FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 4 No. 3 Earth Science and Mineral Resources in Arizona *Sept. 1974*

MINERAL TECHNOLOGY RESEARCH IN THE ARIZONA BUREAU OF MINES

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Assistant Metallurgist

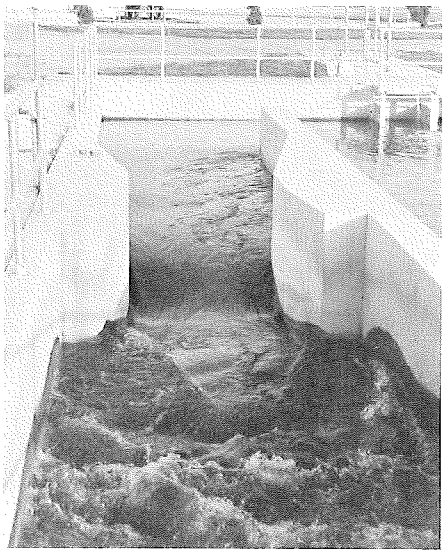
Introduction

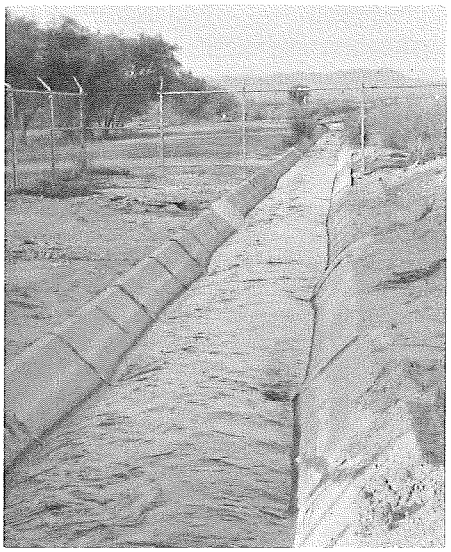
The Arizona Bureau of Mines has been involved in mineral technology research since its establishment in 1915. The research performed in the early years of the Bureau was limited mainly to ore amenability testing and ore assaying. This work was performed to help mine operators test the feasibility of treating new ores and optimize mineral processing techniques. As the mineral technology demands in Arizona have changed, the Bureau has adjusted its research activity in response to new needs. When Arizona's copper industry was faced with depletion of the major high-grade deposits and found it necessary to process low-grade ores, the Bureau, through its research and pilot plant studies, contributed significantly to the industry's successful transition to low-grade ores. Today, society is placing considerable emphasis on conservative use of natural resources and minimal environmental degradation. The Bureau's current mineral technology research reflects these new public concerns.

Use of Reclaimed Water in Mineral Processing

Arizona's most vital natural resource is water. Water is a necessity for life. It is essential to agriculture, mining, and manufacturing. Most of the water used for agricultural, municipal, and industrial purposes in Arizona is pumped from groundwater reservoirs. Each of the groundwater basins has a finite capacity and the unlimited growth of water demand will ultimately result in depletion of this source of water. To help insure an adequate supply of groundwater in the future, our state needs to develop realistic, long-range water use policies and effective conservation and re-use practices.

The Pima Association of Governments (PAG), in developing "A Regional Plan for Water, Sewerage and Solid Waste Management," is assessing many alternative uses for water reclaimed from sewage treatment. The three most reasonable possibilities are: use as mineral processing water, as a replacement for some irrigation water, or as recharge to the groundwater reservoir. Currently, the City of Tucson and the mining companies that have operations south of Tucson, are giving the first alternative serious consideration and it appears likely that at least part of Tucson's sewage effluent will someday be used in copper milling operations. The Arizona Bureau of Mines, in anticipation of this possibility, has for the past two years devoted a major part of its mineral technology research effort to explore the possible use of water reclaimed from sewage treatment as mineral processing water. This investigation is being sponsored by the Water Resources Research Center at the University of Arizona.





Water reclaimed from municipal sewage discharges from the City of Tucson treatment plant and flows into the Santa Cruz River north of Tucson. A portion of this reclaimed water may someday be used for mineral processing by the copper operations south of Tucson.

The copper ores mined in Arizona are of such a low grade that the copper cannot be extracted directly from the ore. The copper minerals in the ore must be separated from the host rock (gangue) and then segregated to form a copper mineral concentrate. This is accomplished by crushing and grinding the ore to a very fine powder to liberate the important copper minerals from the gangue. The pulp formed by the ground ore and water is then subjected to froth flotation to segregate copper sulfide minerals from the gangue and form a sulfide concentrate. In the flotation process, chemicals known as frothing and collecting reagents are added to the ore pulp so that copper mineral particles become attached to air bubbles and float to the surface while the gangue and other unwanted minerals remain in the pulp. The original ore may contain only 0.3 to 0.8 per cent copper. The concentrate will contain from 18 to 30 per cent copper.

Froth flotation is the principal process by which copper sulfide minerals are recovered from ores to form sulfide concentrates. The copper industry relies almost entirely upon this process for its

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THE ARIZONA BUREAU OF MINES

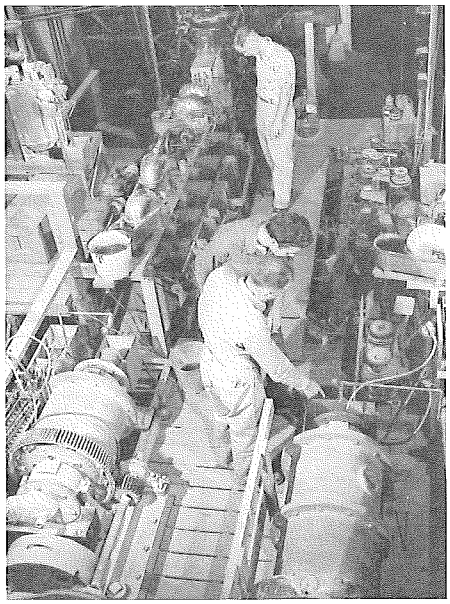
The Arizona Bureau of Mines, or its antecedents, has been functioning in association with the University of Arizona for over eighty years. In 1893, two years after the University opened its doors to students, the first assaying and ore testing service for the Territory was instigated by Dr. Theodore B. Comstock, Director of the University of Arizona School of Mines. The work was first housed in a small frame building near Old Main on the University of Arizona campus. In 1897, a new assay lab was built to provide "service" to the citizens and industries of the territory. In those days, the time and expense involved for the small mine operator or prospector to secure assays on a few samples was prohibitive. Therefore, the assaying and ore testing laboratory was set up on a non-profit basis to analyze samples for one metal for one dollar or four metals for two dollars. Over 1400 determinations were made in the first year. This metallurgical testing station was the forerunner of the present Bureau and was variously known as the University of Arizona Bureau of Mines, the University School of Mines Testing Laboratory, and the Bureau of Mines of the Arizona School of Mines.

The present Arizona Bureau of Mines was created in 1915 by an act of the State legislature and was placed under the authority of the Board of Regents of the University and State Colleges (now the Arizona Board of Regents). The broad objective of the newly formed Bureau was to serve the interest of the people of the state in all matters concerning mineral resources.

Under the first director, Charles F. Willis, who was a prominent mining engineer in the state, the metallurgical services continued essentially unchanged, but the operation was expanded to cover mining safety and the welfare of the miner. Numerous short bulletins were issued on these subjects as well as on first aid, sampling, and field testing and identification of minerals and metals.

After three years, the Regents transferred the administration of the Bureau to the College of Mines and Engineering. At first the Director of the Bureau reported to the Dean of the College but then, a few months later, the two posts were combined. Dr. Gurdon Montague Butler, a geologist, who was Dean of the College, also became Director of the Arizona Bureau of Mines, serving from 1918 until 1940 in the dual capacity. Under Butler, in addition to acting as a mineral experiment station, the Bureau gradually undertook the function of a state geological survey and in 1924 the Bureau and the U.S. Geological Survey jointly published the first geologic map of Arizona.

In 1940 the College of Mines and Engineering was divided into separate colleges, and the Bureau of Mines was placed administratively with the newly created College of Mines. Dr. Butler remained Dean of the College of Engineering and Dr. Thomas G. Chapman was appointed Dean of the College of Mines and Director of the Bureau. The Bureau's activities under Chapman were greatly influenced by the demand for mineral-based materials caused by World War II. The Bureau took part in many cooperative federal programs to find new sources of critical materials. Also, during this period Arizona's copper industry was faced with depletion of the major high-grade deposits. Through its research and pilot plant studies, the Bureau contributed considerably in the industry's



Arizona Bueau of Mines flotation pilot plant — used in the past to simulate several copper flotation operations during the industry's transition from high-grade to low-grade ores. This pilot plant is no longer in operation.

transition to processing low-grade deposits. Dr. Chapman served in the dual capacity until 1956, when Dr. James D. Forrester took over as Dean and Director. Under Dr. Forrester, the mineral experiment station activities continued unchanged while the Bureau's role as a geological survey was increasingly recognized. A new geologic map of Arizona, the product of a 13-year effort, was published jointly by the Bureau and the U.S. Geological Survey in 1969.

In 1971, Dr. William H. Dresher assumed the duties of Dean of the College and Director of the Bureau. Today, under Dr. Dresher's direction, the Bureau continues to grow and adjust its goals to better meet the changing needs of society.

In the early days of the development of the West, and the development of first the Territory and then the State of Arizona, the mineral wealth of the western territory was an early basis for economic and population growth. Specific government-fostered organizations were established to encourage the movement of the country's population into this broad expanse of land and to aid in the development of mineral resources.

This was the atmosphere in which the role of Territorial Geologist was born in the Arizona Territory and later, after statehood, the role which the Arizona Bureau of Mines was to undertake. The mission of the Bureau, as described at its inception in 1915, was to assist in development of the mineral resources of the state through technical and informational assistance to mine operators and the public.

Today, 81 years after the first official ore testing station in Arizona, state and national conditions are changing and, as a result, the goals and motivations of governmental and private organizations also are changing. As a state and a nation, our concerns include not only the maintenance of the living standard that we have established, but also, the problems accompanying growth: environmental conditions, exhaustion of natural resources, material waste, and unnecessary abuse of land.

The Arizona Bureau of Mines, like many other organizations, is changing and growing to meet the altered goals of society. As geologists and mineral technologists, we in the Arizona Bureau of Mines realize that society must seek a balance between a continued high standard of living, maintenance of an acceptable environment, and optimum utilization of our mineral resources. In this era of rapid change, we must be concerned not only with the problems confronting us today, but also we need to anticipate those that are likely to confront us in the future – the location of mineral resources for the future, an adequate water supply, the impact of the geologic environment on land use, the reservation of land for a wide variety of future uses including recreation . . . The Arizona Bureau of Mines, functioning both as a geological survey and a mineral technology experiment station, can play a major role by providing society with the information, technology, and advice

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A GEOLOGIC MYSTERY OR THE "TAR" CASE

by
H. Wesley Peirce
Geologist

"Tar," as used here, is meant to describe a solid, shiny black hydrocarbon substance that readily melts at the temperature of a match flame. It has a conchoidal fracture, occurs naturally in a peculiar southern Arizona sedimentary rock, and probably should technically be called "bitumen." However, we are currently more interested in its occurrence than we are in giving it a name that might be technically acceptable to specialists in the petroleum profession.

So far as we know, there is no record of such a naturally occurring organic substance having been previously observed, reported, and documented in the Basin and Range province of southern Arizona. My own recent encounter came during examination of well cuttings from a deep test hole drilled by Geothermal Kinetics in sec. 1, T. 2 S., R. 6 E., near Chandler in eastern Maricopa County. This hole was drilled from a valley surface elevation of 1338 feet above sea level to a depth below 9000 feet (more than 7660 feet below sea level). Its purpose was to explore for unusually high earth temperatures – a reservoir of heat. However, the geologic information derived from such holes is applicable to diverse interests, our own being a better understanding of what Arizona really is. Perhaps we often forget that there is much more to Arizona than what we superficially see at the surface. Earth (land) management requires knowledge of the earth, not just the surface upon which we live.

The Geothermal Kinetics deep test hole provides us with a rare opportunity to learn something about what fills our basins, or valleys, and how deep they might be. Their bottoms are marked by pre-existing rocks that make up the basin floors. Clues as to what these rocks might be are afforded by rocks exposed in the neighboring mountain ranges. In this particular hole, the floor is about 5000 feet below the surface and is made up of rocks similar to those that are exposed in the Superstition Mountains northeast of the hole position. Thus, it is possible to say at this point that the basin-fill is about one mile in thickness.

The rock unit that contains the bitumen occurs in the interval 3100-3200 feet. The small, black, chip-like fragments are embedded within an ash-gray, finely textured rock that is itself somewhat of a mystery (Fig. 1). Although I can give it a preliminary description, I am not yet willing to name it with conviction. When placed in hydrochloric acid, fragments of the rock fizz or effervesce signifying carbonate content, probably calcite. Soon, a colorless rind forms on the fragment and internal bubbling can be seen with the aid of a binocular microscope. When the acid reaction ceases, the remaining insoluble material tends to retain the shape and size of the original rock fragment. This insoluble framework is amorphous silica (like opal) in which the black bitumen fragments remain enclosed (Fig. 2). The original rock, then, appears to be a porous silica gel in which the pores are filled with microcrystalline calcite.

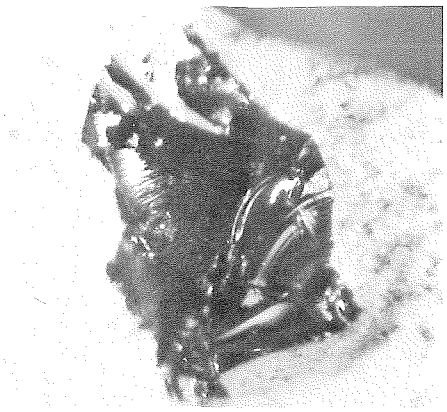


Figure 1. Microscopic picture of tar chip enclosed in sedimentary matrix composed of microcrystalline calcite dispersed through a framework of amorphous silica. Note the conchoidal fracture of the black substance. 60X

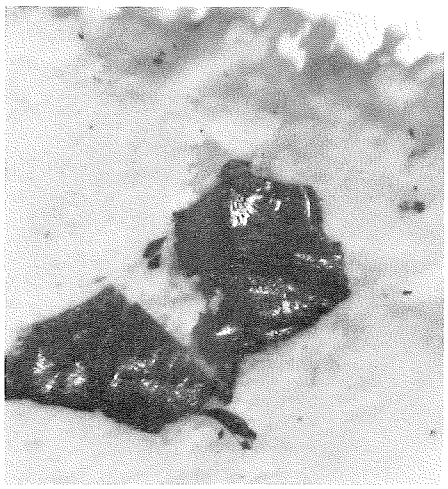


Figure 2. Similar to figure 1 after acid leaching to remove soluble calcium carbonate. Note the remaining insoluble silica framework. 60X

The origin of this sedimentary rock and the genetic history of the enclosed bitumen fragments are challenging geologic mysteries. Although this occurrence does not represent a directly useful resource, the implications are interesting to contemplate, and contemplation often leads to new ideas and additional effort.

NEW BUREAU PUBLICATION POLICY

As many of our more regular correspondents have already found out, publications of the Bureau are no longer distributed free of charge to residents of Arizona. This new policy became effective on the 9th of August, and is the result of new legislation passed by the last session of the Legislature. We are pleased with the preliminary reactions to this new arrangement – the most frequently expressed comment suggests that this policy should have been established years ago.

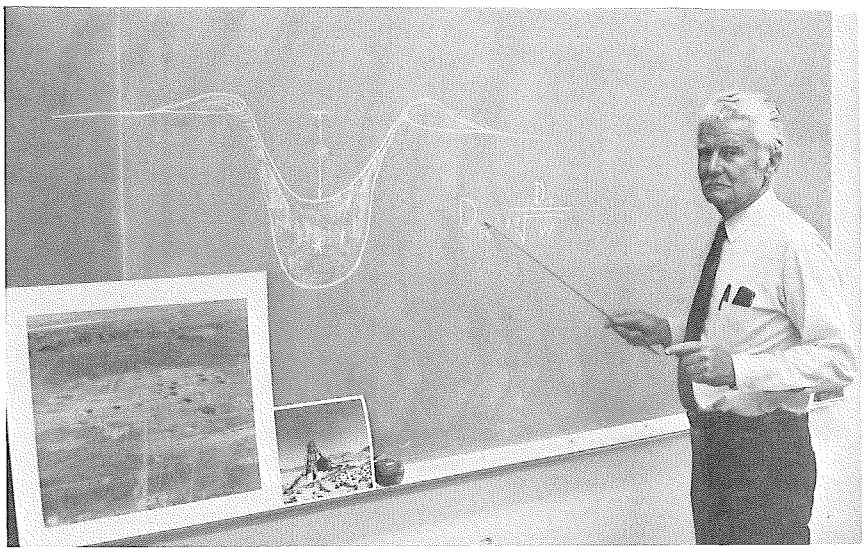
Basically, the new legislation established and funded a revolving publications fund from which the Bureau will pay for its new publications and into which all proceeds from the sale of publications will be deposited. Thus, the publication fund will be self-generating. We anticipate that this new arrangement will enable the Bureau to improve its publication series, to publish on a more frequent schedule, and to issue more timely information.

NEW BUREAU BULLETIN

Bulletin 189, INDEX OF MINING PROPERTIES IN PIMA COUNTY, by Stanton B. Keith, is now available from the Arizona Bureau of Mines. It is the second of the planned series covering Arizona Counties; the first of the series, Bulletin 187, covered Cochise County.

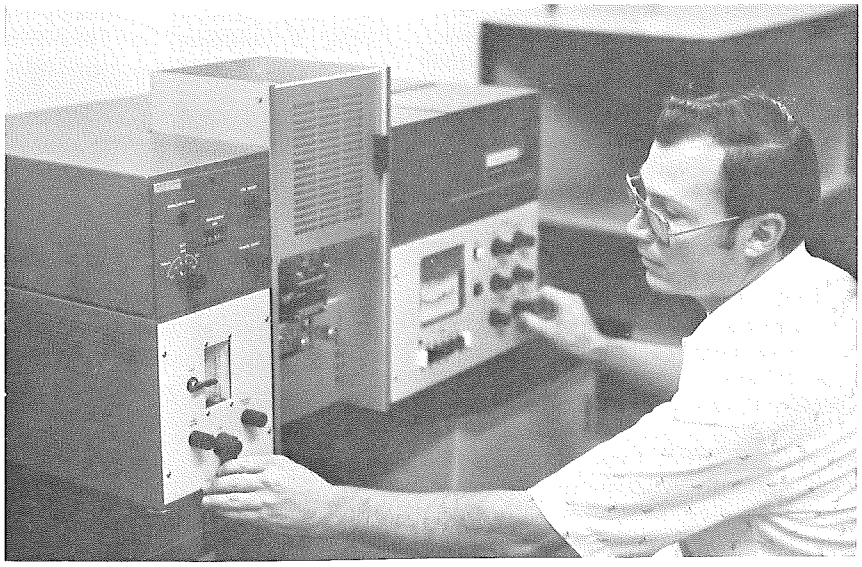
Pima County has had a long and important history as a mineral-producing area in Arizona, dating back to at least the 1600s. Since then, many mines, both large and small, have contributed to the total output. The big increase in production came with the opening up of the large open pit copper mines, now eight in number. The index summarizes the available information on the mines as to location, mineral products, geology, type of operation, and production. References form a compilation from Federal and State publications and file records, articles in technical journals, college and university theses, public and private reports, and newspaper clippings. The new bulletin does not attempt to list every mining property that has existed in the County up through 1972. The selection was made on the basis of the relative importance of their production record, or because the occurrence or the characteristics of the occurrence appeared to indicate the possibility of additional mineral resources. This latter factor would be of value in land use planning.

Bulletin 189 is priced at $2.00 per copy, plus 20¢ for postage and handling if ordered by mail.

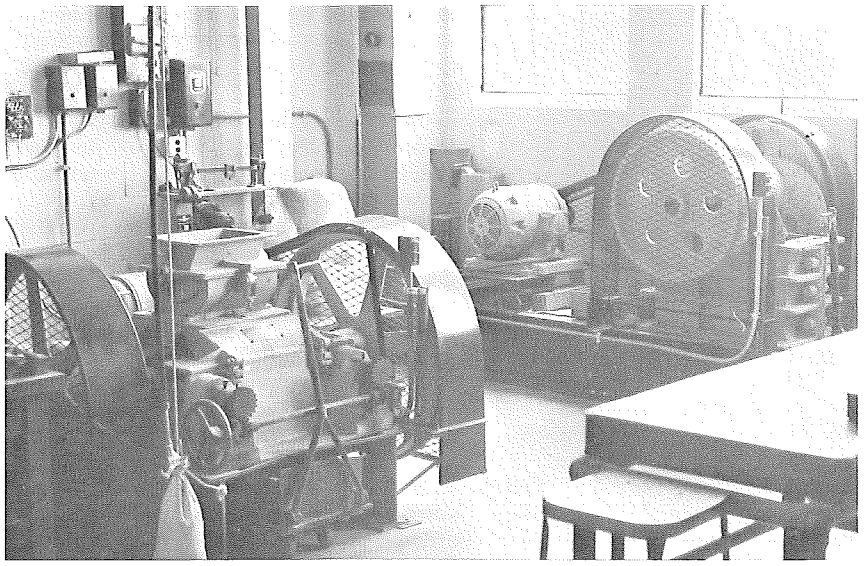


Bureau mining engineer, David Rabb, is teaching a course in solution mining for the University's Department of Mining and Geological Engineering. His expertise in this area adds a new dimension to the mining curriculum. Bureau staff members frequently contribute their services for special teaching assignments in the University.

MINERAL

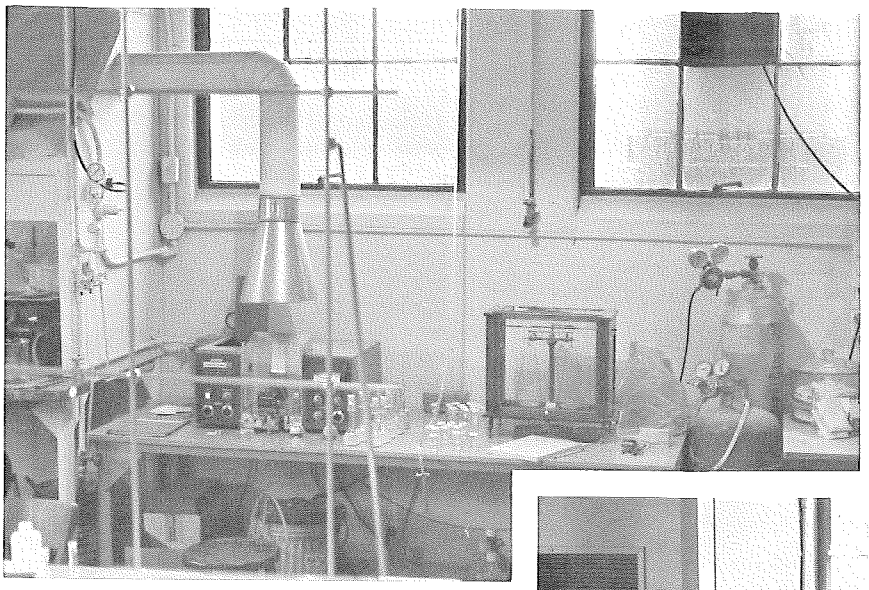


Dr. Walter Fisher, a metallurgist for the Bureau, is assembling the new atomic absorption spectrometer recently acquired by the University's College of Mines. This instrument will provide more accurate and rapid chemical analysis for research projects. Dr. Fisher supervises the use of this and other analytic instruments for the Bureau of Mines and the College.



ACTIVITIES

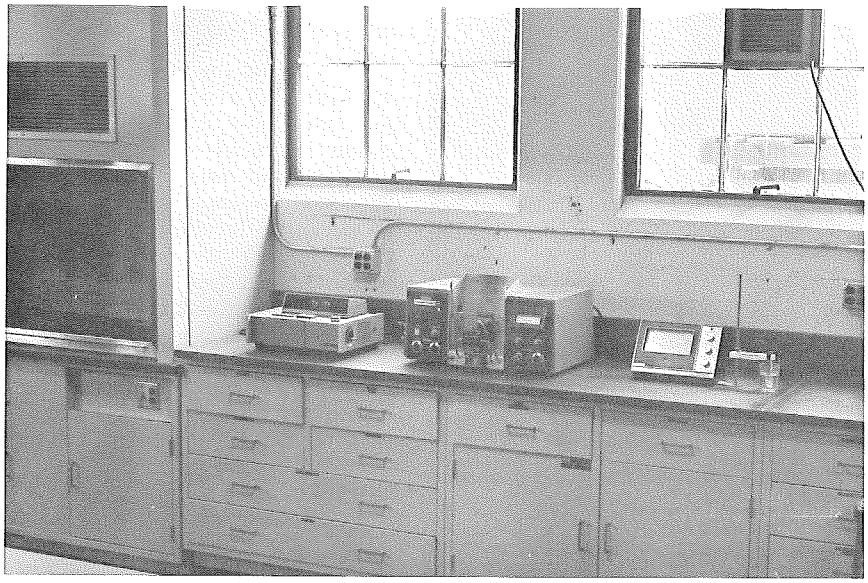
The Bureau maintains a well equipped crushing laboratory for the use of the Bureau and College of Mines. This facility is also used frequently by other departments in the University and several of the local mining companies.



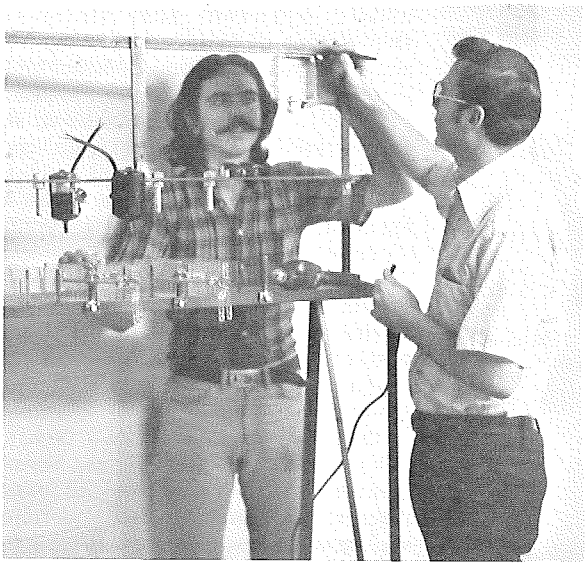
OLD

The Bureau's research laboratory recently got a face lift with the installation of new laboratory benches, sinks and fume hood. This improvement in facilities will promote more precise work and improves safety during research.

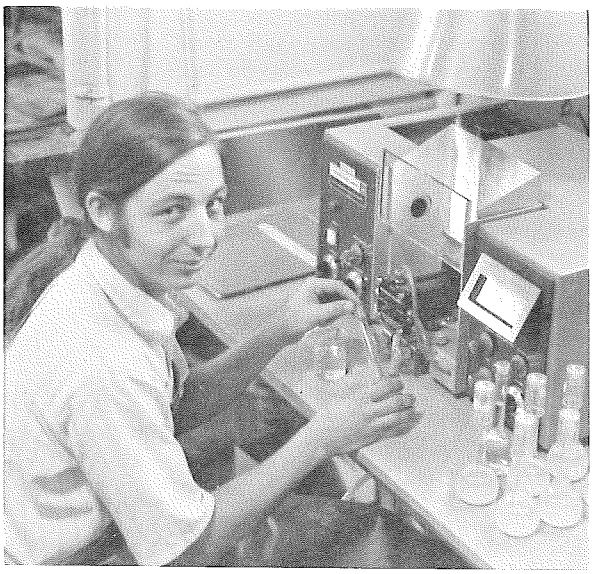
NEW



TECHNOLOGY



Bureau metallurgist, Dr. Walter Fisher, is working with graduate student, Dwight Ridenour, to build a laboratory solvent extraction pilot plant. This unit will be used by the Department of Metallurical Engineering for classroom demonstration and experimentation. It will also prove very valuable as a research unit for both the Department and the Bureau.



Gus Hiller, a University undergraduate student, is performing chemical analysis for a Bureau project using the atomic absorption spectrometer. Work assignments such as this provide not only financial support for University students, but serve as valuable extention of their education.

GEOLOGIC CROSS SECTIONS OF ARIZONA DONATED TO THE UNIVERSITY OF ARIZONA

The Arizona Bureau of Mines is pleased to announce that it has placed on open file 51 geologic cross sections and accompanying location maps which cover the southern half of Arizona and significant parts of southeastern California and southwestern New Mexico. The sections were donated to the University of Arizona by Tucsonan Mr. Carl B. Richardson, their compiler, for release through the Arizona Bureau of Mines.

Mr. Carl Richardson (left) explains to Dr. H. Wesley Peirce, Geologist, Arizona Bureau of Mines, the details of one of the geologic cross sections he has donated to the University of Arizona.

Mr. Richardson initiated his cross section work in the Texas Gulf Coast region 39 years ago. For 25 years he used this technique in evaluating regional geologic relationships as they pertained to possible oil and gas accumulations. Subsequently, after retirement, he decided to apply this method to assist in developing some understanding of the fascinating but complex geology of southern Arizona. After four years of full-time effort, at his home, Mr. Richardson produced 51 cross sections which cover the area in Arizona from the Mogollon Rim south to the Mexican border, and extend eastward into New Mexico across the Rio Grande and westward into California to the Salton Sea and the Mohave Desert. This is an area of almost 150,000 square miles.

The cross sections are drawn on a horizontal scale of 4 miles to 1 inch and a vertical scale of 2000 feet to 1 inch making a vertical exaggeration of about 10 to 1. They are oriented approximately N 60° E and parallel one another at intervals of 8 miles. Each cross section is about 6 feet in length and represents an actual distance of approximately 300 miles.

The geology was compiled from published and other available information indicated beneath each feature. Mr. Richardson hopes that the study of these cross sections will aid geologists as a time-saver in forming preliminary ideas regarding the nature of both the local and regional geology of the region.

The Bureau has prepared reproducible copy which is available to those who want prints made at their expense. Loan arrangements for the reproducible copy can be made at the Bureau offices, Room 324, Geology Building, The University of Arizona.

RESEARCH *Continued*

feed material to smelters and to the various hydrometallurgical refining processes. Since the flotation process is of prime importance to Arizona's copper industry, and because it is known to be very sensitive to chemical contaminants, most of our research has been devoted to determination of what effects sewage effluent might have on flotation.

Preliminary results from this study indicate that there are many problems associated with using sewage effluent in the flotation process. Continued laboratory work will undoubtedly lead to a better understanding of the problems involved. However, it is felt by our staff that ultimately a small plant simulating the actual operations (pilot plant) will have to be constructed and managed cooperatively by the Bureau of Mines, the City of Tucson, Pima County, and the mining companies, in order to provide the operating data necessary to use sewage effluent in a copper concentrator. At the present time, informal discussions between the interested parties are exploring the possibility of constructing such a pilot operation.

Jerry Kelly, graduate research assistant for the Bureau's sewage effluent project, is performing a laboratory flotation test.

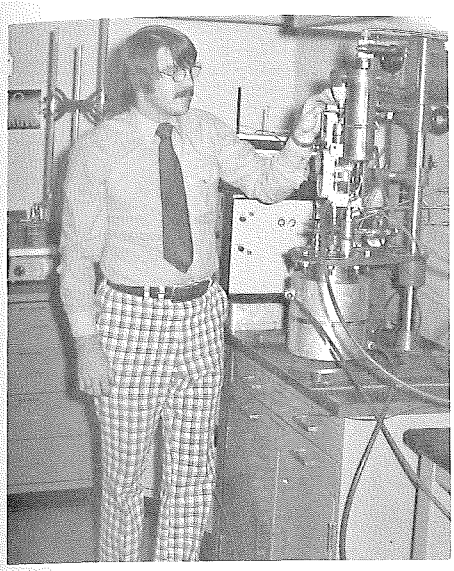
Leaching Studies

National concern for environmental pollution has led to the enactment and enforcement of clean air regulations. The new air quality requirements have placed severe strains on Arizona's copper industry because much of the technology to prevent air pollution from smelters did not exist when the new regulations became effective. New smelting techniques, as well as new or improved methods for cleaning smelter gas, had to be developed in a short period of time. Compliance with the clean air standards is being accomplished by modifying existing smelter facilities, building entirely new facilities using new smelting methods, and by using new hydrometallurgical (solution) extraction processes.

Hydrometallurgical recovery processes are carried out in two basic steps. First, the valuable metal is extracted from the ore and dissolved in a solution by the process of leaching. The leaching stage of extraction is often performed in a stirred reactor in which finely ground ore, or concentrate mixed with a solution, is stirred vigorously by a propeller or turbine. After the metal is extracted into the solution, it is recovered by a precipitation process. The precipitation may be electrowinning in which the metal is displaced from the solution and deposited on an electrode by electricity. Or, the recovery may be accomplished by a chemical reaction which forms a metal or a metal salt.

The Arizona Bureau of Mines is involved in two hydrometallurgical research studies which promise to add to the growing technology in this field. The first project is being conducted as a joint effort between the University's Department of Metallurgical Engineering and the Arizona Bureau of Mines under a grant from the U.S. Bureau of Mines. The purpose of this investigation is to study the extraction of copper from copper ores by dissolution in a cyanide solution. This leaching study is being done by a Metallurgical Engineering graduate student as his thesis research under the direction of a Bureau metallurgist. The results from this study, in addition to adding new knowledge about leaching processes, could provide a new, alternative method for recovering copper from some ores.

One of the many problems faced by a metallurgist is designing a commercial-scale plant on the basis of laboratory research. The current trend in scaling up a leaching process is to study the leaching system on an ever-increasing scale, one step at a time, up to the full-scale plant. In a way, this seems to be a logical approach since there is not a very large step from one pilot plant scale to the next and by the time a commercial



Chemical Engineering graduate student, Steve Light, is conducting research to develop new techniques for scaling laboratory leaching studies up to commercial scale.

scale is reached, most of the operating problems have been overcome. The difficulty with this approach, however, is that it is much too costly in time and money. An alternative or shortcut to this lengthy, expensive procedure would be of significant assistance to the mineral processing industry.

The Arizona Bureau of Mines is currently involved in a joint research effort with the University's Department of Chemical Engineering to develop new scale-up technology that will assist the minerals industry in the design of commercial leaching plants on the basis of small-scale laboratory experiments. The investigation is being sponsored by the U.S. Bureau of Mines and is being conducted by a Chemical Engineering graduate student as part of his thesis research. Successful conclusion of this work could be of considerable value to a number of Arizona copper companies, as well as the industry in general, in the development of new hydrometallurgical recovery processes.

BUREAU *Continued*

necessary to formulate effective land use and mineral resource policy. In filling this role, the Bureau will be acting increasingly in an advisory capacity to state and local government, other state agencies, and the public in these matters.

In order to formalize the changing activities of the Bureau, and to modernize its structure and purpose, a proposal to reorganize the Bureau is being prepared for submission to the next session of the Arizona legislature. The reorganization plan proposes to change the name of the Bureau to the "Arizona Bureau of Geology and Mineral Technology" and to organize the Bureau into a State Geological Survey and a Mineral Technology Research Center. Also included in the reorganization proposal is the provision for an advisory council whose members will be drawn from other state agencies, industry, and the public. The revised purpose of the reorganized Bureau will be "to conduct research and to provide information and advice to the legislature, governmental agencies, industry, and the public" in order to promote the wise use of the lands and mineral resources of the state.

METALLURGIST JOINS BUREAU

The Bureau is pleased to welcome Samuel Rudy to its staff as an Assistant Metallurgist. Sam was formerly with the Foote Mineral Company in Kings Mountain, North Carolina, where he was involved in mineral beneficiation process development. His main areas of interest are mineral beneficiation and hydrometallurgy.

Samuel Rudy — New Assistant Metallurgist

Sam is no stranger to Arizona. He grew up in Bagdad and later attended the University of Arizona where he received the B.S. Degree in metallurgical engineering in 1969. After working for the Duval Corporation in Tucson, Arizona and at Battle Mountain, Nevada for two years, Sam continued his education at the University of Nevada where he earned the M.S. Degree. Upon completion of his M.S. study, he joined the staff of the Garrett Research and Development Company in La Verne, California. At Garrett, Sam helped to develop techniques for recovering valuable materials from municipal refuse. After two years with Garrett, he joined the staff of the Foote Mineral Company. Sam is a member of AIME.

URANIUM SURVEY GRANT

The Geological Survey Branch of the Arizona Bureau of Mines has received a grant of $42,000 from the Uranium Research Branch of the United States Geological Survey. The grant is for a one-year study of the subsurface uranium potential of the Mogollon Slope of Arizona, an area in excess of 5000 square miles. The Mogollon Slope is the region from the Mogollon Rim to the Little Colorado River, between the Verde Valley on the west and the New Mexico state line on the east. The study is envisioned to include an examination of the geologic habitat of uranium occurrences exposed along the Rim zone. This information, combined with existing drilling data, will be used to assess the likelihood of a subsurface geologic environment encouraging to uranium exploration.

THESES

Inquiries concerning the availability of the following theses should be directed to the University or College department under which they are listed. THEY ARE NOT AVAILABLE FOR DISTRIBUTION FROM THE ARIZONA BUREAU OF MINES.

ARIZONA STATE UNIVERSITY

Geology Department

1974. James Douglas Bliss: Selected Topics in the Geochemistry of Mercury; MS, 109p.
1974. Robert Kimball Merrill: The Late Cenozoic Geology of the White Mountains, Apache County, Arizona; Ph.D., 202p., 2 plates.
1974. Jan Stewart Racey: Conodont Biostratigraphy of the Redwall Limestone of East – Central Arizona; MS, 199p.

UNIVERSITY OF ARIZONA

College of Mines

1973. Fahad Isa Masri: The Electro-osmotic Permeability of Tailings from an Arizona Porphyry Copper Mine; MS.
1974. Abdellatif A. Oahwash: An Application of Mathematical Models for Determining the Optimum Pattern of a Geophysical Exploration Program; Ph.D.

College of Earth Sciences

1973. Thomas A. Earl: A Hydrogeologic Study of an Unstable Open-Pit Slope, Miami, Gila County, Arizona; Ph.D.
1973. Louis L. Jacobs: Small Mammals of the Quiburis Formation, Southeastern Arizona; MS , 77p.
1973. Edward I. Wallick, Isotopic and Chemical Considerations in Radio-

carbon Dating of Groundwater within the Arid Tucson Basin, Arizona; Ph.D., 184p.

1974. Jeffrey Alan Boyer: Hydrogeology of the Carefree Ranch Area, Maricopa County, Arizona; MS , 75p.

1974. Jerry Davis: Geothermometry, Geochemistry and its Alterations at the San Manuel Porphyry Copper Ore Body, San Manuel, Arizona; Ph.D.,

1974. Rick Stewart Fredericksen: The Secondary Dispersion of Tungsten in Some Southern Arizona Tungsten Districts; MS, 152p.

1974. William Jones: Geology of the Northern Portion of the Ajo Mountains, Pima County, Arizona; MS.

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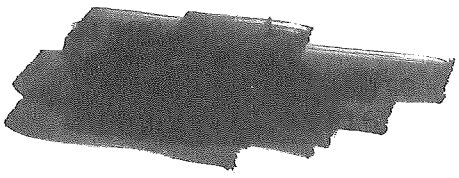

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