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Figure 1. *Typical heap-leaching operation for recovery of gold from crushed ore using dilute cyanide solutions. Heap leaching of crushed ore usually involves 30- to 60-day leach cycles and yields gold recoveries of 60 to 90 percent.*

Gold and Silver Extraction: the Application of Heap-Leaching Cyanidation

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In the last decade, heap leaching has established itself as an efficient method of treating oxidized gold and silver ores. Also known as solution mining, heap leaching involves the extraction of soluble metals or salts from an ore by distributing solutions over an open ore heap piled on an impervious pad. For example, gold and silver can be separated from their ores by the application of a weak solution of cyanide and lime or caustic soda. Figure 1 shows a typical precious-metal heap-leaching operation. This processing technique is an extremely efficient way of extracting metals from small, shallow deposits, but is especially attractive for treating large, low-grade, disseminated deposits. Compared with conventional milling (crushing, grinding, and agitation leaching), recovery of gold and silver by heap leaching offers several advantages: lower capital and operating costs, shorter start-up times, and fewer environmental risks. These advantages, however, are sometimes offset by lower metal extractions.

The first commercial application of heap leaching, by the Carlin Gold Mining Company in northern Nevada, occurred in the late 1960's. Since that time, advances in solution-mining technology and the continued high price of gold have sustained a strong interest in heap leaching. About 25 percent of the new gold and 10 percent of the new silver currently produced in the United States are obtained through heap leaching. Nevada is clearly the leader in precious-metal heap leaching with about 50 stable operations and another 50 that operate depending on the price of gold and silver (Carrillo, 1985). Two examples of large-scale heap-leaching operations, both of which are in Nevada, are the Smoky Valley operation, which mines 11,000 metric tons of ore per day (mtpd) and produces about 3,700 kilograms (kg) of gold and 2,200 kg of silver annually; and the Candelaria plant, which is primarily a silver mine that processes 9,400 mtpd and produces about 90,000 kg of silver annually.

The locations of the major western U.S. gold-and-silver heap-leaching operations are shown in Figure 2. The newest of these are the Picacho mine of Chemgold, Inc. and the Mesquite mine of Goldfields Mining Corporation. Both plants are in California, approximately 25 miles outside Yuma, Arizona.

The purpose of this article is to review important factors related to cyanidation and heap-leaching practice. The article briefly summarizes the history of cyanidation and discusses the operational features of heap leaching using dilute cyanide solutions.

HISTORY OF CYANIDATION

The historical fabric of cyanidation is very colorful: it is woven with many threads of controversy and disagreement. Numerous patent disputes have been documented in technical journals. Cyanidation technology appears to be evolutionary, with advances progressing from prior work. Seven such advances provide a historical summary of cyanide leaching: early cyanide chemistry, the cyanide process, Merrill-Crowe (zinc-dust precipitation), carbon adsorption, carbon-in-pulp (CIP), Zadra (stripping and electrowinning), and heap leaching.

Early Cyanide Chemistry

As early as 1793, aqueous solutions of potassium cyanide were known to exhibit a solvent action on gold (Habashi, 1970). In 1843 Bagration produced the first scientific treatise on the subject. During his investigation, he observed the following:

(1) Dissolution is more rapid when the gold is divided into very small particles.
(2) Dissolution increases with heating.
(3) Gold dissolved in cyanide will precipitate on metallic surfaces in the absence of an applied potential.
(4) The presence of air decreases the time necessary for dissolution (McCann, 1912).

Figure 2. Major western U.S. gold-and-silver heap-leaching operations.

In 1844 Elsner discovered that gold dissolution in cyanide was due to the action of dissolved oxygen and not the decomposition of water, as previously believed (Wilson, 1896). The "Elsner Equation," stated in its original form, is as follows:

$$2Au + 4KCy + O + H_2O = 2KAuCy_2 + 2KOH$$

This early formula established the overall stoichiometry of gold cyanidation and recognized the presence of a gold-cyanide complex.

Bodlaender (1896) rapidly dissolved gold in an aerated cyanide solution and found that significant quantities of hydrogen peroxide (H_2O_2) were produced during the reaction. The formation of hydrogen peroxide as an intermediate product suggested a two-step reaction sequence:

$$2Au + 4CN^- + O_2 + 2H_2O = 2Au(CN)_2^- + 2OH^- + H_2O_2$$

$$2Au + 4CN^- + H_2O_2 = 2Au(CN)_2^- + 2OH^-$$

The sum of these reactions is equivalent to the overall reaction as proposed by Elsner.

Barsky and others (1934) provided some of the first fundamental thermodynamic and kinetic data for the cyanidation of gold and silver. Their work confirmed the accuracy of the equations offered by Elsner and Bodlaender. They determined the values for the free energy of formation of the aurocyanide ion, $Au(CN)_2^-$ and the argentocyanide ion, $Ag(CN)_2^-$. They also investigated the effects of cyanide concentration and pH on the rate of gold and silver dissolution. The maximum rate of gold dissolution was obtained with a 1×10^{-2} M NaCN solution. The rate of gold dissolution was found to be insensitive to pH between about pH 10.5 and pH 12.5.

Boonstra (1943) was reportedly the first to recognize the similarity between gold dissolution in cyanide and metal corrosion processes. This observation established the importance of the electrochemical dissolution mechanism involving distinct anodic and cathodic steps.

The Cyanide Process

It was not until the pioneering work of MacArthur and the Forrest brothers (1887, 1889) that cyanidation became a commercial process. Their patents of 1887 and 1889 were milestones in the metallurgy of gold because they recognized a chemical process for treating gold ores. Their contributions included two important advancements: (1) they used dilute cyanide solutions to produce a selective action on gold instead of using stronger lixiviants, which have a tendency to dissolve impurities; and (2) they proposed a method for recovering gold from cyanide solution by precipitation with zinc shavings.

Although cyanide had been used as early as 1870 to treat gold ores in the United States, the MacArthur-Forrest process was not officially introduced to domestic mining operations until 1892. The first cyanide gold mill in the United States was reportedly established at the Vulture mine near Wickenburg, Arizona (Young, 1967; Figure 3). Haynes (1892) reported the successful treatment of tailings and rebellious ores using cyanide by the Yavapai Gold and Silver Extraction Company in Prescott, Arizona. At about the same time, several plants near Tombstone, Arizona were using cyanide leaching to recover silver. By 1896, there were seven major cyanide plants in the United States, the largest of which was the Mercur mill in Utah. This plant had a capacity of 183 mtpd and achieved gold extractions ranging from 80 to 87 percent (Packard, 1896).

Merrill-Crowe

Early cyanide practice involved gold precipitation onto zinc shavings. Cementation of gold onto a metallic zinc surface is represented by the following reaction (Wilson, 1896):

$$2Au(CN)_2^- + Zn^0 = 2Au^0 + Zn(CN)_4^{2-}$$

The electrochemical cementation reaction shown above is relatively simple, involving the discharge of a noble metal ion (the gold-cyanide complex) at the expense of a more reactive metal (the zinc dust).

Zinc-dust precipitation, known as the Merrill system, was introduced in the United States in 1897 and is the basis of modern practice (Julian and others, 1921). Oxygen necessary for the oxidation of gold during cyanide leaching is detrimental to efficient zinc-dust precipitation. Merrill recognized this and designed a process to avoid air contact with the zinc during precipitation. Crowe (1919) improved the process by removing dissolved oxygen from the gold-bearing cyanide solution prior to addition of the precipitating agent. This approach improved the efficiency of gold precipitation and decreased zinc consumption. The Merrill-Crowe process consisting of solution clarification, deaeration, zinc-dust precipitation, and precipitate filtration continues to be an important precious-metal recovery method used by many modern plants.

Carbon Adsorption

Gross and Scott (1927) undertook the first rigorous study of the adsorption and desorption of gold and silver cyanide on carbon. They reviewed the early history of carbon adsorption, noting that charcoal

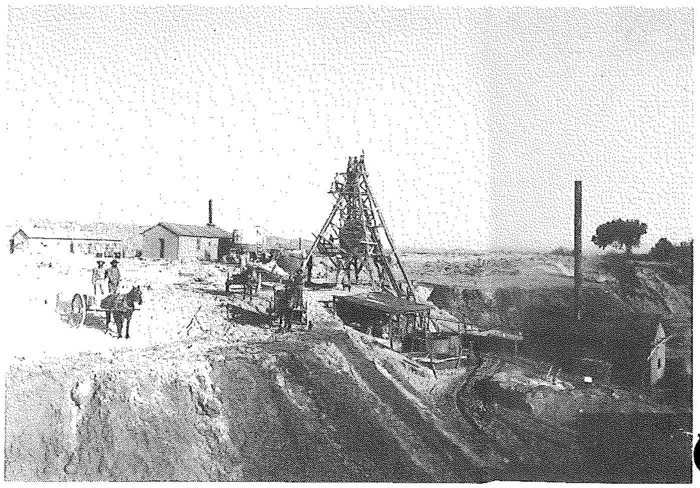

Figure 3. Reportedly the first U.S. cyanide plant, as seen in the early 1890's, at the Vulture mine, Wickenburg, Arizona. Photo courtesy of the Arizona Historical Society.

was first used in chlorination plants to recover gold. As cyanidation became more popular than chlorination, it was only natural that charcoal would be used to recover precious metals from cyanide solution. Charcoal was used at a number of locations by the turn of the century. As improvements in zinc-dust precipitation emerged, however, interest in the use of charcoal declined.

Early investigators believed that charcoal precipitated gold from solution (Green, 1913; Feldtman, 1915; Edmands, 1918). Actually, a reduction mechanism by which gold is deposited in the metallic state on the carbon surface does not explain the experimental evidence. Unfortunately, complete understanding of the adsorption mechanism is still lacking. High surface area (active sites) and pore diffusion are important aspects of the adsorption and desorption processes.

Carbon-In-Pulp

A major contribution to carbon-in-pulp (CIP) technology was made during the 1930's by Chapman (1939) of the Department of Metallurgy, University of Arizona. Chapman and his graduate students investigated dissolution of gold by cyanide and adsorption of dissolved gold onto activated charcoal in ore pulps. The general process used flotation to separate and recover the gold-bearing charcoal from the leached tailings. The flotation of powdered carbon proved to be highly selective, producing a charcoal concentrate that could be either smelted directly or ashed to recover the gold. A portion of the early research at the University of Arizona was devoted to the activation of carbon prior to adsorption of gold from cyanide solution (Rabb, 1939).

The lack of a convenient method for stripping adsorbed gold and silver from loaded carbon handicapped the development of CIP practice. Without stripping, it was impossible to recycle carbon in a closed-circuit system (adsorption, stripping, and reactivation). These techniques were pioneered by the U.S. Bureau of Mines (Zadra and others, 1952; Hussey and others, 1979) and have been improved and engineered for large-scale operations by MINTEK in South Africa (Laxen and others, 1979). Advantages of the CIP process include the ability to handle ores with poor settling and filtration characteristics by eliminating the need for costly liquid-solid separation systems; efficiency in the recovery of gold from dilute process streams; high capacities; and relatively simple design and operation.

Zadra

The next major contribution to the cyanide process was the recovery of gold by activated carbon, stripping the carbon with hot caustic cyanide solution, and electrowinning the gold and silver onto stainless-steel wool. This process was developed in the early 1950's by Zadra and others (1952). Stripping times ranged from 24 to 48 hours, as originally practiced. These times were quite long, consuming more chemicals and requiring more carbon in the circuit. In recent years, the U.S. Bureau of Mines and the Anglo-American Research Laboratory have developed pressure stripping of gold from carbon, which requires only 6 to 8 hours. Other improvements in the Zadra technique include the design of advanced electrowinning cells.

Heap Leaching

During the last decade, heap leaching of gold and silver ores has evolved into an extremely efficient method of treating small deposits once considered uneconomic; heap leaching as a mineral technology, however, has been practiced for centuries. As early as the mid-16th century, some mines in Hungary were recycling copper-bearing solution through waste heaps. By the 18th century, large-scale heap leaching was practiced by the Rio Tinto Company in Spain to recover copper from cupreous pyrites. By 1900 these leaching operations were employing such techniques as leach/rest cycles to maximize copper recovery (Taylor and Whelan, 1942).

As mentioned earlier, heap leaching of precious metals was commercially developed in the late 1960's. Improvements in heap-leaching performance and efficiency have continued to emerge in the areas of feed preparation (agglomeration), heap design and construction, solution distribution, and metal recovery.

GOLD AND SILVER HEAP LEACHING

To be amenable to heap leaching, a gold-bearing rock should be competent, porous, and relatively cyanicide free and should contain clean, fine-grained gold particles (Potter and Salisbury, 1974). It is also essential that good aeration and uniform solution contact be maintained. These same factors influence the heap leaching of silver ores.

Since precious-metal ore bodies vary significantly in geology, mineralogy, and metallurgy, it is difficult to generalize about flow-sheet design. The layout of a typical heap-leaching operation is depicted in Figure 4. Like other solution-mining methods, heap leaching is sensitive to site-specific factors. These factors include topography and space, climatic conditions, availability of pad construction materials (i.e., clays), environmental restrictions, and water. Because of its intrinsic simplicity and flexibility, heap leaching is ideally suited to deal with these factors.

Leaching Methods

There are basically two variations of the heap-leaching method that are used on a commercial scale. The first approach is based on the leaching of run-of-mine ore. Long leaching cycles and low-grade ores are usually associated with this variation. The second approach, which involves the leaching of crushed ore, normally requires shorter leaching cycles. High-grade deposits generally justify the increased cost of crushing and are often expressly treated to maximize gold and silver recovery by increasing the exposure of gold and silver to the leaching solution.

Heap-leaching operations that use crushing typically leach ore crushed to 20 millimeters (mm), and sometimes as fine as 6 mm. The leach cycle for this type of operation usually takes a few weeks to several months. Most ores that do not contain excessive amounts of clay will exhibit good permeability down to ore sizes of approximately 10 mm. Feeds below this size or those that contain high proportions of clay can be treated by agglomerating techniques that stabilize fine clay particles. Run-of-mine feed sizes are those produced by the mining operation (blasting or ripping) and may typically contain 150-mm rocks, but may also include some boulders. The leach cycle for run-of-mine uncrushed ore frequently takes months or years.

The cycle commences when ore is delivered to specially prepared, impermeable drainage pads. The leach pad serves two important functions: to protect the environment and to collect and eliminate loss

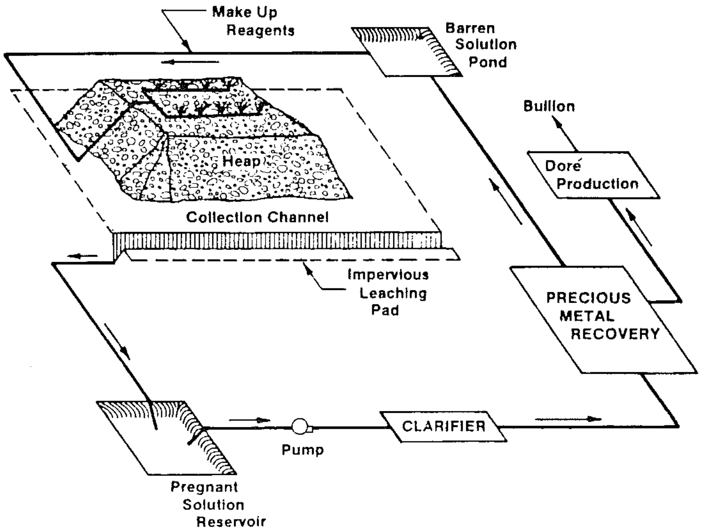

Figure 4. *General layout of a heap-leaching operation. In addition to the main leaching circuit, which is described in the text, the figure shows the ancillary operations of doré production and reagent makeup. Doré production involves the smelting and refining of steel wool and zinc precipitates to produce bullion. Reagent makeup relates to the addition of chemicals to control cyanide concentration, pH, and scaling problems.*

of pregnant solution, the solution that is saturated with the dissolved metal. Several types of materials are used to construct leach pads, including both natural and manmade materials such as synthetic membranes and geotextile fabrics. Van Zyl (1984) has listed the criteria that pad materials must satisfy: pad-permeability requirements (environmental restrictions), cost constraints, pad-construction considerations, and heap-construction factors. Single-use pads are often constructed from clay or plastic liners, whereas multiuse pads, which are used for more than one leaching cycle, are best made from asphalt or reinforced concrete. In all cases, pad construction must entail careful preparation of the base and subbase layers. In single-use pads, it is common to cover the pad area with a network of perforated pipes to aid drainage and to collect pregnant leach solution. These pipes are normally protected by a layer of coarse gravel.

There are several techniques for placing ore on the leaching pad. Chamberlin (1981) discussed heap-construction methods to maximize permeability and leaching efficiency. Some techniques used to build heaps include haulage trucks and dozers to spread the ore, front-end loaders, conveyor-stackers, and movable bridge-conveyor distribution units.

Solution distribution is of special importance in every heap-leaching operation. Leach solutions can be applied to the surface of heaps by a variety of methods such as ponding/flooding, trickle systems, multiple low-pressure sprinklers, single high-pressure sprinklers, and subsurface injection.The most popular systems used in gold-and-silver heap leaching are the impulse sprinkler and the wobbler-type sprinkler. These types of sprays provide uniform solution coverage of the heap surface. Solution application rate is also a critical factor in heap leaching. For typical heap-leaching operations, the maximum effective application rate that can be used without causing channeling and short circuiting of solution is about 4 cm/hr (1 gal/ft^2/hr). Higher application rates restrict the movement of oxygen through the heap, dilute the pregnant-solution grade, and increase pumping costs. In general, solution-application rates for heap leaching range between 0.8 and 1.2 cm/hr (0.2 and 0.3 gal/ft^2/hr).

Solutions migrate downward through the heap under free-flow conditions (gravity). The percolating solutions dissolve gold and silver as they contact the ore minerals. Gold and silver occur mainly along fracture surfaces in oxidized ores. Values exposed by crushing are readily accessible to the lixiviant and are recovered by simple surface flushing. Leaching solution can also penetrate particle fractures by capillary action; in this domain, long-range diffusion must occur. The pregnant leach solution is collected on the pad and drains to a collection system, which delivers it to a pregnant-solution reservoir. From this reservoir, the solution is pumped to a precious-metal recovery circuit.

Gold and Silver Recovery

There are two primary commercial methods of recovering gold and silver from alkaline cyanide heap-leach solutions: zinc-dust (Merrill-Crowe) precipitation and adsorption by activated carbon. The choice between carbon adsorption and zinc precipitation depends on several factors including solution concentration, solution volume, and solution clarity. Potter (1981) concluded that large volumes of low-grade solutions, mainly containing gold, are most economically treated by carbon adsorption, whereas small flows of relatively rich solutions or solutions containing large quantities of silver should be treated by zinc-dust precipitation. The feed solutions to a carbon-adsorption circuit do not have to be clarified. For optimal efficiency of zinc precipitations, however, it is essential that feed solutions be clarified.

Merrill-Crowe zinc-dust precipitation, as noted earlier, is a very mature and well-established technology. The basic process consists of solution clarification, deaeration, precious-metal precipitation, and precipitate filtration. As stated earlier, cementation of gold onto a metallic zinc surface is represented by the following reaction:

$$2Au(CN)_2^- + Zn^0 = 2Au^0 + Zn(CN)_4^{2-}$$

A similar reaction can be written to express the precipitation of silver. Based on the stoichiometry of this reaction, the theoretical zinc requirement for gold precipitation is equivalent to 0.17 grams of zinc per gram of precipitated gold. Actual zinc consumption in practice is much higher than this, ranging from 10 to 30 grams of zinc per gram of precipitated gold for dilute heap-leach solutions. The difference between actual and theoretical ratios is attributed to the presence of impurities and dissolved oxygen.

Zinc precipitation is the preferred process for silver ores because of the high silver concentrations and poor silver-loading characteristics of carbon. Zinc-dust precipitation is especially attractive for small volumes of solution because they can be processed in modular Merrill-Crowe units.

A continuous multistage carbon-adsorption circuit is an efficient way of recovering gold and silver from high-volume, low-grade, heap-leach solutions. The standard design involves pumping pregnant leach solution countercurrently to activated carbon in a series of five or more columns. Carbon in the size range of 16 x 30 mesh is fluidized by the upward flow of solution and is advanced through the circuit to achieve loading in the range of 3,430 to 6,860 grams per metric ton (100 to 200 ounces per short ton). Carbon loadings in excess of this range are generally avoided because of gold losses to the barren solution. Loadings lower than these values would require advancing the carbon more frequently. This additional handling could result in a higher rate of carbon attrition and an attendant gold loss with fine carbon.

Loaded carbon is advanced from the first-stage adsorption circuit to stripping. The popular stripping methods involve variations of hot, atmospheric sodium hydroxide (NaOH) and sodium cyanide (NaCN), pressurized NaOH and NaCN, and alcohol stripping. Gold and silver are usually recovered from the rich strip solution by electrowinning onto steel-wool cathodes.

In time, surface sites on carbon are contaminated with organic materials and other impurities, and pores are blocked by precipitated salts (calcium carbonate). It is necessary to periodically reactivate the carbon to remove these contaminants and to restore the intrinsic chemical activity of the carbon. Reactivation requires a series of chemical and thermal treatments: acid washing to remove surface deposits, and calcining to 750° C by indirect means to activate the surface site. After screening to remove fines, the regenerated carbon is returned to the final stage of the adsorption circuit.

SUMMARY

The extractive metallurgy of gold and silver from ores is primarily based on cyanidation practice. Cyanidation has been practiced commercially for a century. The chemistry of leaching gold and silver in cyanide solutions is elegant and the process of metal recovery by this approach is very efficient. Unlike stronger lixiviants, dilute cyanide solutions exhibit a high degree of selectivity in the dissolution of gold and silver from their ores. Another attractive feature of cyanide is that gold and silver can be conveniently recovered from solution by several methods.

Heap leaching using the principles of cyanidation has recently developed into an important alternative for treating gold and silver ores. Compared to other techniques, heap leaching is a simple process. Though it is especially appropriate for treating large, low-grade, disseminated deposits, heap leaching is also an expedient way of extracting precious-metal values from small, shallow deposits.

New leaching technologies are being developed in the United States and abroad. There is considerable interest in the development of ion-exchange resins for the recovery of gold from cyanide solutions. Resins have the potential of being more selective than carbon, and the design of resin-in-pulp circuits could eliminate such processes as pressure stripping and carbon reactivation. Other emerging technologies include solvent extraction and direct electrowinning from dilute solutions. Alternative lixiviants for extracting gold and silver are also being developed; for example, thiourea and thiosulfate have been examined for various gold- and silver-bearing materials.

Heap-leaching technology is continuing to advance. In-situ leaching, however, is another option for extracting gold and silver from their ores. The possibility of in-situ leaching opens up an area of technology with many challenges as well as the potential for considerable rewards.

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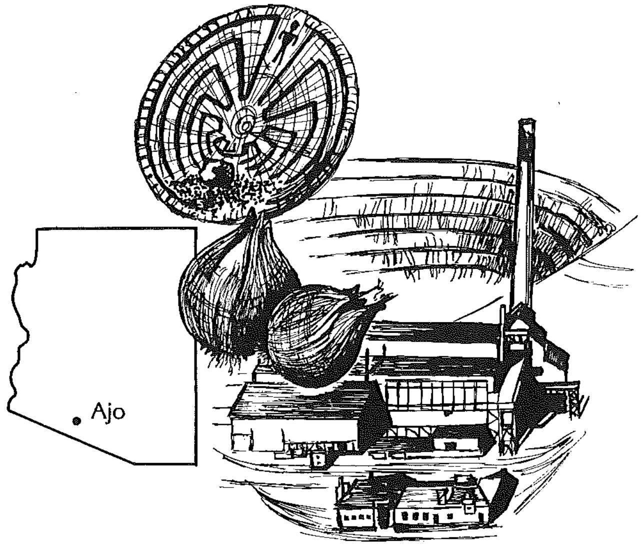
GEOLOGIC PLACE NAMES: AJO



Ajo, Pima County, Arizona. Population 5,650. Pronounced ä´hō. Derived from the Papago word *au'auho*, which means "paint."

A similarity between the sound of the Papago word for this locality and the Spanish word *ajo* for many years led to misapprehension concerning the origin of the name of present-day Ajo. The Papago Indians used *au'auho* in connection with the mines at Ajo because the ores were a source of red paint which the Papagos used to decorate themselves. This was so noted by one of the earliest American travelers in the region. Nevertheless, the fact that the Mexican miners pronounced the word without the double pronunciation of the *au* of the Papago resulted in a word that sounded much like *ajo*. This, added to the fact that the Ajo lily (the root of which looks and tastes much like a spring onion) grows abundantly in this area, led to the belief that the locality was named Ajo because of the wild lilies.

The first American citizen to notice the mining possibilities in the region was Capt. Peter R. Brady, who was with the surveying party for the Thirty-Second Parallel railroad in 1853. When the party broke up in San Francisco, Brady was influential in organizing a group of men to explore mining possibilities at Ajo. This group soon had shipped out all the rich, easily smelted ores from Ajo's mines. Despite the fact that the remaining ores were unquestionably rich, there was no satisfactory way to reduce them economically, and for many years the treasure in copper at the Ajo mines remained relatively untouched. The hills with their rich exposed ores were a speculator's paradise.

In 1910 the population—including Mexicans, Indians, and American citizens—was fifty people. The main business among these people was grazing cattle. Lack of water was a serious problem and poverty [was] rampant. In February 1911, there were only four Americans at what later came to be known as Old Ajo. However, Ajo was on the verge of becoming a boom town. With the discovery of a leaching process which made it possible to work the ores efficiently and inexpensively, Ajo entered into a prosperous period. The New Cornelia Copper Company was organized, a smelter built, and wells dug. From three to five thousand people were employed by the mines.

The battle between the few old timers in Old Ajo and the powerful mining company was soon joined. The old town of Ajo was far too close to huge deposits of low grade ore which the copper company wanted to develop. The company located its own town a mile to the north, which it proposed to call Cornelia. However, nearly all of Old Ajo burned down, and the name Ajo became attached to the new town.

—Excerpted from Granger, B. H., 1960, Will C. Barnes' Arizona place names: University of Arizona Press, p. 257-258.

Arizona State Trust Lands: Mineral-Resource Revenues and Activities

by Robert A. Larkin

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The Arizona State Land Department was established in 1915 to administer lands held in trust for the public schools and other beneficiaries. The department's primary goal is to maximize trust revenues through the sale and leasing of State trust lands. In fiscal year (FY) 1984-85, revenues reached an all-time high of $53,074,616, a 69 percent increase from the $31,435,300 generated in FY 1983-84. Of the FY 1984-85 total, $4,286,137 or 8 percent, came from nonrenewable-resource activities. The highest revenues from nonrenewable resources, $11,313,970, were generated in FY 1979-80, just prior to the recession. This represented roughly half of all revenues received that year by the Land Department.

The following article explains how the State Land Department was created and describes the activities of its Nonrenewable Resources and Minerals Section. The latter include such diverse duties as issuing leasing permits and protecting archaeological sites.

BACKGROUND

The Territory of Arizona was established by Congress in 1863. At that time, specific sections of land in each township (sections 16 and 36, if available) were set aside for the benefit of the public schools. In 1910 Congress prepared Arizona for statehood by passing the Enabling Act, which set aside additional land in each township (sections 2 and 32, if available). The act also identified 2,350,000 acres of additional land grants to the State and established a framework by which State lands were to be managed. The act included the following requirements and restrictions, which are still in effect today:

(1) The lands must be held in trust and used only as specified in the act.
(2) Revenues received from lease of the lands and natural products of the lands are subject to the same trust as the lands that produce them.
(3) The lands are not subject to mortgages or other encumbrances.
(4) Lands and natural products are to be leased or sold only after establishment of fair market or "true value."
(5) Lands and natural products may not be sold except to the highest bidder at public auction after 10 weeks of advertising.

Testing gold-recovery equipment at placer operation along the Agua Fria River north of Phoenix.

By enactment of the State Land Code, the Arizona State Land Department was created in 1915 to administer State lands held in trust. This law also gave the department authority over stone, gravel, timber, and other natural resources produced from these lands. The trust officer is the State land commissioner. Today the department has more than 140 employees and manages approximately 10 million acres. Its main office is in Phoenix; field offices are maintained in Flagstaff, Prescott, and Tucson.

NONRENEWABLE-RESOURCE ACTIVITIES

The Nonrenewable Resources and Minerals Section is part of the Natural Resources Division of the State Land Department. Nonrenewable resources include minerals, common mineral materials, oil and gas, geothermal energy, and cultural resources. The section oversees mineral-material sales and issues prospecting permits; mineral, oil and gas, and geothermal leases; and permits for geophysical exploration. Ancillary programs are also conducted, including research on proposed land sales and exchanges, environmental impact studies, review of mining and reclamation plans, and contracting for archaeological surveys and excavations.

The variety of functions performed by the section presents a challenge for its staff members. Decisions regarding land use are not simple or straightforward. Multiple land use is necessary and helps to maximize trust revenues. The section must use management strategies that allow development of nonrenewable resources.

Staff time is mostly spent on processing applications for leases and permits. Application categories are briefly described below. For further information, potential applicants should contact the Nonrenewable Resources and Minerals Section, Arizona State Land Department, 1624 W. Adams St., Phoenix, AZ 85007; telephone: 602-255-4628.

Prospecting Permits

Permits are issued to individuals or companies who wish to explore for valuable mineral deposits. The section receives approximately 3,000 applications per year. During the 1984-85 fiscal year, prospecting permits covered more than 300,000 acres of State land, indicating a strong interest in exploration for a variety of commodities, especially gold and uranium. Upon receipt of a permit application, the section conducts the necessary land records review, and in most cases, a field review. A bond amount is established and a plan of operation is requested from the applicant. After the application has been processed, the permit is mailed to the applicant for signature. A copy must then be returned to the section with the appropriate rental payment and restoration bond. The permit is issued for 1 year at a time, but may be renewed four times for a total of 5 years. Rentals received from prospecting permits in FY 1984-85 totaled $454,460, a 31 percent decline from the FY 1983-84 total of $654,403.

Mineral Leases

Mineral leases are issued to applicants with proof of valuable mineral discovery. The lease, which may extend to 20 years, confers the right to mine and ship ores and to conduct all support operations. In addition to a nominal annual rental, the State is entitled to 5 percent of the net value of the minerals produced. Net value is defined as the gross value after processing minus transportation costs from production to processing sites, processing costs, and taxes. The normal procedure for issuing a lease is to convert a prospecting permit. The section recommends that sufficient mineral exploration be conducted under a prospecting permit before a mineral-lease application is submitted.

More than 600 mineral leases are currently held on State land for commodities such as copper, silver, gold, iron, tin, uranium, limestone, marble, gypsum, zeolites, pumice, bentonite/silica sand, building stone, mica, clay, slate, fire agate, onyx, and pipestone. Exploration for uranium has increased in the past few years. Most activity is occurring north of Flagstaff and in the Arizona Strip north of the Grand Canyon. The bulk of royalty revenues comes from four copper-mining operations in Pima County: Magma in San Manuel; and ASARCO, Eisenhower, and Cypress-Pima near Green Valley. During the past several years, mineral royalties have diminished significantly because of decreased copper prices and reduced production. Total royalties from mineral leases in FY 1984-85 were $1,246,661. This represents a 42 percent increase from the $879,053 generated in FY 1983-84, but an 86 percent decline from the $9,061,000 generated in FY 1979-80.

Mineral-Material Sales

Common mineral materials, classified as natural products of the land, are sold at public auction. Resources in this category include sand, gravel, rock, common building stone, riprap, cinders, decomposed granite, topsoil, and any other mineral material used in the construction industry. Sales agreements with the highest bidder extend a maximum of 10 years.

After the section receives an application to purchase natural products, a section appraiser determines the surface land value of the parcel in question. The land value is used to determine an annual minimum guaranteed royalty to the State trust. A minimum royalty rate is also established, which is expressed as a price per ton of material, the price at which bidding begins. The annual royalty and the price per ton are computed based on the following factors: location of the site; quality and quantity of material; marketability; access to the site and the market; surface land value; residual value of the extraction area; past production, if applicable; and length of the term. Once the annual royalty and price per ton are determined, notification of the auction is published in newspapers for 10 weeks. The successful bidder must pay all appropriate administration and advertising fees and submit a plan of operations to the section. Prior to pit entry, the purchaser must survey and stake the leased area, including the haul road.

There are currently more than 300 active sales agreements. During FY 1984-85, royalties from mineral-material sales totaled $1,154,819, a 7 percent increase over the previous year's total of $1,078,366.

Oil and Gas Leases

Leases are issued to allow exploration for and production of oil and gas. Although no producing wells are currently on State land, interest in exploration is active in Cochise, Coconino, Mohave, and Yuma Counties. During the last 5 years, the total acreage under lease has fluctuated greatly, but is now stable at approximately 1.6 million acres. The section issues noncompetitive leases on a first-come, first-served basis. If oil or gas is discovered on State land, a "known geological structure" of a producing field is identified by defining the trap or accumulation of oil or gas. All acreage presumed to have production potential is designated. This acreage is then subject to competitive leasing, which involves submission of sealed bids by interested applicants. After the section establishes leasing terms, the State Oil and Gas Conservation Commission regulates exploration and production procedures.

Leases are issued for an initial term of 5 years. If oil or gas is produced, the trust receives a royalty of 12½ percent of the value (excluding oil or gas used in operations), minus the cost of dehydrating the oil and extracting liquid products from the gas. Annual rentals for initial lease terms are $1.00/acre/year and increase to $1.50/acre/year if the lessee renews the lease. In FY 1984-85, oil and gas leases paid $1,233,164 in revenues to the State, a 20 percent decline from the FY 1983-84 total of $1,547,364. In FY 1979-80, oil and gas leases paid $1,822,144.

Geothermal Leases

Regulations regarding geothermal leasing on State land are essentially the same as those for oil and gas leasing, with one major difference: the initial term for geothermal leases is 10 years. The Oil and Gas Conservation Commission regulates geothermal exploration and production in Arizona. There is currently one geothermal lease on State land near Agua Caliente.

Special Land Use Permits

This permit category is normally administered by another unit in the State Land Department because a variety of land-use activities are included within it. The Nonrenewable Resources and Minerals Section does, however, process Special Land Use Permits (SLUPs) that allow large-scale geophysical surveys on land not otherwise leased by the applicant. In addition to the application fee, rentals are due based upon the total number of sections to be traversed during exploration. Statewide permits are also available within the SLUP category.

OTHER PROGRAMS

Land Exchanges

Selected State trust lands are currently being exchanged with Federal agencies, private firms, and individuals. The exchanges, which are administered by two other units within the State Land Department, are conducted for several reasons:

(1) To consolidate surface and subsurface ownership;
(2) To remove State ownership from national parks and monuments, wildlife refuges, and wilderness areas;
(3) To consolidate "checkerboard" land ownership for more effective land management; and
(4) To acquire high-value land that will provide revenue to the State trust.

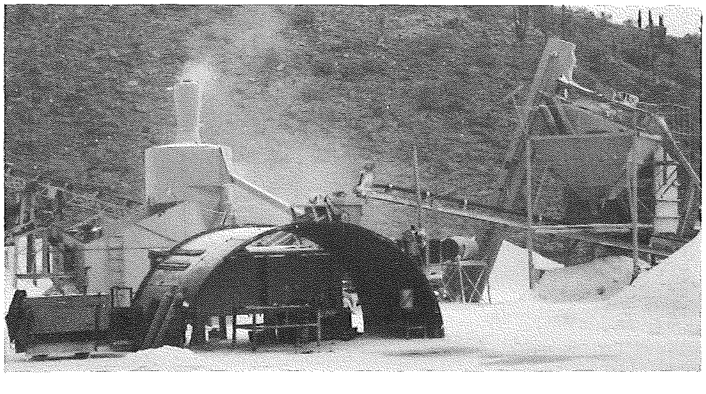
To support the program, the Nonrenewable Resources and Minerals Section researches the mineral potential of the land involved. State lands are not exchanged unless the land to be acquired is at least equal in value to the land to be sold. Major land exchanges allow the State Land Department to manage resources more effectively by "blocking up" landholdings. This involves trading sections of land that are dispersed throughout Arizona for contiguous sections of land.

Environmental Impact Studies

Prior to surface disturbance, lessees and permittees are required to submit a plan of operations for exploration or mining and for subsequent reclamation. The section determines potential impacts of proposed operations and works with lessees to determine appropriate land-reclamation activities.

Cultural Resource Program

The section represents the State Land Department in matters related to archaeological sites. Because the sites are protected by law, land-use planning must consider the location and significance of each site. The section has received several grants to conduct research at archaeological sites and to intervene when sites are threatened by leasing activities.



Crushing marble north of Tucson.

The Arizona Bureau of Geology and Mineral Technology: A Brief History

Mineral resources have played an important role in the settlement and economy of Arizona. Recognizing this importance, the U.S. Congress, the Governor of Arizona Territory, the University of Arizona, and the State legislature established the Arizona Bureau of Mines, which today is the Arizona Bureau of Geology and Mineral Technology. During the two decades before statehood, research and service activities by faculty members at the university served as the foundation for the Bureau.

Although Congress established the Territory of Arizona in 1863, the Civil War discouraged settlement until the 1870's, when the discovery and mining of mineral deposits brought an influx of newcomers. These deposits had been exploited by Spanish miners during the 1700's and by Indians before them. A number of mining camps were active by the early 1880's. At that time, little was known about the geology of Arizona; information that was available was general and of little use to prospectors. Despite this dearth of information, prospectors had little difficulty identifying mineral deposits because Arizona was not heavily vegetated and many deposits were exposed at the land surface.

Because of the abundance of these deposits, it was logical for Governor Tritle to request detailed geologic surveys of the territory in 1883. It was not until 1888, however, that the U.S. Congress created the post of "territorial geologist," which was filled on an irregular basis until statehood in 1912. The primary responsibility of this unpaid position was to prepare a summary of Arizona's geology and mineral resources for the territorial Governor's annual report to the Secretary of the Interior. Those who served as territorial geologist were John F. Blandy (1889-90), Dr. William P. Blake (1898-1904), and Dr. Cyrus F. Tolman, Jr. (1911-12). Although they did not carry the official title of territorial geologist, Dr. Theodore B. Comstock and Blake performed comparable duties during the periods 1891-94 and 1896-97, respectively. All but Blandy were faculty members in the University of Arizona School of Mines.

When it first opened in 1891, the University of Arizona was comprised of just two "schools": the School of Mines and the School of Agriculture. Comstock, who served as director of the School of Mines, established a metallurgical testing laboratory in 1893. The laboratory was referred to as the "University of Arizona Bureau of Mines" or the "University School of Mines Testing Laboratory." Rock and mineral determinations, ore testing, and complete assaying were done, largely by faculty in the School of Mines. Comstock served as director of the laboratory until 1895, when he became the first president of the university.

In 1915, three years after statehood, the Arizona legislature established the Arizona Bureau of Mines, an official State agency under the authority of the board of regents of the University and State Colleges of Arizona. The regents, in turn, specified that the new agency be administered by the University of Arizona, where a "Bureau of Mines" was already in operation. The functions of the territorial geologist and the University of Arizona "Bureau of Mines" were incorporated and expanded. Charles F. Willis, an instructor in geology and mining engineering, became the Bureau's first director in 1915 and served until 1918, when the College of Mining and Engineering was created. When Willis resigned, the dean of the college, Dr. Gurdon M. Butler, was named director of the Bureau. He served in that capacity until 1940.

JOHN F. BLANDY

John F. Blandy, first territorial geologist of Arizona, was one of the most respected mining engineers of his time. His education included two years at the School of Mines in Freiburg, Germany. His professional experience was notable: engineer at the Lake Superior copper mines for 8 years; president and general manager of the Little Schuylkill Company in the anthracite coal region of Pennsylvania for 15 years; author of several technical articles; and organizer of the American Institute of Mining Engineers.

Born in Newark, Delaware in 1833, Blandy moved to Prescott, Arizona in 1880, where he represented some of the largest mining companies in the country. He was frequently asked to compile mining statistics for the U.S. government, a job he also performed as territorial geologist of Arizona from 1889 to 1890. N. O. Murphy, acting Governor of Arizona in 1890, commended Blandy's role as territorial geologist: "In my judgment a more capable and efficient man for the office cannot be found in Arizona. He has both the experience and theoretical education, being a practical miner, as well as a graduate from a school of mining engineers." Blandy died in Prescott in 1903 at the age of 70.

At first, the Arizona Bureau of Mines served mainly as a mineral-testing facility (Figure 1). Gradually the Bureau became involved in activities comparable to those of State geological surveys. These activities included preparing geologic maps and studying relationships between the geologic framework and ore genesis. The major mineral deposits, present at or near the land surface, had been relatively easy to discover. Because they were being depleted and new deposits were much more difficult to locate, the Bureau's expanded activities were essential.

In 1940 the College of Mining and Engineering was divided into two separate colleges. Responsibility for the Bureau of Mines was assigned to the dean of the College of Mines, Dr. Thomas G. Chapman, who served until 1956. During this period, Bureau staff conducted research and pilot-plant studies that led to the design of the ore-concentrating facilities at five of the nine major low-grade copper deposits developed since 1945. Chapman was succeeded by Dr. James D. Forrester, who served until 1971, followed by Dr. William H. Dresher.

Dresher, who realized that the Bureau's enabling act was outdated, was primarily responsible for the writing and passage of the revised act in 1977. The new act changed the name to the Arizona Bureau of Geology and Mineral Technology and established two branches: the Geological Survey Branch, which is the Arizona State Geological Survey, and the Mineral Technology Branch, which continued the Bureau of Mines function. The Bureau's responsibilities were expanded to include research and information on geologic hazards and land-use limitations. For the first time, Arizona officially had a State geological survey. The new enabling act specified that the Bureau was to be a division of the University of Arizona administered by the Board of Regents and supervised by the president of the university or his designate. The president has continued to ask the dean of the College of Mines to supervise the Bureau, a practice that has been followed since 1918.

Dresher resigned in 1981 and was succeeded by Dr. Richard A. Swalin in 1984. In the interim period, Dr. William P. Cosart was acting dean of the College of Mines and acting director of the Bureau.

In July 1985 the separate colleges of Mines and Engineering were reunited as the College of Engineering and Mines, becoming one college as they had been from 1918 to 1940. Swalin was appointed dean of the merged college and continues to serve as director of the Bureau.

Current research by the Geological Survey Branch of the Bureau emphasizes improving the understanding of Arizona's geologic framework. This work includes the preparation and interpretation of detailed geologic maps. In much of the State, the geology has never been mapped in detail. Assessment of mineral potential and identification of mineral-exploration target areas requires

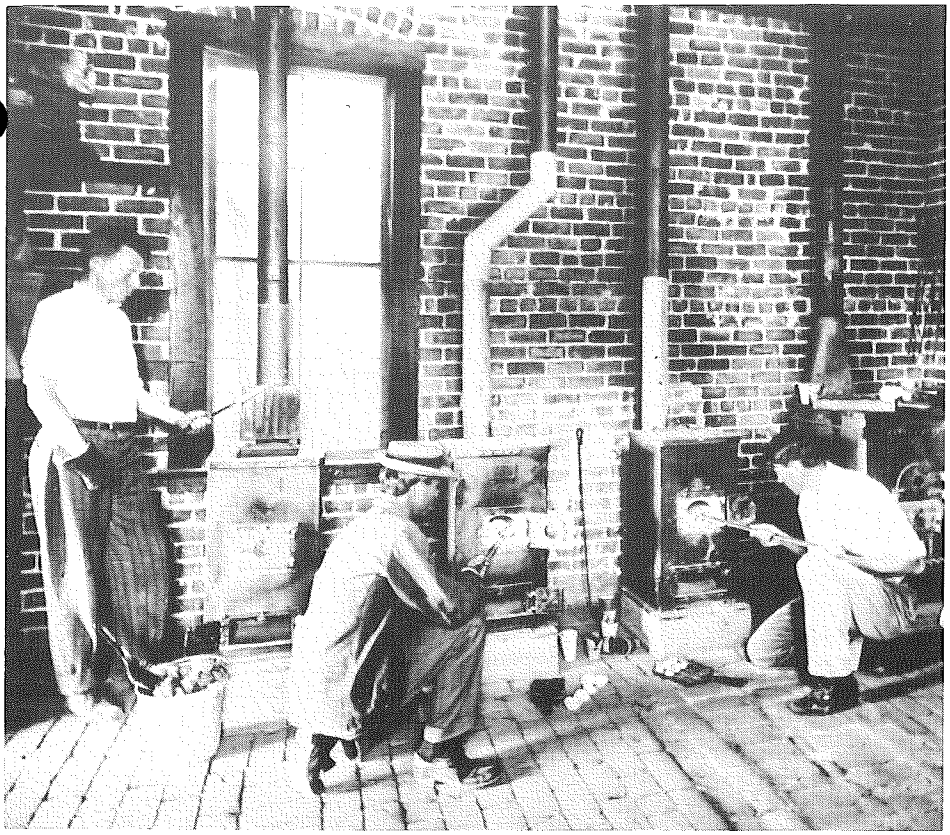


Figure 1. *University of Arizona students conduct fire assays for gold and silver at the Arizona Bureau of Mines, circa 1920.*

thorough understanding of the geologic framework and its relationship to ore genesis. Understanding of geologic hazards and land-use limitations is also based on knowledge of the geologic framework and detailed geologic maps. To make geologic information more available to the public, a computerized database, the Arizona Geologic Information System, is being compiled.

The Mineral Technology Branch is focusing current research on both basic and applied studies in mining, mineral processing, and extractive metallurgy. Mining research is contributing to two important areas: (1) the detection and characterization of gases produced by explosives in underground mining operations; and (2) the application of robotics in mining to eliminate personal injury and increase production. In the areas of mineral processing and extractive metallurgy, basic investigations are being conducted in the hydrometallurgical treatment of refractory gold and silver ores and the recovery of gold and silver from solution. A survey of Arizona copper dump-leaching activities is being made to determine the potential for recovery of minor elements from the leach solutions. Some of these metals may be of strategic importance to the State and Nation, as well as to copper producers as valuable by-products. In-situ leaching is another area in which the Mineral Technology Branch plans to develop experimental programs.

Selected References

Anthony, J. W., 1956, Arizona Bureau of Mines: unpublished manuscript, 7 p.

Moore, R. T., 1971, The Arizona Bureau of Mines, *in* Oakeshott, G. B., ed., Origin and development of the State geological surveys: Journal of the West, v. 10, no. 1, p. 136-141.

PROFESSIONAL MEETINGS

Frontiers in Geology and Ore Deposits of Arizona and the Southwest. Symposium and field trips, March 17-23, 1986, Tucson, Ariz. Contact AGS Conference, University Conference Dept., 1717 E. Speedway, Suite 3201, Tucson, AZ 85719; (602) 621-1232. (See also "Spring Symposium on Geology and Ore Deposits," p. 11.)

Arizona-Nevada Academy of Science. Annual meeting, Glendale (Phoenix), Ariz., April 19, 1986. Contact Jim Bales, 8643 E. Buena Terra, Scottsdale, AZ 85253; (602) 949-1549.

Cenozoic History of the Colorado Plateau Margin — the Stratigraphic Record. Rocky Mountain Section, Geological Society of America. Symposium and field trips, Flagstaff, Ariz., April 28—May 4, 1986. Contact Stanley S. Beus, Dept. of Geology, Box 6030, Northern Arizona Univ., Flagstaff, AZ 86011; (602) 523-4561.

STAFF NOTES

Janet Christner, recently promoted to Administrative Assistant I at the Bureau, is responsible for accounting and budget procedures, coordinates administrative paperwork, and acts as assistant to the head of the Geological Survey Branch. She has secretarial, accounting, and administrative experience and owns an Arizona real estate license. She is currently working on a B.A. degree at the University of Arizona.

Olga Hernandez, who oversees the Publications Sales Office of the Bureau, has been employed as Secretary II since July. She handles publication sales and distribution, answers phone inquiries, assists visitors, and performs various word processing tasks. She has 4 years of secretarial experience in personnel administration and is bilingual in Spanish and English.

Mark Pritzker has been appointed to a joint position in the Bureau's Mineral Technology Branch and the Department of Materials Science and Engineering at the University of Arizona. He received his Ph.D. in materials engineering science from the Virginia Polytechnic Institute and State University (VPI) in 1985. Dr. Pritzker's dissertation involved an electrochemical study of the solution and flotation chemistry of the mineral galena. He was the recipient of the 1985 Gillies Ph.D. Graduate Award from VPI for "leadership and great promise."

Dr. Pritzker received his B.S. in engineering from McGill University and his M.S. from the University of California at Berkeley. From 1978 to 1979, he worked for the Canada Centre for Mineral and Energy Technology (CANMET). His research interests include the electrochemistry and numerical modeling of processes associated with the flotation and hydrometallurgy of sulfide minerals and precious metals.

Margaret Stalker has been hired as Secretary III for the Mineral Technology Branch of the Bureau and the Mining and Mineral Resources Research Institute. Her job involves accounting, word processing, and conference coordination. Her previous experience includes personnel administration and promotional research. She holds a B.S. in business education from the University of Arizona.

Recent Publications on the Geology of Arizona

The following publications were recently added to the Bureau library, where they may be examined during regular working hours. Copies may also be obtained from the respective publishers.

U.S. Bureau of Mines

Bulletin

675	Mineral facts and problems, 1985, preprints: aluminum, cement, gem stones, graphite, helium, indium, quartz crystal, sand and gravel, silver, tellurium, thorium, and titanium.

Mineral Land Assessment Reports

MLA 22-85	Lane, M. E., 1985, Mineral investigation of the Arrastra Mountain Wilderness Study Area, La Paz, Mohave, and Yavapai Counties, and Peoples Canyon Wilderness Study Area, Yavapai County, Arizona, 37 p., 2 plates, scale 1:62,500.
MLA 34-85	Light, T. D., 1985, Mineral investigation of the Sierra Ancha Wilderness and Salome Study Area, Gila County, Arizona, 141 p., scale 1:48,000.

U.S. Geological Survey

Bulletins

1646	Tooker, E. W., ed., 1985, Geologic characteristics of sediment- and volcanic-hosted disseminated gold deposits—search for an occurrence model, 150 p.
1654	Tabor, R. W., Mark, R. K., and Wilson, R. H., 1985, Reproducibility of the K-Ar ages of rocks and minerals—an empirical approach, 5 p.

Maps

I-1310-C	Drewes, Harald, Houser, B. B., Hedlund, D. C., Richter, D. H., Thorman, C. H., and Finnell, T. L., 1985, Geologic map of the Silver City 1° x 2° quadrangle, New Mexico and Arizona, scale 1:250,000.
I-1570	Drewes, Harald, 1985, Geologic map and structure sections of the Dos Cabezas quadrangle, Cochise County, Arizona, scale 1:24,000.
MF-1412-D	Drewes, Harald, Moss, C. K., Watts, K. C., Jr., Forn, C. L., and Bigsby, P. R., 1983, Mineral resource potential map of the North End Roadless Area, Chiricahua Mountains, Cochise County, Arizona, 9 p., scale 1:50,000.
MF-1567-A	Karlstrom, T. N. V., Billingsley, G. H., and McColly, Robert, 1983, Mineral resource potential and geologic map of the Rattlesnake Roadless Area, Coconino and Yavapai Counties, Arizona, 9 p., scale 1:24,000.
MF-1614-C	Bankey, Viki, and Kleinkopf, M. D., 1985, Geophysical maps of the Whetstone Roadless Area, Cochise and Pima Counties, Arizona, scale 1:48,000.
MF-1644-A	Conway, C. M., McColly, R. A., Marsh, S. P., Kulik, D. M., Martin, R. A., and Kilburn, J. E., 1983, Mineral resource potential map of the Hells Gate Roadless Area, Gila County, Arizona, 10 p., scale 1:48,000.
MF-1681	Gray, Floyd, Miller, R. J., Peterson, D. W., May, D. J., Tosdal, R. M., and Kahle, Katherine, 1985, Geologic map of the Growler Mountains, Pima and Maricopa Counties, Arizona, scale 1:62,500.
MF-1783	Brooks, W. E., 1985, Reconnaissance geologic map of part of McLendon Volcano, Yavapai County, Arizona, scale 1:24,000.

Open-File Reports

Studies of geology and hydrology in the Basin and Range Province, southwestern United States, for isolation of high-level radioactive waste [84-738 to 84-745]:

84-738	Bedinger, M. S., Sargent, K. A., and others, 1985, Basis of characterization and evaluation, 189 p., scale 1:2,500,000.
84-739	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds, 1985, Characterization of the Trans-Pecos region, Texas, 122 p., scale 1:1,000,000, 1:500,000, 7 plates.
84-740	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., 1985, Characterization of the Rio Grande region, New Mexico and Texas, 148 p., scale 1:500,000, 7 plates.
84-741	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., 1985, Characterization of the Sonoran region, Arizona, 141 p., scale 1:500,000, 5 plates.
84-742	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., 1985, Characterization of the Sonoran region, California, 103 p., scale 1:250,000, 1:500,000, 6 plates.
84-743	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., 1985, Characterization of the Death Valley region, Nevada and California, 173 p., 7 plates.
84-744	Bedinger, M. S., Sargent, K. A., and Langer, W. H., eds., 1985, Characterization of the Bonneville region, Utah and Nevada, 139 p., scale 1:500,000, 6 plates.
84-745	Bedinger, M. S., Sargent, K. A., and Langer, W. H., 1985, Evaluation of the regions, 195 p., 2 sheets.

84-830	Wilt, J. C., Keith, S. B., and Theodore, T. G., 1984, [1985], A listing and map showing molybdenum occurrences in Arizona, 62 p., scale 1:1,000,000.
85-28	Ege, J. R., 1985, Maps showing distribution, thickness, and depth of salt deposits of the United States, 11 p., 4 plates.
85-113	Chaffee, M. A., 1985, Geochemical evaluation of the Winchester Roadless Area, Cochise County, Arizona, 8 p.
85-394	Reimer, G. M., 1985, Helium soil gas survey of a collapse feature on the Hualapai Indian Reservation, Arizona, 12 p.
85-399	Gilmore, T. D., and Elliott, M. R., 1985, Sequentially and alternatively developed heights for two representative bench marks—near Palmdale, California and along the Bill Williams River, Arizona, 50 p.
85-400	Senterfit, R. M., Mohr, P., and Horton, R., 1985, Geophysical studies of breccia pipe locations on the Hualapai Indian Reservation, Arizona, 30 p.
85-410	Annual summary of ground-water conditions in Arizona, spring 1983 to spring 1984, 2 sheets.
85-462	Harms, T. F., Bradley, L. A., Tidball, R. R., Motooka, J. M., and Conklin, N. M., 1985, Analytical results and sample locality maps of stream sediments, heavy-mineral concentrates, and plant samples from Black Rock, Fishhooks, and Needles Eye Wilderness Study Areas, Graham and Gila Counties, Arizona, 49 p., scale 1:24,000, 3 plates.
85-469	Wenrich, K. J., Van Gosen, B. S., Balcer, R. A., Scott, J. H., Mascarenas, J. F., Bedinger, G. M., and Burmaster, Betsi, 1985, A mineralized breccia pipe in Mohawk Canyon, lithologic and geophysical logs, 72 p.
85-527	Peterson, J. A., Cox, D. P., and Gray, Floyd, 1985, Mineral resource assessment of the Ajo and Lukeville 1° by 2° quadrangles, Arizona, 77 p., scale 1:250,000, 3 plates.

Water-Supply Papers

2258	Hollett, K. J., 1985, Geohydrology and water resources of the Papago Farms-Great Plain area, Papago Indian Reservation, Arizona, and the upper Rio Sonoyta area, Sonora, Mexico, 44 p.
2271	Gilliom, R. J., Alexander, R. B., and Smith, R. A., 1985, Pesticides in the Nation's rivers, 1975-1980, and implications for future monitoring, 26 p.

Other Publications

Arthur D. Little, Inc., and Jones, Day, Reavis & Pogue, 1985, Impact of the President's tax reform proposals on the United States mining industry: 72 p.

Cather, S. M., and Johnson, B. D., 1984, Eocene tectonics and depositional setting of west-central New Mexico and eastern Arizona: New Mexico Bureau of Mines and Mineral Resources, Circular 192, 33 p.

Davis, G. M., 1985, Geology of the southern Plomosa Mountains: Tempe, Arizona State University, M.S. Thesis, 158 p., scale 1:24,000.

Dietz, David, and Williams, Charles, 1985, Geophysical investigations of Butler Valley, Arizona: University of Arizona Water Resources Research Center, 22 p.

Goodlin, T. C., and Mark, R. A., 1985, Geologic map of and cross sections through the Hot Springs Canyon area, Cochise County, Arizona: Tucson, University of Arizona, M.S. Thesis maps, scale 1:24,000, 2 sheets.

Myers, I. A., 1984, Geology and mineralization at the Cyclopic mine, Mohave County, Arizona: Las Vegas, University of Nevada, M.S. Thesis, 64 p., 6 sheets.

Owen-Joyce, S. J., 1984, Hydrology of a stream-aquifer system in the Camp Verde area, Yavapai County, Arizona: Arizona Department of Water Resources Bulletin 3, 60 p., scale 1:24,000, 3 plates.

Smith, R. C., 1984, Mineralogic and fluid-inclusion studies of epithermal gold-quartz veins in the Oatman district, northwestern Arizona: Tucson, University of Arizona, M.S. Thesis, 232 p., 1 sheet.

Stoneman, D. A., 1985, Structural geology of the Plomosa Pass area, northern Plomosa Mountains, La Paz County, Arizona: Tucson, University of Arizona, M.S. Thesis, 99 p., 4 plates.

U.S. Bureau of Land Management, 1985, Yuma district resource management plan and environmental impact statement: 310 p., scale 1:250,000.

Yeats, K. J., 1985, Geology and structure of the northern Dome Rock Mountains, La Paz County, Arizona: Tucson, University of Arizona, M.S. Thesis, 123 p., 3 plates.

Spring Symposium on Geology and Ore Deposits

On March 20-21, 1986 at the University of Arizona, Tucson, the Arizona Geological Society will host a symposium entitled, "Frontiers in Geology and Ore Deposits of Arizona and the Southwest." Fourteen separate preconference and postconference field trips, to be held on March 17-19, 22, and 23, will round out the conference.

The symposium will highlight recent advances in tectonics and ore deposits of the Southwest. Papers with a regional focus include overviews of Precambrian tectonics and ore deposits, Mesozoic structure and tectonics in western Arizona and the Southwest, Laramide magmatism and metallogeny, the regional nature of detachment faults in western Arizona, potassium metasomatism in the Southwest, mineralization related to detachment faults, preliminary CALCRUST results, and ore deposits of contiguous Mexico. Papers with a specific focus include mineralization at Picacho mine, Imperial County, Calif.; mineralization of the McCabe-Gladstone deposit, Yavapai County, Ariz.; and mineral deposits associated with topaz rhyolites in the Southwest.

Field trips include topics such as Precambrian evolution of the Payson-Mazatzal area, Mesozoic to mid-Tertiary tectonics and mineralization of west-central Arizona, stratigraphy and petroleum potential of the Pedregosa basin in southeastern Arizona, and geologic hazards and hydrology of southern Arizona. The fourteen field trips will give participants an opportunity for "hands-on" exposure to the geology of the Southwest.

Activities for spouses and guests will feature views of Arizona, from desert flora and fauna to the culture of its people.

For more information, contact AGS Conference, University Conference Dept., 1717 E. Speedway, Suite 3201, Tucson, AZ 85719; (602) 621-1232.

New Bureau Publications

The following open-file reports may be purchased over the counter or by mail from the Bureau offices at 845 N. Park Ave., Tucson, AZ 85719. Orders are shipped via UPS; street address is required for fastest delivery. All orders must be prepaid by check or money order made out to the Arizona Bureau of Geology and Mineral Technology. Shipping and handling charges are listed below. If your total order is

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Chenoweth, W. L., and Learned, E. A., 1985, Historical review of uranium-vanadium production in the northern and western Carrizo Mountains, Apache County, Arizona: Open-File Report 85-13, 35 p., scale 1:126,000; text: $5.75; map: $2.00.

The carnotite deposits of the northern and western Carrizo Mountains have been mined for their radium, vanadium, and uranium content since 1920. This report summarizes uranium and vanadium production in these mountains and provides hard data for a previously confused chapter in the history of uranium mining in Arizona. The report was made possible by the release of heretofore confidential data prepared by the Indian Trust Accounting Division of the General Services Administration for a court hearing in 1983 (Navajo Tribe vs. United States).

Capps, R. C., Reynolds, S. J., Kortemeier, C. P., Stimac, J. A., Scott, E. A., and Allen, G. B., 1985, Preliminary geologic maps of the eastern Big Horn and Belmont Mountains, west-central Arizona: Open-File Report 85-14, 25 p., scale 1:24,000, 2 sheets; text: $4.00; maps: $3.25 each.

This report presents preliminary 1:24,000-scale geologic maps of the eastern Big Horn and Belmont Mountains in west-central Arizona. The mapping, completed between January and April 1985, was jointly funded by the U.S. Geological Survey and the Arizona Bureau of Geology and Mineral Technology as part of the cost-sharing Cooperative Geologic Mapping Program (COGEOMAP). The Big Horn and Belmont Mountains were chosen because neither range had been previously mapped, except in broad reconnaissance for previous State geologic maps, and because both ranges have substantial mineralization and exploration activity.

The Big Horn and Belmont Mountains are composed of a metamorphic-plutonic basement that is overlain by middle Tertiary volcanic and sedimentary rocks. Volcanism was accompanied by low- to high-angle, normal faulting and rotation of the older volcanic units and subjacent crystalline basement. Slight to moderate angular unconformities within the volcanic sequence attest to synvolcanic tilting and faulting. The area contains a number of distinctive types of precious- and base-metal mineralization. Many mineral deposits in this area, including significant occurrences of gold, manganese, and barite-fluorite mineralization, are associated with middle Tertiary faults and intrusive-volcanic centers.

Chenoweth, W. L., 1985, Early vanadium-uranium mining in Monument Valley, Apache and Navajo Counties, Arizona and San Juan County, Utah: Open-File Report 85-15, 13 p.; $2.00.

This report summarizes the history of vanadium and uranium production in the Monument Valley area. The report contains previously confidential data prepared by the Indian Trust Accounting Division that are similar to data released in Open-File Report 85-13.

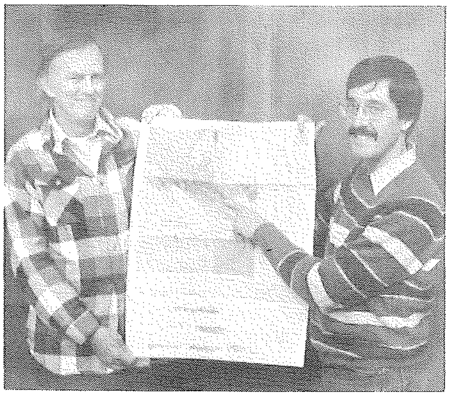
Cooperative Geologic Mapping

The Geological Survey Branch (GSB) of the Arizona Bureau of Geology and Mineral Technology has been awarded $63,204 from the U.S. Geological Survey (USGS) to support geologic mapping in the Hieroglyphic Mountains during fiscal year 1985-86. This award is the USGS's contribution to the Cooperative Geologic Mapping Program (COGEOMAP), a jointly funded effort with the State geological surveys. The GSB will provide an equal amount of funding through the mapping efforts of its own staff.

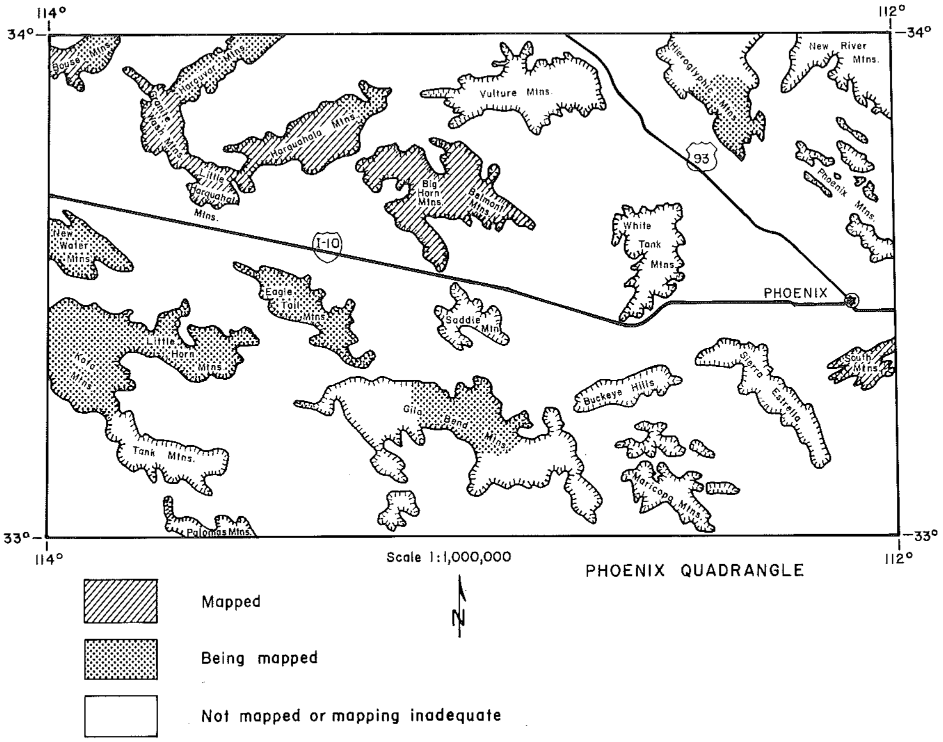
Dr. Stephen J. Reynolds (GSB) is principal investigator and project leader. Dr. David M. Miller serves as the COGEOMAP coordinator for the USGS, having succeeded Dr. Juergen Reinhardt. COGEOMAP is administered through the USGS Office of Regional Geology, under the direction of Dr. Eugene H. Roseboom.

This is the GSB's second year as a participant in the COGEOMAP program. During fiscal year 1984-85, GSB staff mapped in the Big Horn, Belmont, and Granite Wash Mountains and in the Bouse Hills, and USGS geologists mapped in the Kofa, New Water, and western Big Horn Mountains. A geologic map and descriptive summary of the Big Horn and Belmont Mountains, resulting from the 1984-85 COGEOMAP project, was recently released as Bureau Open-File Report 85-14 and is announced on page 11.

Dr. Stephen J. Reynolds.



Dr. Eugene H. Roseboom and Dr. David M. Miller.



Status of geologic mapping in the Phoenix quadrangle.

GEOSCIENCE DAZE COLLOQUIUM

The students of the Department of Geosciences, University of Arizona, will be holding their 14th annual *Geoscience Daze* on March 11-13, 1986 in the Gallagher Theater, Student Union Building. More than 50 papers will be presented on various aspects of geosciences. The public is cordially invited; admission is free. For more information, contact Mae Gustin, Geoscience Daze Committee, Dept. of Geosciences, Univ. of Arizona, Tucson, AZ 85721; (602) 621-6024.

Fieldnotes

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