hundred to about 10,000 ft. Most of the cities and irrigated areas in the southern half of the State rely on this type of aquifer. Since recharge is minimal in arid regions such as Arizona, pumpage from ground-water results in a draw-down of the water table. In many of the ground water areas the water-table has declined by several hundred feet, with the most pronounced declines of more than 500 feet in the more heavily-pumped agricultural and populous urban areas (U.S.G.S. Water-Resources Investigation Report 90-4179).

The sandstone aquifers consist mainly of fine-grained sandstone beds whose permeability may be enhanced by faulting and fracturing. These aquifers are found only in the Plateau Uplands and along the northern edge of the Central Highlands. Depths commonly range from 50 to 2,000 ft, and yields are typically between 0 and 50 gpm but may exceed 500 gpm. Individual aquifers vary from about 200 to 500 ft in thickness and are separated by thick layers of impervious sediments. Most water in the northern part of the State comes from this type of aquifer, primarily from the Coconino and Navajo sandstones.

The least important aquifers are the bedrock type, which are composed of relatively impermeable crystalline and sedimentary rocks. They are found at depths of about 50 to 1,000 ft and have typical yields of 0.5 to 2 gpm but may exceed 200 gpm. These aquifers supply only individual domestic users in rural areas.

About 88% of ground-water withdrawals are for irrigation, 7% are for public use, and only about 4% are for industrial use, including mining. These figures closely parallel those for surface water.

The USGS, in cooperation with the Arizona Department of Water Resources, has conducted a program of ground-water studies in the State since 1939. These studies define the amount, location, and quality of ground-water resources in Arizona and monitor the effects of their usage. Since 1974, a major thrust of this program has been to inventory the ground-water conditions in each of the 68 ground-water areas of the State (figure 19 and table 15 in Appendix). Several selected ground-water areas are studied each year, water levels are measured annually in a statewide observation-well network, many ground-water samples are collected and analyzed annually, and ground-water pumpage is computed for most of the areas.

Ground-water quality is highly variable between ground-water areas, and in some cases, within areas. Water quality of selected wells is collected and published on an annual basis by the U.S. Geological Survey in cooperation with the State of Arizona and other agencies, as U.S.Geological Survey Water-Data Reports.

Ground-water rights in Arizona are based on a comprehensive and complex ground-water code that was enacted in 1980. This statute created four Active Management Areas (AMA), shown in figure 20, within which there are severe limitations on uses of ground water. Within these AMA's, ground water can be obtained for mining purposes only through acquisition from the Arizona Department of Water Resources of a mineral extraction and metallurgical processing permit or a dewatering permit. In addition, certain grandfathered ground-water rights exist as specified in the code. Outside AMA's, ground water may be pumped as long as it is used reasonably and beneficially. All wells, including exploration wells, however, require a permit issued by the Department of Water Resources. The code also created three Irrigation Non-expansion Areas (INA), also shown in figure 20, within which ground-water users must file annual withdrawal reports. Although these areas do not currently have any special restrictions on water withdrawals for mining use, the very fact that ground-water use in these areas needs to be regulated suggests that additional restrictions could be imposed in the future.

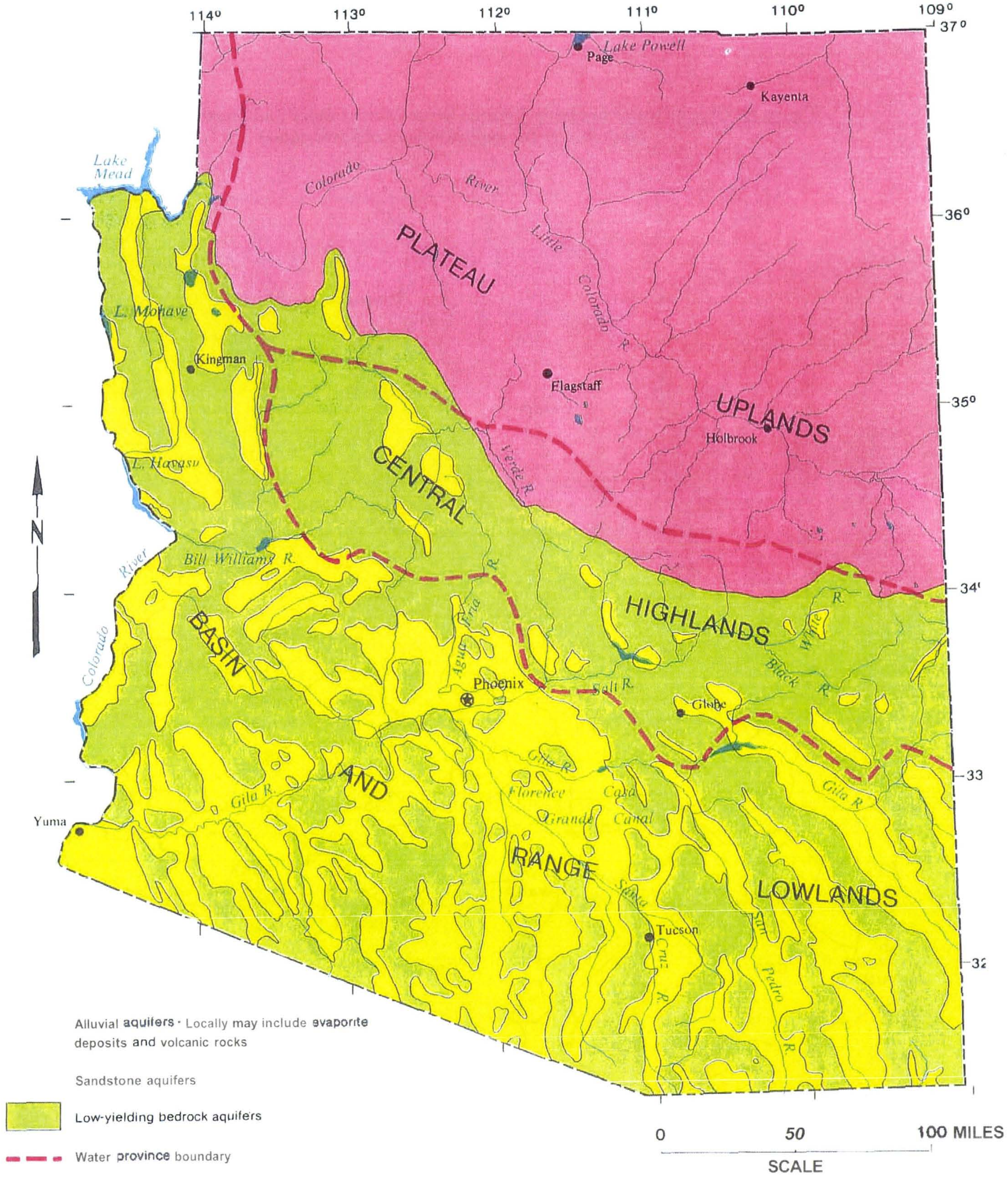
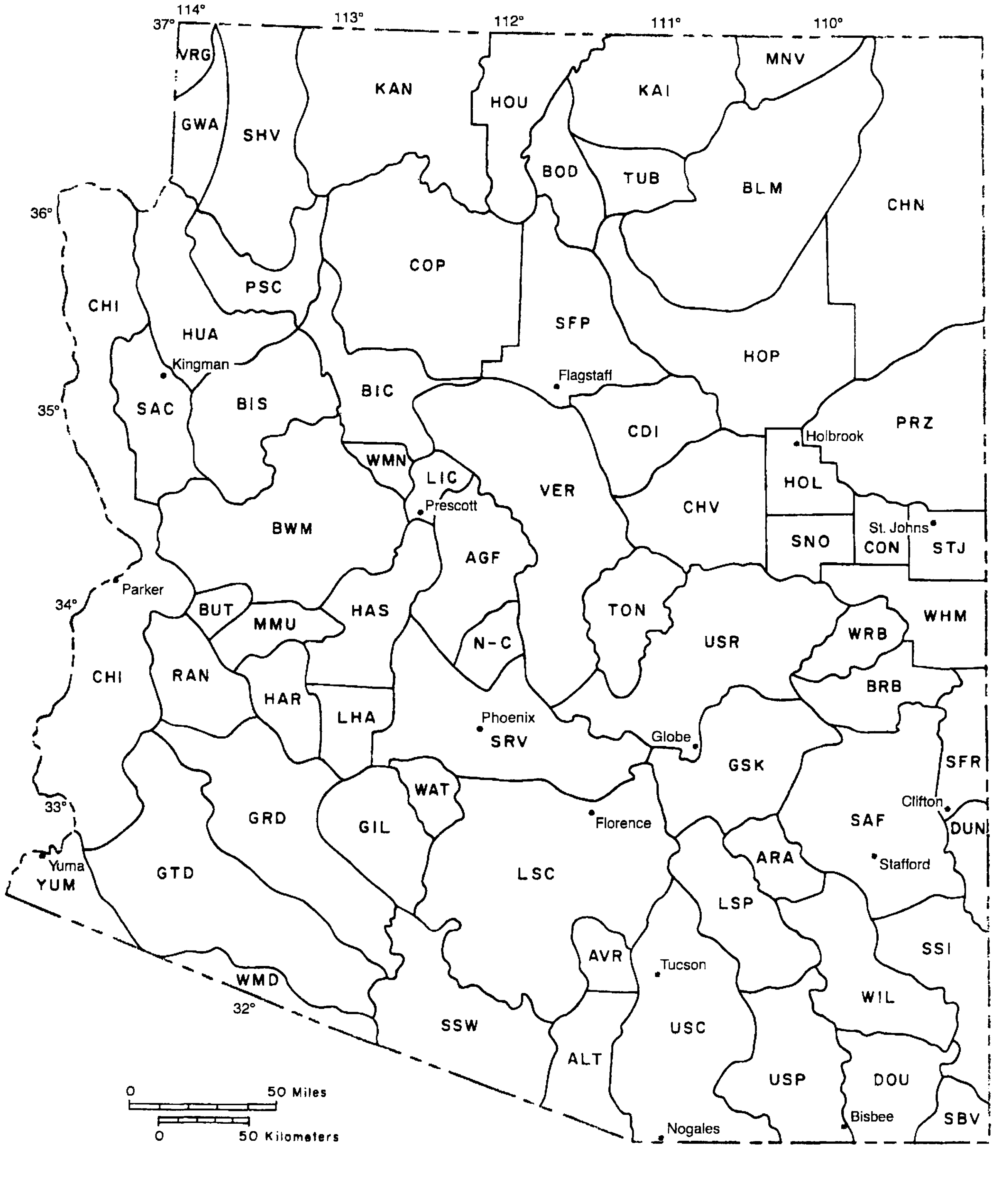


Figure 18: Groundwater provinces in Arizona (from Sawyer, 1992)

Figure 19: Groundwater basins in Arizona (from Montgomery and Harshbarger, 1989)
(see table 15 for explanation of abbreviations)



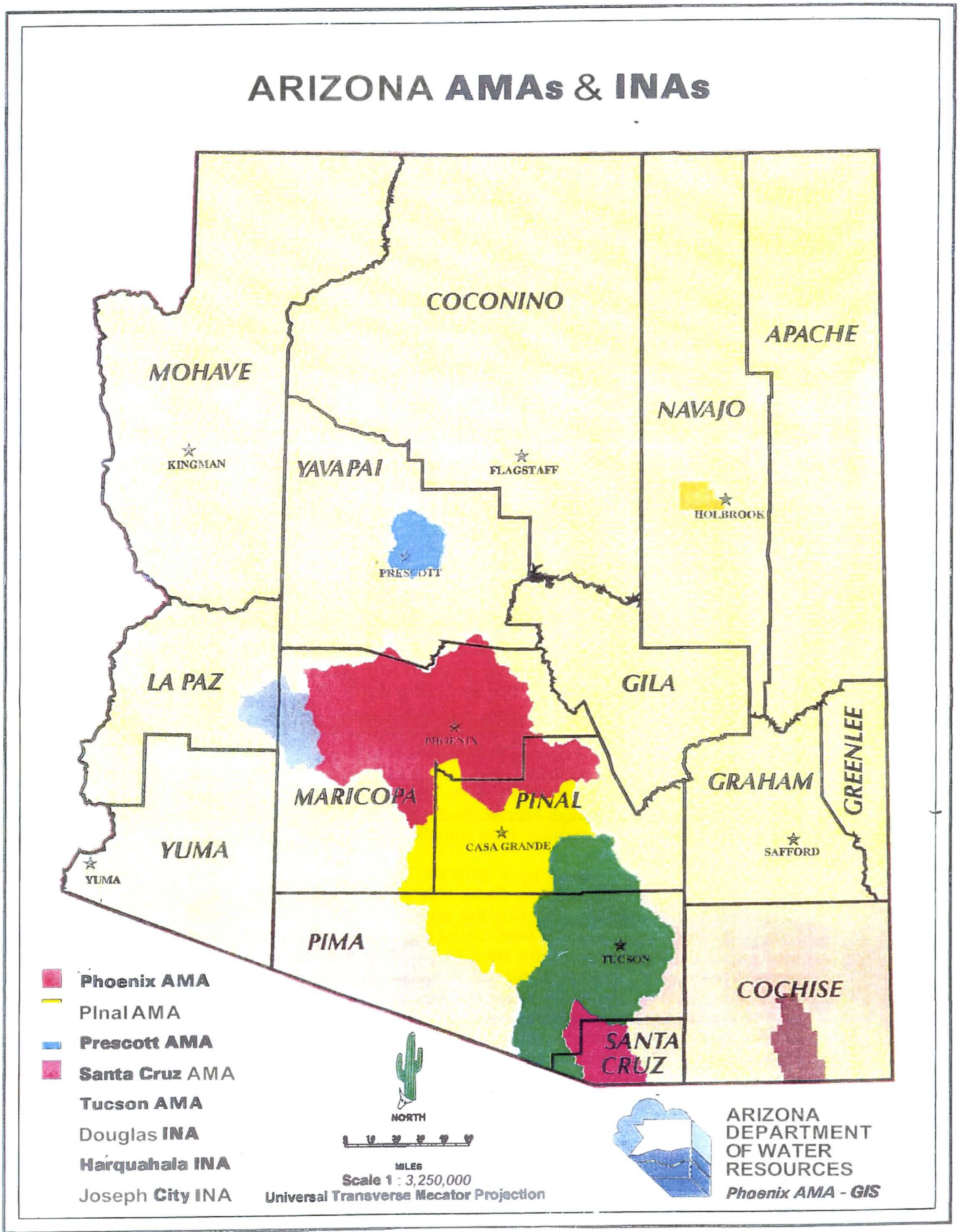


Figure 20: Managed groundwater areas in Arizona (ADWR)

2.4.2 Transportation (railways, highways, roads)

Transportation systems in Arizona, both road and rail, are well developed and provide access to most areas of the State. Short-line rail routes in Arizona were built in large part to transport mine products to smelters and refineries. Highways were developed in response to growth of commerce and the need to communicate between communities and the rest of the Nation. Regional transportation systems are linked to the statewide system in Arizona, thus providing transportation services to destinations outside the State.

Railways

Arizona's railway system comprises 2,121 mi of track consisting of 1,327 mi of mainlines and 800 mi of branch lines. Table 14 and figure 21 summarize the State's rail carriers and rail system. Two major railways provide transportation services within the State of Arizona: the Burlington Northern and Santa Fe Railway Company (BNSF); and the Union Pacific Railroad(UPRR). Both companies provide transcontinental connections. The State is also served by eleven additional railroads: the Apache Railway Company (ARR), the Arizona and California Railroad (A&CRR), the Arizona Central Railroad (ACRR), the Arizona Eastern Railway (AER), the Black Mesa and Lake Powell Railroad (BM & LPRR), the Copper Basin Railway (CBRR), the Grand Canyon Railway (GCRR), the Magma Arizona Railway (MRR), the San Manuel Railroad Company (SMRR), the San Pedro & Southwestern Railway (SPSWRR), and the Tucson, Cornelia, and Gila Bend Railroad (TC & GBRR) (under embargo).

The UPRR is the largest carrier that serves Arizona with 698 mi of track (figure 21). UPRR's transportation services include rail and piggyback systems.

The UPRR links markets throughout the West and Midwest, and offers direct mainline service to major markets in most states in the area. Additionally, through service is offered to points in the eastern United States.

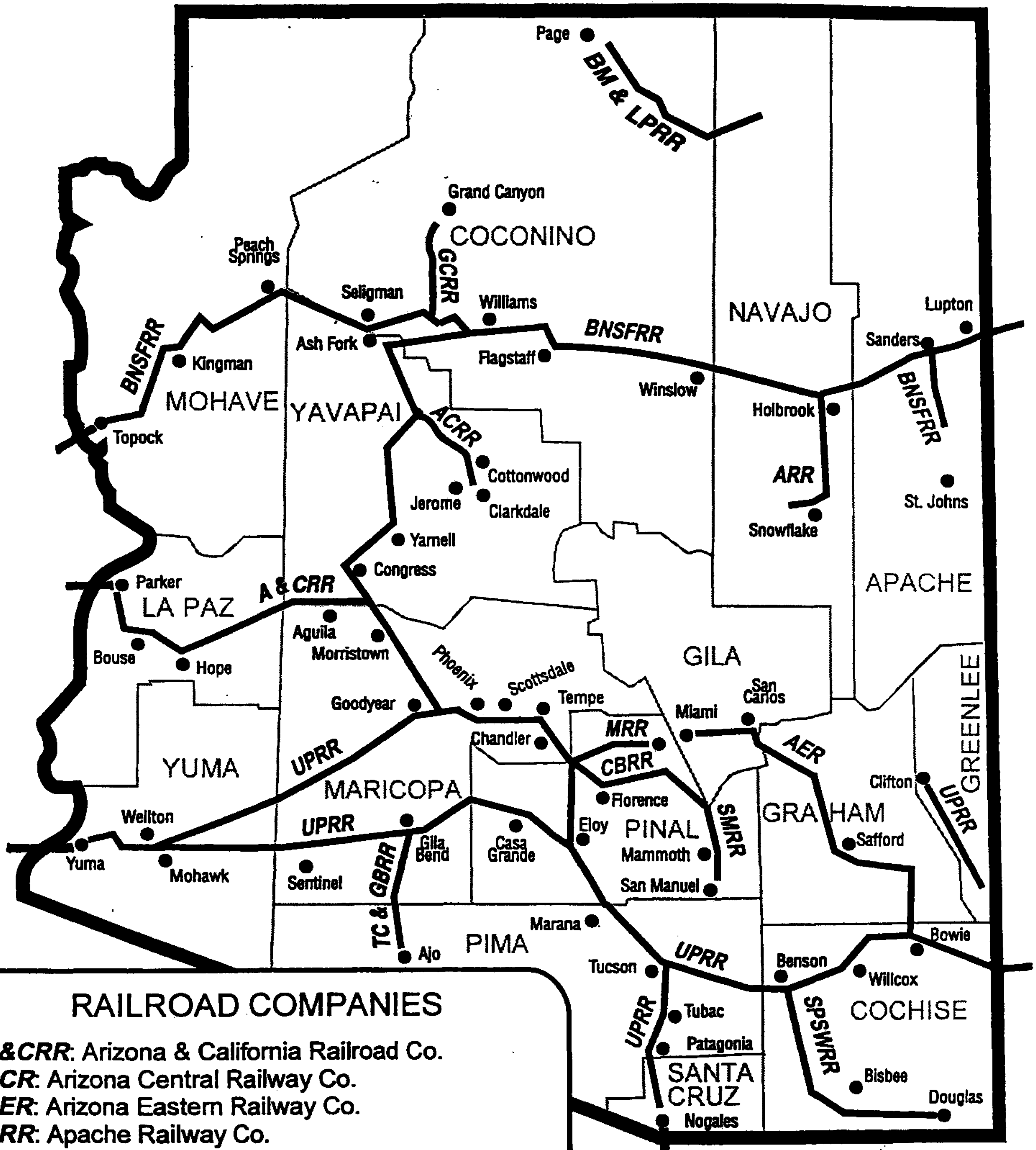
Extending east-west across the southern portion of Arizona, the UPRR operates between El Paso, TX, and Niland, CA. Connections are made with the BNSFRR at Vaughn, NM, El Paso, TX, and Phoenix, AZ. Connections are also made with the TC & GBRR at Gila Bend, servicing Ajo in Pima County, with the MRR at Magma, servicing Superior in Pinal County, and with the Copper Basin Railway near Florence serving mines in Hayden and San Manuel. Also, the UPRR connects with short lines to serve such mining communities as Morenci, Globe, and Bisbee.

The BNSFRR is the second largest carrier with 629 mi of track, servicing the upper northern and north-central areas of Arizona. The BNSFRR mainline crosses the State from the eastern border (near Lupton), passing through Navajo, Holbrook, Flagstaff, Williams, Kingman, and Topock, to Needles in California. This mainline links with the ARR at Holbrook and the Grand Canyon Railway (GCR) at Williams Junction.

Arizona is also served by a BNSFRR line of approximately 250 mi running from its connection point with the UPRR at Phoenix through Wickenburg, Hillside, Drake, and Williams. Connecting to this mainline is a short line serving Clarkdale. The Arizona & California Railroad links Wickenburg to Parker in the west-central part of the State and continues on into California. The mainline of the BNSFRR that runs from east (Gallup, NM) to west (Needles, CA) through the northern portion of the State is part of an interstate network serving the States of California, Arizona, New Mexico, Colorado, Texas, and Kansas.

The smaller rail carriers are important to the mining industry because they provide the final links to such mining centers as Miami, Globe, Superior, San Manuel, and Ajo . Their railage is summarized in table 16. One-third of the shortline carload business is derived from the mining industry.

Railroads in Arizona - 1996
Approximate Alignments



RAILROAD COMPANIES

A&CRR: Arizona & California Railroad Co.
ACR: Arizona Central Railway Co.
AER: Arizona Eastern Railway Co.
ARR: Apache Railway Co.
BNSFRR: Burlington Northern Santa Fe Railroad
BM&LPRR: Black Mesa & Lake Powell Railroad
CBR: Coper Basin Railway Co.
GCR: Grand Canyon Railway Co.
MRR: Magma Arizona Railroad
SMRR: San Manuel-Arizona Railroad
SPSW: San Pedro & Southwestern Railroad Co.
TC&GBRR: Tucson, Cornelia & Gila Bend Railroad
UPRR: Union Pacific Railroad

Source:
ADOT Transportation Planning Division
Arizona Corporation Commission

Figure 21: Railways in Arizona
(ADOT)

Table16. Rail carriers and railage

Shortline Carrier	Kilometers	(mi)	Percent	Principal Business
Apache Railway Co.	72	(45)	2.1	Forest products
Arizona & California Railroad	260.8	(163)	7.7	All freight
Arizona Central Railroad	60.8	(38)	1.8	Passenger, coal, cement
Arizona Eastern Railway	214.4	(134)	6.3	Copper
Black Mesa & Lake Powell RR	134.6	(84)	3.9	Coal
Copper Basin Railway	120	(75)	3.5	Copper
Grand Canyon Railway	102.4	(64)	3.0	Passenger
Magma Arizona Railway	44.8	(28)	1.3	Copper
San Manuel Railroad Company	48	(30)	1.4	Copper
San Pedro & Southwestern RY	126.4	(79)	3.7	Passenger, lime
Tucson, Cornelia, & Gila Bend RR	69.5	(43)	2.0	Copper
Total Shortline Miles	1270.4	(794)	37	
Mainline Carrier	Kilometers	(mi)	Percent	
Burlington Northern Santa Fe RR	1006.4	(629)	30	
Union Pacific Railroad	1116.8	(698)	33	
Total Mainline Miles	2123.2	(1327)	63	
Total Rail Miles	3393.6	(2121)	100	

Source: (ADOT; Russell Gottschalk)

Highways

The State of Arizona extends about 460 mi north-south and approximately 350 mi east-west. A well-developed network of interstate, Federal, State, County, and Indian highways provides access to most parts of the State and serves the interstate and intrastate transportation needs of Arizona's people and industries (figure 22). This highway system is important to the mining industry of Arizona both for bringing in supplies and equipment and for shipment of mine, mill, smelter, and refinery products and for transporting products to markets.

Segments of six interstate highways serve the State. Interstate 40 (I-40), across northern Arizona, and I-10. across the southern part of the State, provide the two major east-west routes with instate lengths of 373 mi and 402 mi, respectively. Interstate 8 extends eastward from Yuma to its junction with I-10 southeast of Phoenix, a distance of 178 mi. The major north-south routes are I-17 from Flagstaff to Phoenix (146 mi) and I-19 from Tucson to the Mexican border (63 mi). Finally, I-15 (29 mi.) crosses the extreme northwestern corner of the State. These roads form the core of the highway system in Arizona but would be of limited use without the Federal, State, County, and Indian roads that form the remainder of the network.

Various restrictions on highway use in Arizona are imposed by regulation, and these regulations often impact the mining industry. Vehicles that do not exceed 102 ft in length are exempt from permits and may operate on all Interstate and State highways shown in figure 23. However, there are certain rules and regulations that apply to the movement of any vehicle, material, or commodity load in excess of the legal size or weight permitted on highways under the jurisdiction of the Arizona Department of Transportation. For example, Class A permits allow loads up to 14 ft in width, 16 ft in height, 120 ft overall length, and 250,000 lb gross combined weight. Loads requiring Class A permits must be escorted if traveling on any of the restricted highways shown in figure 24. Other classes of permits may be required, depending on the load, and the Arizona Department of Transportation should be consulted for further information.

Intrastate movement of mine and mill products is commonly accomplished by truck, often by contract carrier. Long-distance interstate movement of mine or mill products is most often accomplished by rail after the products are trucked to railheads.

1996 Highway Functional Classification

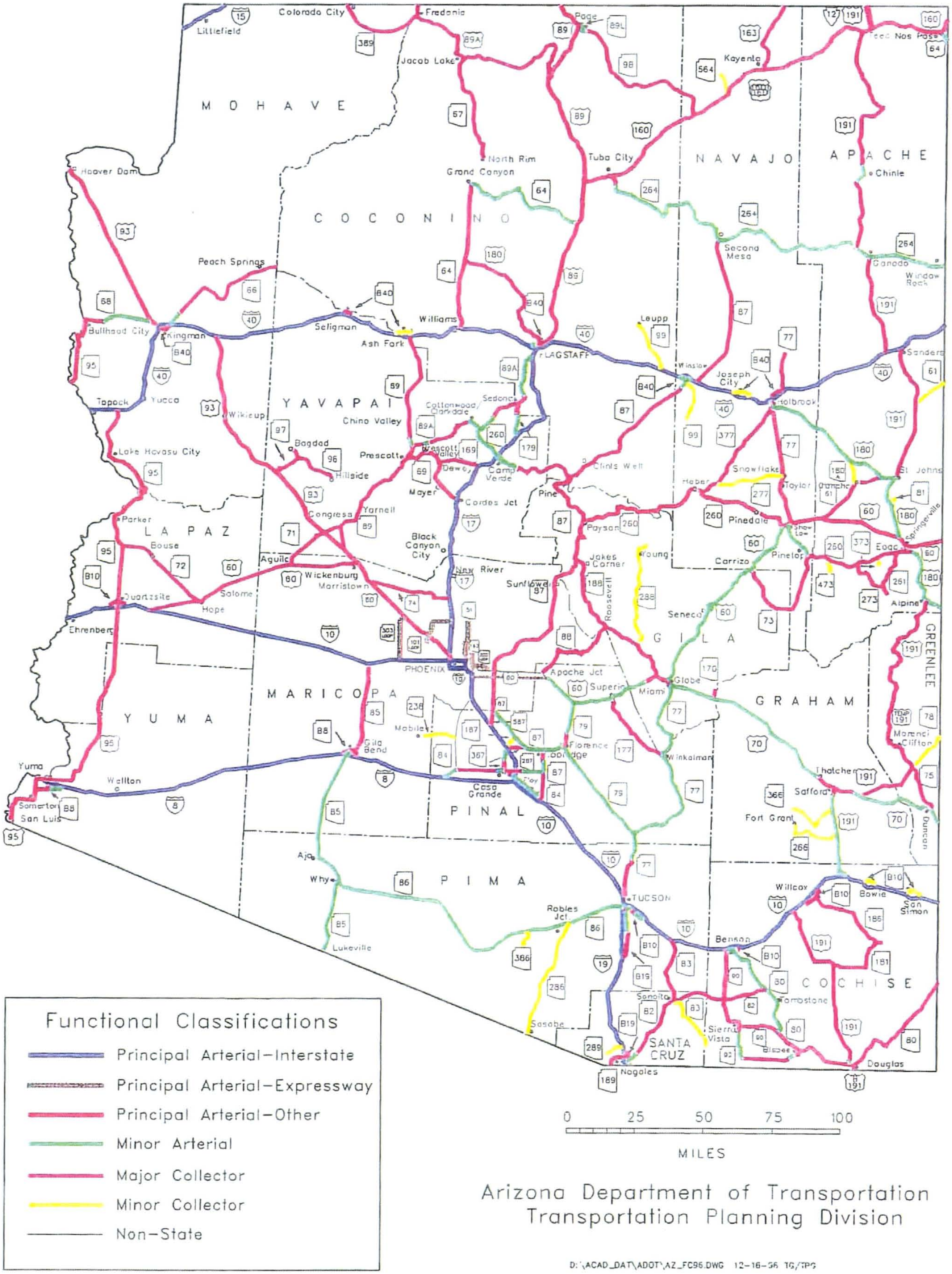


Figure 22: 1996 Highway functional classification in Arizona (ADOT)

ROUTES DESIGNATED FOR OPERATION OF 102' VEHICLES

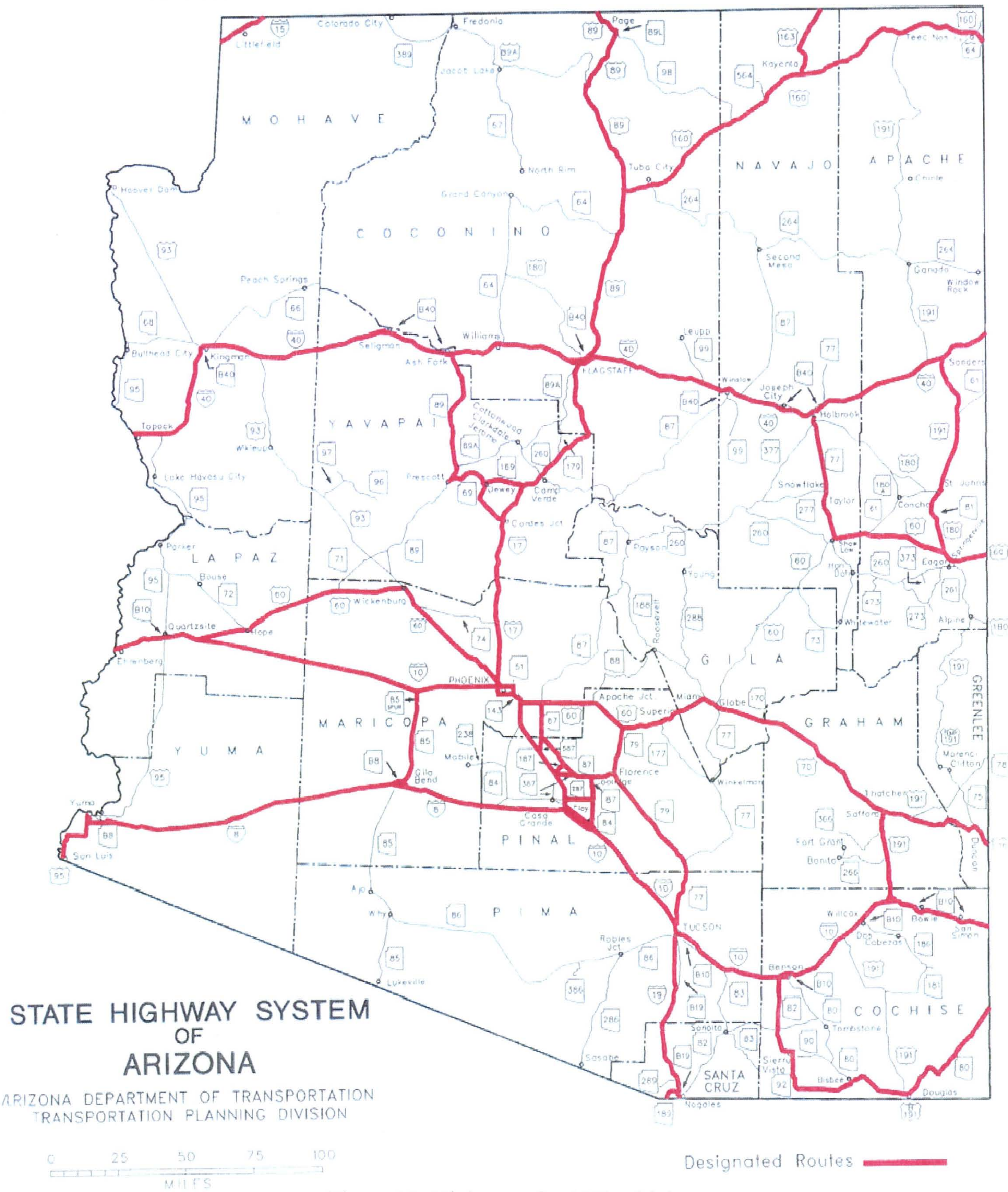


Figure 23: Highways for 102' vehicles
(ADOT)

ESCORT REQUIREMENTS FOR CLASS PERMITS

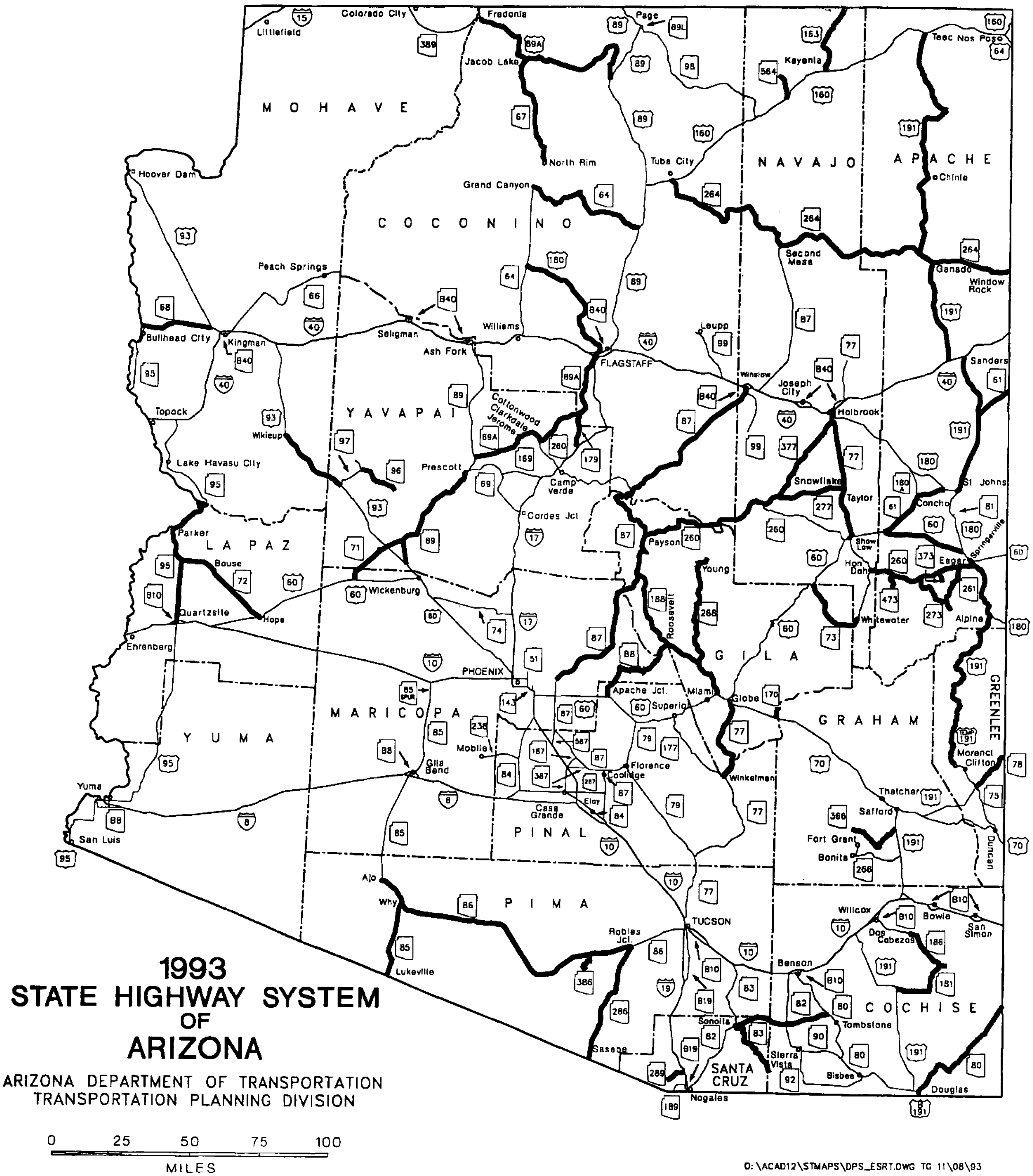


Figure 24: Highways requiring escort
(ADOT)

2.5 Markets for Arizona Mineral Products

Metals

In Arizona:
- Wire mills
- Nonferrous foundries
- Processors of intermediate forms such as anodes and concentrates

Out-of-state:
- Wire mills
- Brass mills
- Tubing mills
- Plate and sheet fabricators
- Magnet wire mills
- Chemical producers
- Nonferrous foundries
- Processors of intermediate forms such as anodes and concentrates

Industrial Minerals

In Arizona:
- Private construction projects
- Public construction projects
- Copper mine beneficiation plants
- Farmers
- Manufacturers
- City, county, and state governments
- Packagers
- Blenders
- Waste handlers
- Environmental clean ups

Out-of-state:
- Private construction projects
- Public construction projects
- Copper mine beneficiation plants
- Farmers
- Manufacturers
- Waste handlers
- Environmental clean up services

Coal, Oil and Gas

All of the coal production from Arizona is currently dedicated to two customers, the Salt River Project as fuel for the Navajo Generating Station, and to the Southern California Edison as fuel for the Mohave Power Plant.

Oil that is produced in Arizona is purchased by Giant Industries, P.O. Box 12999, Scottsdale, AZ 85267, and is transported by trucks to refineries in Bloomfield, New Mexico or Aneth, Utah. The average price paid for crude oil produced in Arizona during 1996 was about $17 per barrel.

Natural gas that is produced in Arizona is purchased by Western Gas Resources, 12200 N. Pecos Street, Denver, Colorado 80234, and is transported by pipeline to Aneth, Utah. The average price paid for Arizona natural gas during 1996 was about $1.87 per thousand cubic feet.

The market and customers for the probable production of carbon dioxide gas from the St. Johns field is still being researched. Interest has been shown by several west coast oil producers for use of the CO_2 in enhanced recovery operations in mature oil fields in the Los Angeles/Bakersfield areas. The delivery of the gas would be dependent on construction of a pipeline to the market area. Preliminary indications are that there is enough reserve to justify the expense of the transportation infrastructure.

2.6 Governmental and Regulatory Factors (federal, tribal, state, local)

2.6.1 Land Ownership

About 72% of the land in the State (including Indian reservations) is owned or controlled by the Federal Government and is subject to the provisions of Federal laws. The availability of Federal lands in Arizona for mineral exploration and development varies according to land use classification.

The State of Arizona owns about 15% of the land, on which mining rights are subject to State laws. The remaining land in Arizona, about 13%, is privately owned. Table 17 shows ownership or assignment of lands. Specific laws, regulations, and management practices determine the availability of lands under the particular jurisdiction. If a landowner has obtained the mineral rights, then acquisition by third parties of those rights is not governed by Federal or State laws, but rather is determined by the concerned parties through negotiation. If the Federal Government has reserved the mineral rights, either on State or private lands, then the same may be obtained pursuant to Federal laws .

Table17. Land Ownership or Control in Arizona (from Sawyer, 1992)

Distribution	Acreage	Percent
Federal:		
Bureau of Land Management	13,899,000	19.1
Forest Service	10,807,000	14.9
Department of Defense	3,574,000	4.9
National Park Service	2,414,000	3.3
Fish and Wildlife Service	[1]723,000	1.0
Bureau of Reclamation	480,000	0.7
Other Federal agencies	92,000	0.1
Total Federal control	31,989,000	44.0
Bureau of Indian Affairs/Indian Reservations:		
Navajo	9,874,899	13.6
Papago	2,855,874	3.9
Hopi	2,472,254	3.4
San Carlos	1,877,216	2.6
Fort Apache	1,664,872	2.3
Hualapai	992,463	1.4
Gila River	371,929	0.5
Colorado River	225,996	0.3
Others	222,097	0.3
Total Indian lands	20,557,600	28.3
Total State lands	10,903,000	15.0
Total private lands	9,238,400	12.7
Grand total	72,688,000	100.0

1. Includes 825,000 acres of the Cabeza Prieta Game Range at the Barry M. Goldwater Air Force Range and shown in the Department of Defense total.
2. Includes only that part of the reservation located in Arizona.

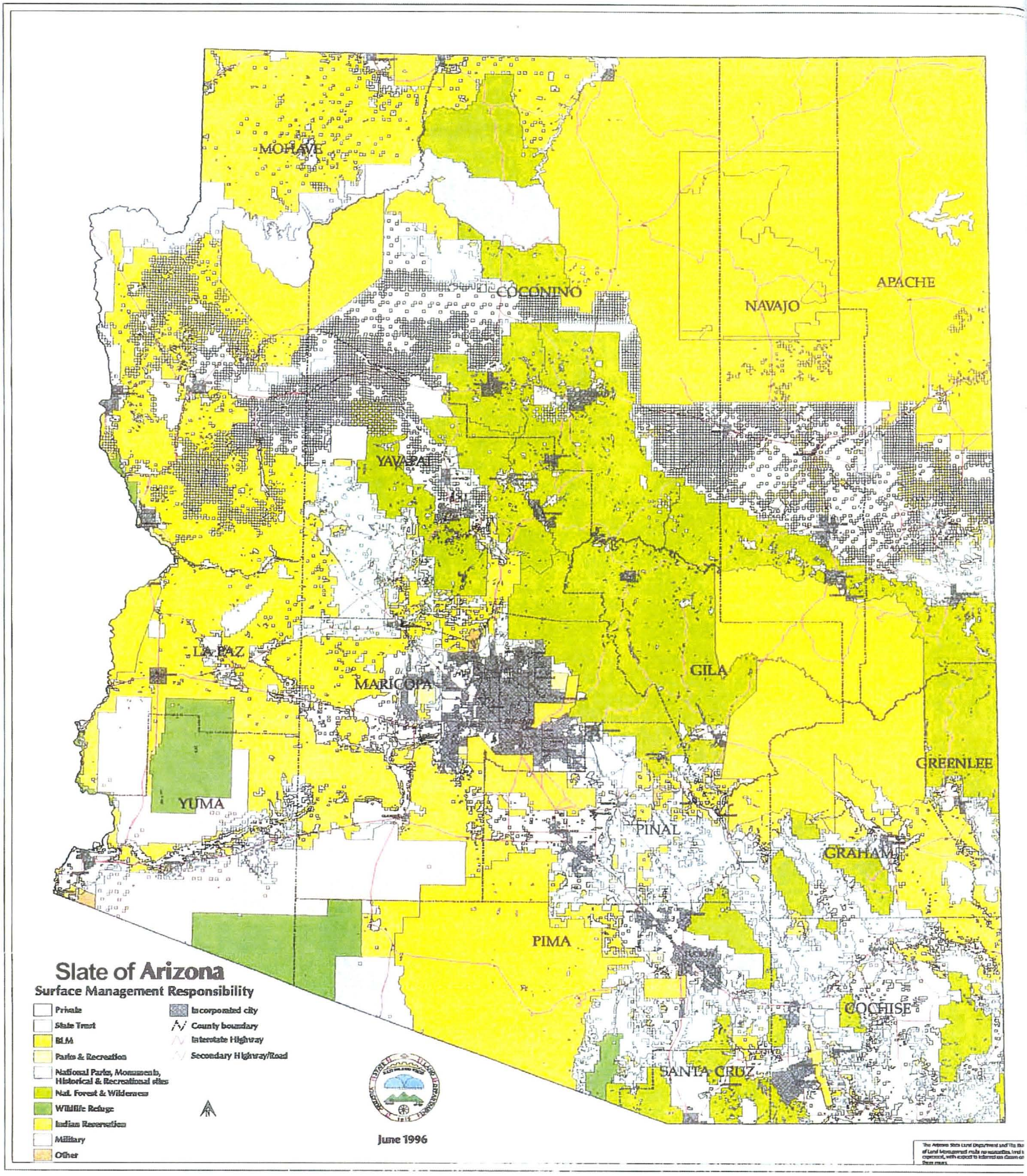


Figure 25: Land ownership in Arizona
(ASLD, 1997)

2.6.2 Mining Regulations

Exploration for and development of mineral commodities and sources of energy as well as production, milling, smelting, and refining are essential to the economy of Arizona as well as individual communities. Mining contributes to economic growth by providing jobs and a source of income through taxes, freight revenues, and support of subsidiary industries. Regulations governing the mining industry in Arizona are thus generally favorable relative to many other states. Regulations governing exploration for, and development of, mineral resources in Arizona exist at both the Federal and State levels. Most permitting required for mineral development in Arizona occurs at the State level; however, there are also local and Federal agencies that may have jurisdiction depending on the owner of the land or the applicable land management agency. The counties and other municipalities have only limted jurisdiction over mining operations. The services of the ADMMR and the Arizona Department of Commerce are available to assist investors.

Mineral entry and mining locations on public lands, Federal mineral leasing laws, mineral materials disposal, multiple use of Federal lands, acquisition of mineral rights on State lands, permits, environmental protection, taxes, water and water rights, roads, rails, rights-of-way, waste disposal, mining partnerships, and grubstake agreements on Federal and State lands are covered by an ADMMR booklet, "Laws and Regulations Governing Mineral Rights in Arizona" , and by ADMMR Circular No. 13 . Both are available from the ADMMR (1502 W. Washington Street, Phoenix, AZ 85007, 602-255-3791. Similar information is available from the BLM and U.S. Forest Service (USFS) offices. Specific procedures for determining land status relative to mining claims or leases is given in ADMMR Circular No. 2. Detailed information on land, mineral rights and water rights title data is published in two ADMMR booklets: 1) *Manual for Determination of Status and Ownership, Arizona Mineral and Water Rights;* and 2) *Laws and Regulations Governing Mineral Rights in Arizona.* All of these publications are available from the Arizona Department of Mines and Mineral Resources, 1502 W. Washington, Phoenix, AZ 85007.

Regulations governing exploration for, and development of, mineral resources in Arizona exist at both the Federal and State levels. About 72% of the land in the State (including Indian reservations) is owned or controlled by the Federal Government and is subject to the provisions of Federal laws. The availability of Federal lands in Arizona for mineral exploration and development varies according to land use classification. Under this system, many Federal lands have been withdrawn from mineral entry for a variety of reasons. Interested parties seeking information on the status and specifics of Federal tracts, parcels, and mineral ownership, should refer to the official records of the U.S. Bureau of Land Management (BLM), 222 North Central Avenue, Phoenix, AZ 602-650-0516. Rights to mineral commodities on Federal lands are obtained by claim location, lease, or sale, depending on the mineral(s) and type of Federal lands. Locatable minerals include all metallic and most nonmetallic commodities. Leasable minerals include oil and gas, phosphate, sodium, potassium, and coal. Federal laws determine the leasing terms and limit extraction rates. The sale of sand, gravel, stone, clay, pumice, and cinders is at the discretion and control of the managing agency. In February, 1997, the Bureau of Land Management amended the regulations on hard rock mining on public lands to require submission of, or certification of, financial guarantees to cover 100 percent of the cost of reclamation for all operations of greater than casual use. These regulations require bonding for all plans to 100 percent of a third party registered professional engineer's estimate of the cost of reclamation.

Permits for activity on Native American reservation lands in Arizona, other than the Navajo Nation, are administered by the Phoenix Area Office of the Bureau of Indian Affairs (BIA) - Land Operations 400 N. Fifth Street, Two Arizona Center, 12th Floor, Phoenix, AZ 850004, 602-379-4511. Permits for activity on the Navajo Nation are administered by the (BIA) Navajo Area Office, P.O. Box 1060, Gallup, NM 87305, 505-863-8314. A Directory of Tribal Leaders, revised in September, 1996 is available from the Phoenix Area Office, which includes BIA officials and officials of the reservations in Arizona. Pursuant to the Indian Mineral Development Act of 1982 and with the approval of the Secretary of the Interior, tribes may enter into agreements with third parties for the exploration, extraction, processing, or other development of mineral resources on Indian tribal lands and lands allotted to Indians in severalty.

The State of Arizona owns about 15% of the land, and mining rights on that land are subject to a complex set of State laws. The most restrictive regulatory compliance State laws relate to mining safety and health, air, and water controls. Arizona has adopted all mandatory Federal health and safety standards of the Mine Safety and Health Administration (MSHA) and the Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor. The State Mine Inspector is responsible for enforcing and administering the Arizona Mining Code, and thereby protecting the life, safety, health, and welfare of employees in Arizona mines, mills, smelters, refineries, and mine-related operations. Information pertaining to laws and regulations of mine activities and mine labor are available from the State Mine Inspector (1700 W. Washington, Phoenix, AZ 85007-2859, 602-542-5971) and from the Industrial Commission of Arizona (800 West Washington, Phoenix, AZ 85007, 602-542-4411).

Table 18 (Appendix 5.6 outlines State and Federal permits, with agency contacts, required for planning, development, and construction. This table is based on the following ADMMR publications: Circular No. 51, "Pertinent Data for New or Prospective Mining Operations in Arizona, 1996"; Circular No. 62, "State Agencies Concerned With Mining & Mineral Resources in Arizona, 1995"; Circular 67, "Federal Agencies Concerned with Mining in Arizona, 1996"; on the ADMMR publication entitled "Laws and Regulations Governing Mineral Rights in Arizona"; and on "Permit Requirements for Development of Energy and Other Selected Natural Resources for the State of Arizona," prepared for the Four Corners Regional Commission and the USGS . The first five documents are obtainable from the ADMMR and the last from the USGS, Environmental Affairs Office, 760 National Center, Reston, VA 22092. The ADMMR and the Office of Economic Planning and Development should be contacted for information regarding amendments or additions to regulations and permitting processes for the mining industry in Arizona. An additional document not summarized in this table, Circular No. 66 "County Agencies Concerned with Mining & Mineral Resources in Arizona, 1996: is available from the ADMMR. Furthermore, the interpretation of the laws and regulations and the process of permitting frequently require legal determinations; consequently, consultation is suggested.

The remaining land in Arizona, about 13%, is privately owned. Mining claims are locatable on private land, pursuant to Federal laws, providing that the Federal Government has retained the mineral rights (table 18 in Appendix, figure 25). If a private landowner has obtained the mineral rights, then acquisition by third parties of those rights is not governed by Federal or State laws, but rather is determined by the concerned parties through negotiation.

2.6.3 Acquisition of Mineral Rights

Acquisition of mineral rights is necessary as the first step in the development of a mine. The outline that follows provides a general guide to the process. The references listed in the bibliography and those noted elsewhere provide the details of permits and procedures for mineral rights acquisition, mine permiting, mine development, production and product marketing. Land ownership and land management is discussed further under section 2.6.2 (Mining Regulations). The following is a simplified outline for acquiring, developing, and exploiting mineral rights for locatable minerals (metallic mineral commodities and some nonmetallic minerals) in Arizona.The following general steps are recommended, which may be accomplished by an individual, a company, or a consultant.

1. Find an ore deposit, a likely place to discover one, or at least some good prospecting ground.
2. Determine the land status; that is, who owns or controls the mineral rights and surface rights. (See I. below)
3. Acquire the mineral rights. (See II below)
4. Obtain necessary permits and carry out necessary exploration work to determine if a viable ore deposit exists.
5. If a viable ore deposit is found, then obtain necessary permits to develop and operate a mine. (See III below)

I. Determine the ownership of mineral rights and surface rights. Circular C2 and Special Report SR11 will provide guidance. Each will be under either Federal, State, or private control. It is the mineral rights that are most important.

A. Federally controlled mineral rights

1. Closed (generally called withdrawn from) to mineral entry with no current valid mining claims located (claimed or staked) before withdrawal. *Thus mineral rights cannot be acquired.*

2. Open to mineral entry

a. No current mining claims. *Acquire mineral rights by locating mining claims.* Each claim, typically 20 acres requires field location work, a recording fee at the county recorders office of from $8.00 to $15.00 and filing/rental fees to the Federal Government of $135.00 the first year, or fraction of a year, and an annual advance rental fee of $100.00 per year payable on or before August 31 to the federal government.

b. Current mining claims cover area of interest. *Acquire mineral rights by lease or purchase from claim owners.*

B. State Trust Lands mineral rights controlled by the Arizona State Land Department

1. Closed. *Thus mineral rights are closed to mining.*

2. Open to mineral entry

a. No current prospecting permits, mineral leases, or material sales. *Acquire prospecting permit by applying to the State Land Department.* A non-refundable application fee is required for each Section or portion of a Section. If the Land Department agrees to allow the permit, an advance rental payment is required for the first two years. Advance rent must be paid for the third year, for the fourth year, and for the fifth year. Annual extensions must be obtained for each year even though the first two year's rent is paid initially. Prospecting permits require the holder to perform minimum exploration expenditures for each of the first two years and each of the last three years. Permits have a maximum life of five years. The holder of a prospecting permit has a preferential right to apply for a production lease.

b. Current mining leases or prospecting permits cover area of interest. *Acquire mineral rights by lease or purchase from permit or lease owners.*

C. Privately owned mineral rights. *Note that the owner of the mineral rights may not be the same as the owner of the surface. Acquire mineral rights by lease or purchase from owners.*

II. Do exploration work, delineate ore deposit, design mine and ancillary facilities

A. Federally controlled mineral rights with Federally controlled surface require a plan of operations with the Forest Service or the Bureau of Land Management which includes reclamation. A performance bond may be required. Certain very small disturbances and casual use activities may not require a plan. Disturbances under 5 acres may not require a plan on land administered by the Bureau of Land Management. No fees for the plan of operations are required, but the cost of gathering sufficient data that may need to be submitted to obtain the plan may be significant.

B. State Trust Land mineral rights require an exploration plan that may include reclamation requirements and bonds, as part of the conditions of the obtaining the prospecting permit.

C. Private land exploration requires an approved reclamation from the State Mine Inspector when the exploration is for metal deposits and the disturbance is greater than five acres. A performance bond may be required.

D. When mineral rights fall under A, B, or C, and the surface rights are controlled by a different owner or administrating agency, both may require separate approved plans.

III. Obtain mining permits, construct facilities, and develop and mine deposit

A. Federally controlled mineral rights with Federally controlled surface require a plan of operations with the Forest Service or the Bureau of Land Management which includes reclamation plans. A performance bond may be required. Certain very small operations may not require a plan. Disturbances under 5 acres may not require a plan on land administered by the Bureau of Land Management. No fees for the plan of operations are required, but the cost of gathering sufficient data that may need to be submitted to obtain the plan may be significant. Permits required by other Federal, State, and local agencies must generally be in place before the Federal land management agency will approve a plan of operations.

B. State Trust Land mineral rights require a lease from the State Land Department. Leases include rental fees, production royalties, reclamation plans, and performance bonds.

C. Privately owned mineral rights require a reclamation plan approved by the State Mine Inspector's Office for metal mines that disturb over 5 acres.

D. Severance or production taxes must be paid on sales of mineral production to the Arizona Department of Revenue. The rate for metals is 2.5% and for nonmetals is 3.125%. See section 2.6.3 Taxation

2.6.4 Taxation

The impact of taxation on a particular mineral deposit in Arizona depends both on the physical characteristics of the deposit and on its economics. Mines, oil and gas producers, and geothermal energy producers and some other natural resource producing property are valued by the staff of the Natural Resources Group of the Centrally Valued Property Unit, Division of Property Valuation and Equalization of the Arizona State Department of Revenue. The Natural Resources Group is also responsible for the preparation of the *Appraisal Manual for Centrally Valued Natural Resource Property,* which is published each year to serve as a guide in the appraisal of these properties. The current issue for tax years 1997-1998 is available from the Arizona Department of Revenue, 1600 W. Monroe, Phoenix, Arizona 85007.

For property tax purposes, according to A.R.S. 42-201, a producing mine is defined as "...any mine or mining claim from which any coal, mineral, or mineral substance, other than clay, sand, gravel, building stone, or any mineral or mineral substance normally processed into artificial stone, that has been extracted for commercial purposes.

In Arizona, the full cash value for a mining property is based on the going concern, unit valuation business concept. This concept drives a single unitary value for all taxable property necessary to operate the mine as a unit. The components of value include such items as real estate, mineral-in-place value, supplies inventory, construction-work-in-progress, plus any and all plants and equipment utilized in the operation. The full cash value of the property is determined by correlating data from all applicable approaches to value which may include the income, cost and market techniques.

The State of Arizona has a classified property assessment system. Under this type of system, the assessed value entered on the tax rolls depends on the full cash value and the assessment ratio for thea class of property. The full cash value for a producing mine is assigned to Class 1 property and assessed at a 27% ratio for the 1997 tax year. The Class 1 assessment ratio will decline by 1% per year until a level of 25% is reached in 1999. Nonproducing mines may be assigned to either Class 3 or Class 4 property and respectively assessed at either a 16% or 25% ratio. Environmental technology property is assigned to Class 8 property and assessed at a 5% ratio for ad valorem taxation purposes.

The actual tax bill is the product of the full cash value, multiplied by the assessment ratio, multiplied by the tax rate established for the specific location of the property. The property tax rate is determined for each tax jurisdiction by combining the individual tax rates for state, county, city, school district and all other taxing authorities into the overall rate.

Producing oil, gas and geothermal interests are assigned to Class 2 property and assessed at a 27% ratio for 1997. This ratio, as with Class 1 properties, will decline by 1% per year until a level of 25% is reached in 1999. Full cash value of oil, gas and geothermal properties are not unit valuations like mines. They are special valuations based on the gross value of production, i.e. gross production multiplied by well-headprice minus certain exemptions including Indian interests and amounts used at the well site for production purposes. The real and personal property associated with oil, gas and geothermal interests are valued by the local County Assessor separately from the producing interests.

Tax Incentives for Oil and Gas Property Development

The Arizona Property Tax Reform and Reduction Act, passed by the 42nd Legislature in July 1996, reduced the property tax assessment ratio for all real and personal property used for producing oil, gas, and geothermal interests to 28% of full cash value from 100%. The goals of this legislation are to provide tax equity for oil, gas, and geothermal interests, and to encourage leasing and exploration activity. The tax rate will decrease an additional 1% per year until holding at 25% in 2000 and thereafter. The tax-assessment ratio-reduction is effective in achieving tax equity, but it is still too early to dertemine whether it has been effective in encouraging leasing and exploration activity. A future review of state tax rate tables and permit records will help determine its effectiveness.

3. ANALYSIS OF THE CURRENT SITUATION

3.1 Overview of Producers

The economic impact of the minerals and mining industry in Arizona is tremendous, with direct income from the sales of mineral and energy products in excess of $4 billion in 1995, and $3.5 billion in 1996. The nonfuel mineral production is by far the greatest contributor with sales of $3.966 billion in 1995 and $3.279 billion in 1996. Of this, the copper industry was dominant with sales of $3.6 billion in 1995 and $2.9 billion in 1996.

Arizona's mining industry is highly diversified with 63 companies operating 113 active mines that produce 24 major metallic and industrial minerals. The copper industry, which directly contributed over $2 billion to Arizona's economy in 1996, consists of four large firms and several very small ones. The large Arizona firms were also the largest copper producers in the United States, having produced about 65% of the copper mined in the nation. These include: ASARCO, Incorporated, with operations in Gila, Pima, and Pinal counties; Cyprus Amax Minerals Company, with admininstative offices in Tempe and operating subsidiaries in Gila, Mohave, Pima, Pinal, and Yavapai counties; The Broken Hill Proprietary Company, Limited, with administrative offices in Tucson and operations in Gila and Pinal counties; and Phelps Dodge Corporation, with its headquarters in Phoenix and producing operations in Greenlee and Cochise counties.

Even though copper prices decreased during 1996, the major producers are continuing to expand their operations by the acquisition of new mining properties, re-opening of former mines, and the improvement of production techniques in established mines.

An additional 78 companies produce rock products and other industrial minerals. A great majority of these companies produce sand and gravel, which is consumed locally. Continuing population growth in the municipal areas of Arizona, with its associated construction of housing, business, transportation and communication infrastructure assures the continued success of the industrial minerals industry. Others produce a variety of products such as cement and lime, clay, cinders, diatomite, gemstones, gypsum, limestone, perlite, salt, and zeolites. Many of these mineral commodities are also in demand locally, but some are exported.

All production of fossil fuel energy resources in Arizona has been from the Navajo and Hopi Indian Reservations in northeastern Arizona. Coal production, with a market value of $300 million in 1996, was done entirely by the Peabody Coal Company. Oil and gas was produced by four small companies in 1996. The combined oil and gas production was valued at about $2.5 million in 1996. Although not yet in production, Ridgeway Arizona Oil Corporation has drilled eleven wells that define a large carbon dioxide/helium field in the St. Johns to Springerville area.

Large reserves of uranium ore have been located, but there has been no production since 1991. International Uranium USA has announced plans to resume production of uranium in the near future, from mines north of the Grand Canyon.

The infrastructure that is required to support the mineral industry is well developed in Arizona, and maps of facilities and services such as: electrical suppliers; electrical lines; gas suppliers; gas lines; transportation systems, including highway and rail; water resources; and land ownership; have been acquired from state and federal agencies and are included in this report. Industrial and mining equipment, supplies and services are readily available, and forty-two mineral processing facilities are currently active Arizona.

Employment in the Minerals Industry

Arizona residents received a significant amount of personal income in 1996 as a result of the copper industry's direct and indirect contributions to the State's economy. Nearly 73,000 Arizona residents had jobs as a result of combined direct and indirect contributions of the copper industry to personal, business, and government income in the state. The total number of jobs created for

Arizonans was more than five times the number of workers employed directly in copper production.

The industrial minerals industry employed directly 7,781 workers in 1996, who mined, processed, transported, and produced materials such as sand, gravel, cement, concrete, and asphaltic products. These products are used by workers in all types of construction, including heavy construction, street and highway construction, commercial and residential construction, which contributed to the support of an additional 124,526 jobs in the construction industry. The total employment in Arizona as a result of direct and indirect employment in the industrial minerals industry was 132,307 in 1996.

Peabody Western Coal Company employed nearly 700 persons in the coal mines on Black Mesa in 1996. They worked in a variety of capacities as miners, equipment operators, engineers, accountants, scientists and reclamation specialists. In addition to direct salaries and wages, royalties and taxes generated from the mining operations provided the Navajo and Hopi tribes with approximately $40 million in annual revenue. The electricity generated with the coal powered many of Arizona's residences, businesses, mines, and other industries.

3.2 Overview of Mining Services and Equipment Suppliers

A review of the AMIGOS Trade Association's Southwestern Buyer's Guide for Mining & Industry, Ninth Edition, indicates over 200 members that are providers of supplies, equipment and services to the mines and other industry in Arizona. They include heavy equipment firms, machinery suppliers, metal recyclers, construction companies, banks, manufacturers, transportation firms, tire dealers, chemical companies, engineering firms, and insurance firms. The Guide is organized in alphabetical lists of company names, and of supplies and services. Additional information about mining services and suppliers is available from the AMIGOS Trade Association, P.O. Box 25187, Phoenix, AZ 85002, telephone 602-279-3199. A similar organization, the Arizona Rock Products Association (ARPA), represents sand and gravel mining firms, crushed stone producers, ready-mix concrete suppliers, asphaltic and concrete product manufacturers, and cement producers. All either produce mined products or provide materials and related services to support mineral resource development. Additional information about these services is available from the Arizona Rock Products Association, 1825 W. Adams, AGC Building, Phoenix, AZ 85007, telephone 602-266-4416.

Oil and gas drilling equipment is not available in Arizona. Well drilling and completion equipment such as rotary drilling rigs, cementing and logging equipment and services must come from out of state suppliers, generally Farmington or Artesia, New Mexico, for northern and eastern Arizona operations, or from Long Beach, California for western Arizona operations.

Transportation services are adequate with approximately 1900 for-hire and private trucking companies with an inventory of almost 11,000 either commercial or apportioned truck-tractors pulling about 49,000 registered commercial trailers. Most national firms are represented within the state.

3.3 Opportunities for the Industry

Nearly 200 principal deposits of critical and strategic minerals have been identified by Sawyer in Arizona. Sawyer reviews 16 mineral commodities that are considered to be important to the economies of Arizona and the United States. Many other mineral commodities have been identified, described, located, and claimed and are being produced. Many more deposits are known but are not in current production because of limited industrial applications or markets. Some of these will become economic in the future through changes in market demand, the development of new uses, and changes in technology. The potential for the development of additional mineral deposits is great because Arizona and Sonora are located in the major mineralized area of western North America.

Arizona currently produces two-thirds of the copper in the U.S., and will continue to be a major competitor in the world market. Additional reserves are identified for future expansion or replacement of depleted deposits.

It is expected that future discovery of additional large, low-grade deposits of gold ore, and improvements in processing will lead to more increases in gold production.

Arizona produces about $4.0 billion in metals and only about $0.3 billion in industrial materials. However common industrial minerals, such as sand and gravel, are essential for the support of population growth. Arizona is a rapidly growing state, with a population now passing the 4.5 million mark. The growing population of Arizona will require a significant expansion in the minerals industries that depend upon growth rate. Arizona has the potential for development of additional deposits through new discoveries. Many industrial mineral products are relatively cheap, dollarwise, but they have high utilitarian value.

In order to provide these materials there will be an ongoing need to acquire information about where important reserves of these minerals occur, their production possibilities, and their markets. It should be the task of natural-resource-related agencies, both State and Federal, to gather and disseminate the appropriate information. Resource discovery and development opportunities must be identified if the State and Nation are to be continuously supplied with the mineral-rock ingredients that form the foundation of modern civilization.

Expanding the use of Arizona industrial minerals is based on three factors: (1) the marketplace, (2) the specifications of the materials, and (3) the political and environmental scene. Most performance or high-value added minerals are relatively insensitive to transportation costs.

Arizona is adjacent to California, a State that has the sixth largest economy in the world and a state that has chosen the most stringent environmental laws of any State in the West. This location may mean that Arizona will be a prime area for developing the industrial materials which now cannot be produced in California. California's extreme public concern about environmental clean up and extreme definition of hazardous-waste also will create markets for those minerals used in waste treatment. Many clays and zeolite minerals are of particular interest for waste disposal and treatment.

Although copper will long dominate Arizona's mining industry there is expected to be an expanding place for small-volume, high-value-added, specialized, high technology industrial-mineral resources. Arizona is known to have some of these resources, but the availability of many more remains to be determined. The minerals industry in Arizona must be proactive, and support research and development of the resource and marketing opportunities, in order to take advantage of a non-static market.

Energy resources are somewhat limited, but there is potential for additional development and marketing of coal, uranium, petroleum resources, and geothermal energy. All of the current coal production from Arizona is dedicated to existing power plants, however there are adequate reserves to supply new markets. Numerous uranium deposits have been located, and Arizona could again have significant production if the demand and price increases.

A large carbon dioxide/helium gas field has been discovered recently in east-central Arizona, and the extent of the resource is currently being determined by development drilling. This is in an area of known geothermal energy, which could also serve as an energy source for appropriate industrial development.

Two state agencies are charged by statute to promote and assist in the development of the State's mineral and energy resources. The services provided by these agencies enhance the opportunities for individuals and/or organizations to participate in the development of mineral and energy resources of Arizona.

The Arizona Department of Mines and Mineral Resources (ADMMR) is a State agency charged by statute to promote the development of the State's mineral resources. It is a proactive agency. The agency collects, analyses, and disseminates technical information to encourage the development of Arizona's mineral resources and educate the public about mineral resources and their place in society. The ADMMR staff includes technical expertise in many phases of mineral resource development including ore deposits, mineral economics, marketing, mineral processing, finance, etc.

The agency maintains a database of over 10,000 mineral resource occurrences in the state. The database indexes hard copy mine data files and thousands of published documents. on current and past producing mines and prospects. The agency publishes reports, directories, circulars, and a quarterly newsletter to further disseminate information.

The AGS (Arizona Geological Survey) is a State agency that among other duties collects, analyses, and disseminates data on the geologic setting of Arizona which includes the relationships between the State's geology and mineral resource deposits. The agency also publishes bulletins, maps, reports, directories, circulars, and a quarterly newsletter to further disseminate information. Of particular interest to the mineral resource development community is the AGS making available reprints of the geology and mineral resources chapters of a bulletin published by its predecessor, the Arizona Bureau of Mines. The bulletin is *Mineral and Water Resources of Arizona*, Bulletin 180, originally published in 1969. It contains individual chapters on nearly every mineral commodity known to occur in Arizona. Although the economic and industry data is 30 years old, the deposit geology and state deposit location has changed very little.

3.4 Challenges to the Industry

The main challenges to mineral and mining related economic development in Arizona that have been identified are to:

- coordinate efforts to reduce environmental conflicts between industry and government
- continue the development of environmentally acceptable mining practices
- strive for fuller and more efficient utilization of the skilled labor force that is available in the minerals and mining industry in Arizona
- work to influence governmental-policy to recognize the necessity of an active sand and gravel industry, and the need to locate and assure the availability of these resources near their place of consumption
- work to limit the present trend toward withdrawing access to public and private lands and restricting the development of natural resources. Examples of the problems that are created by this trend are:

  1. Expanding land use restrictions greatly increases the possibility of inadvertently overlooking important and valuable resources. Mineral deposits can only be mined where they occur. They can only be found where we can search. The industry will only search where some reward for discovery can be expected.
  2. Pressures are mounting to restrict the locations of sand and gravel mining operations, thus increasing the cost and reducing the availability of this essential construction material. Construction on flood plains, building of large bridges, and channel stabilization projects combine to restrict the locations of sand and gravel mining.
  3. Many industrial minerals are large tonnage and low unit value commodities. They must be produced near the market to control cost. That market is most commonly the urban construction industry, including business and housing developments with large populations. Growth and maintenance in urban areas require consumption of large amounts of mineral resources. Most growth is associated with urban regions where there is active competition for land use in and peripheral to the urban regions. In turn these developments commonly result in heavy public pressure to stop mining and expand the urban development and quality of life areas such as parks and wildernesses that prevent use of industrial mineral deposits. Responsible zoning must include provisions for protecting mineral resources for the future.

4. STRATEGIC RECOMMENDATIONS TO PROMOTE MINING IN THE ARIZONA/SONORA MINING CLUSTER

This report describes the current status of the minerals and energy industry in Arizona. It has been coordinated with a parallel investigation of the minerals industry in Sonora, which will be published as a separate report. Both studies have incorporated input from the key players in the industry of both states, including: mining companies, suppliers of equipment and services, natural gas and electricity suppliers, governmental agencies, and educational institutions. Both of these reports will make some preliminary recommendations for the development of the industry, but more importantly, they will provide the basis for further discussion and recommendations by the users of the reports.

Preliminary discussions with Guillermo Salas, Victor Calles and Hector Hinjosa at the Arizona /Mexico Commission meeting in Hermosillo on 5/17/97 resulted in the following recommendations to facilitate the development of the minerals industry in the Arizona-Sonora region:

- need to reduce transportation delays at the border that affect the cost and efficiency of mineral commodity transport
- need for increased communication between key participants in the minerals and mining industry of Arizona and Sonora
- need for increased communication between educational systems in Arizona and Sonora, particularly in the areas of technical expertise and scientific research
- joint state funding for mineral development projects
- regular periodic meetings between the Arizona Mining Association and the Sonora Mining Association
- joint planning for environmental issues by a bi-state council
- joint Arizona/Sonora attendance at mining conferences
- joint effort for marketing of mineral resources, both within and outside of, the Arizona/Sonora region
- cooperative mineral related research projects in universities of Arizona/Sonora
- export coal to Sonora
- improve the rail connection between Nogales and the Port of Guaymas, and restore the rail connection between Douglas and Cananea.

We recommend that the Arizona/Mexico Commission refer this report, and the Sonoran counterpart, to its Mining Cluster Committee for review, with the objective of formulating recommendations to the governments of both states for the development of formal policies that will facilitate the mutually beneficial development of the mineral and energy industry.

The authors suggest that such a review process include some fundamental questions that must be addressed by the governments and people of Arizona and Sonora in order to develop a uniform mineral resource development policy in the two states:

- Does each state consider a mineral resource operation in either state of equal importance to both states?
- Does Arizona consider a mineral resource operation in Sonora preferable to one in an adjacent state in the United States?
- Does Sonora consider a mineral resource operation in Arizona preferable to one in an adjacent state in Mexico?
- Will there be any public sector sharing of the proceeds (primarily taxes) from an operation in one state with the governments in another state or nation in order to facilitate greater efficiency of the development and marketing of mineral resources?
- Will each state adopt the same environmental regulations and permitting procedures?
- Will the governments of Sonora and Mexico adopt the same level of citizen intervention in issues of common concern across the border?

- Will the citizens and courts of each state have equal authority over mineral resource operations in either state?

It is further recommended that each of the reports that have been developed for the minerals and energy industries in Arizona and Sonora, be published by the appropriate state agencies, and be periodically updated in their entirety. The information that is contained in them is fundamental to the success of the industry, but it must be kept current and readily available for maximum benefit to the public. The Arizona Report will be maintained as an Open-File Report by the Arizona Department of Mines and Mineral Resources.

5. APPENDICES

5.1 List of Figures and Tables

5.2 Selected References

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5.4 Economic Development Questionnaire

Strategic Economic Development Vision for the Arizona-Sonora Region
Component 4.2: Mining and Minerals Cluster

1. How would you rate the prospects for growth in Arizona's minerals, mining and energy resources industry over the next five years?

Poor   Fair 1   Good 1   Very Good   Excellent

2. What major factors led you to describe the prospects for growth in this manner?

Natural resource base in Arizona.
Fairly positive mining attitude,
Very good infrastructure base.
Greater difficulty in mine permitting and development resulting from more stringent state and federal laws.

3. How adequate do you feel Arizona's transportation infrastructure (highways, rail lines, air service, etc.) serves the needs of the minerals and energy resources companies? Would you recommend any particular changes (if so, what)?

Interstate highway system is fair to good in east-west direction; almost nonexistant in north-south direction.
Secondary roads are typical of rural highways in mine areas.
Some short spur railroads are being abandoned for lack of sufficient use.
Fair.

4. What kinds of businesses providing support services (transportation, maintenance, finance, exploration, engineering, etc.) to minerals and energy resources companies do you feel offer good potential for growth in Arizona?

Smelting and refining.
Heavy equipment sales and maintenance.
Transportation, engineering

5. What steps do you feel should be taken (by mining firms, other firms in the industry, government agencies, or others) to improve the potential for growth in Arizona's minerals and energy resources industry:

Speed up the permitting process.
Quit misusing environmental protection laws as inti-mining laws.
Work to address ever-increasing regulatory laws

6. Please share any additional comments you might have about the minerals and energy resources industry in Arizona.

Arizona is the number one metal/nonmetal mining state by virtue of her copper deposits, other minerals and a long history of being a pro-mining state.

5.5 Table 15. Ground-Water Areas

Abbreviations of the 68 ground-water areas in Arizona (refer to figure 19)

AGF	Agua Fria basin	LSP	Lower San Pedro basin
ALT	Altar Valley	LSC	Lower Santa Cruz basin
ARA	Aravaipa Valley	LVR	Lower Verde River
AVR	Avra Valley	MMU	McMullen Valley
BIC	Big Chino Valley	MNV	Monument Valley
BIS	Big Sandy Valley	N-C	New River-Cave Creek
BWM	Bill Williams	PSC	Peach Springs Canyon
BLM	Black Mesa	PRZ	Puerco-Zuni
BRB	Black River basin	RAN	Ranegras Plain
BOD	Bodaway Mesa	SAC	Sacramento Valley
BUT	Butler Valley	SAF	Safford basin
CDI	Canyon Diablo	SRV	Salt River Valley
CHV	Chevelon	SBV	San Bernardino Valley
CHN	Chinle	SFP	San Francisco Peaks
COP	Coconino Plateau	SFR	San Francisco River basin
CHI	Colorado River, Hoover Dam to Imperial Dam	SSI	San Simon basin
CON	Concho	SSW	San Simon Wash
DOU	Douglas basin	SHV	Shivwits
DUN	Duncan basin	SNO	Snowflake
GIL	Gila Bend basin	STJ	St. Johns
GRD	Gila River from Painted Rock Dam to Texas Hill	TON	Tonto basin
GSK	Gila River from head of San Carlos Reservoir to Kelvin	TUB	Tuba City
GTD	Gila River from Texas Hill to Dome	USR	Upper Salt River basin
GWA	Grand Wash	USP	Upper San Pedro basin
HAR	Harquahala Plains	USC	Upper Santa Cruz basin
HAS	Hassayampa basin	VER	Upper Verde River
HOL	Holbrook	VRG	Virgin River
HOP	Hopi	WAT	Waterman Wash
HOU	House Rock	WMD	Western Mexican drainage
HUA	Hualapai Valley	WHM	White Mountains
KAI	Kaibito	WRB	White River basin
KAN	Kanab	WIL	Willcox basin
LIC	Little Chino Valley	WMN	Williamson Valley
LHA	Lower Hassayampa	YUM	Yuma

5.6 Table 18. Permits Required

Table 18: Permits Required in Arizona Before Initiation of Mining or Milling.

Requirement	Granting Agency or Agency to Contact
State:	
Starting business in Arizona	Arizona Corporation Commission, 1200 W. Washington St. Phoenix, AZ 85007 602-542-3135
License to do business	Arizona Department of Revenue,1600 W. Monroe, Phoenix, AZ 85007 602-542-4656
Permit to construct campsite	Arizona Department of Environmental Quality, 3033 N. Central Phoenix, AZ 85012 602-542-1000
Air quality permit to construct	Arizona Department of Environmental Quality, Air Quality, 3033 N. Central Phoenix, AZ 85012 602-207-2308
Air quality permit to operate	Do.
Arizona water pollution control permit	Arizona Department of Environmental Quality, Water Quality, 3033 N. Central Phoenix, AZ 85012 602-207-2305
Authorization for disposal of solid wastes	Do.
Hazardous waste	Arizona Department of Environmental Quality, Waste Programs, 3033 N. Central Phoenix, AZ 85012, 602-207-2381
Permits for uranium mills	Arizona Radiation Regulatory Agency, 4814 S. 40th St., Phoenix, AZ 85040, 602-255-4845
Endangered wildlife	Arizona Game and Fish Department, 2222 W. Greenway Road, Phoenix, AZ 85014 602-942-3000
Endangered plants	Arizona Department of Agriculture, 1688 W. Adams, Phoenix, AZ 85007, 602-542-4373
Prospecting permits and mineral leases on state lands	Arizona State Land Department, Mineral Division, 1616 W. Adams, Phoenix, AZ 85007 602-542-4628

Requirement	Granting Agency or Agency to Contact
Drilling permits for oil, gas or geothermal	Arizona Oil & Gas Conservation Commission Arizona Geological Survey 416 W. Congress, Suite 100 Tucson, AZ 85701, 520-770-3500
Permit to appropriate the public waters or drill into ground water	Arizona Department of Water Resources, 500 N. Third Street, Phoenix, AZ 85007 602-417-2470
Permit to construct tailings dam	Do.
Commencement or suspension of an operation	Arizona State Mine Inspector, 1700 W. Washington, Phoenix, AZ 85007-2859 602-542-5971
Permits for mining reclamation on 5 or more acres of private land	Do.
Explosives Regulation Compliance	Do.
Labor laws	Industrial Commission of Arizona, 800 W. Washington, Phoenix, AZ 85007 602-542-4515
State Clearinghouse	Arizona Department of Commerce, 3800 N. Central Avenue, Phoenix, AZ 85007 602-280-1315
Federal:	
Use of BLM-administered land	Bureau of Land Management, State Office, 222 N. Central Avenue, Phoenix, AZ 85004 602-650-0522
BLM mining plan of operation	Do.
Use of BLM-administered land under wilderness review	Do.
Temporary use of BLM-administered land	Do.
Right-of-way for transmission corridor	Do.
Road access (right-of-way)	Do.
Prevention of significant deterioration	Environmental Protection Agency, Region 9-Public Information, 75 Hawthorne Street, San Francisco, CA 94105 415-744-1500

Requirement	Granting Agency or Agency to Contact
Mining in National Forest	U.S. Forest Service, S.W. Regional Office, Federal Building 517 Gold Avenue, SW, Albuquerque, NM 87102 505-842-3721
National Forest mining plan of operation	Appropriate District Ranger's Office
Flora and fauna	U.S. Forest Service, S.W. Regional Office, Federal Building 517 Gold Avenue, SW, Albuquerque, NM 87102 505-842-3292
Notification of commencement or suspension of an operation	U.S. Department of Labor, Mine Safety & Health Administration, 60 E. Main Street, Mesa, AZ 85201 602-649-5452
Patenting mining claims	Bureau of Land Management, State Office 222 N. Central Avenue, Phoenix, AZ 85004 602-650-0522
Labor laws	U.S. Department of Labor, Wage and Hour Division, 3221 N. 16th St., Phoenix, AZ 85016 602-640-2990
Purchase, transport, or storage of explosives	Bureau of Alcohol, Tobacco, and Firearms, 3003 N. Central Avenue, Phoenix, AZ 85012 602-640-2938

City and County:

General plan, building permit, special-use permit, Contact respective city or county government zoning change, business license, taxation affected by a proposed operation for information on what permits may be required and what taxes may be imposed.