FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

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COAL
Arizona's Most Important Energy Resource?

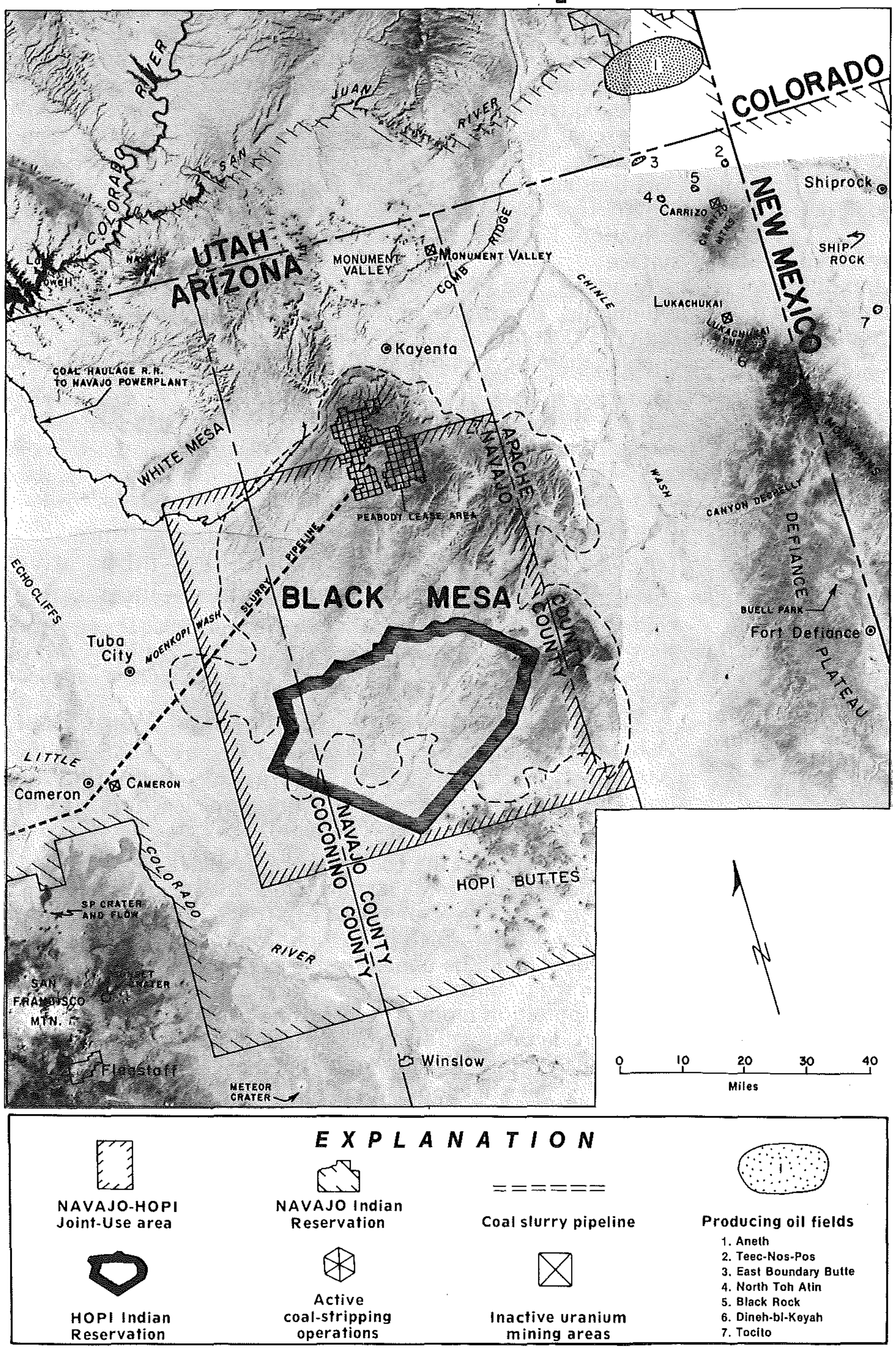

Figure 1. 20,000 square miles of Arizona and adjoining states are shown on this LANDSAT imagery.

by H. Wesley Peirce
Geologist

Coal *is* Arizona's most abundant naturally occurring fuel energy resource. This fact alone seems sufficient justification for considering seriously its possible place in Arizona's critical energy situation. This brief article attempts to encourage and assist state and area leaders in developing a realistic Arizona coal perspective that, hopefully, will lead to a deliberate, responsible course of action designed to assess fully the future viability of Arizona coal resources.

The sum of geologic experience in Arizona indicates that the principal coal resources are on, around, and beneath Black Mesa, a 3,200-square mile geologic remnant located exclusively on Indian lands in parts of Coconino, Navajo, and Apache counties, in the plateau country of northeastern Arizona. Although there are other occurrences of coal and carbonaceous materials in Arizona, they do not appear to contain resources of economic potential beyond possible local usage.

Black Mesa Indian lands containing coal resources are of three basic categories: (1) Hopi land, (2) Navajo land, and (3) Joint Use land that is currently the subject of complex litigation. The present coal operations of the Peabody Coal Company embrace lands of the latter two categories. Figure 1 shows the details of the Peabody Coal Company project on Black Mesa. Coal for the Four Corners power plant in New Mexico is supplied from coal resources on Navajo lands in New Mexico, and additional coal leases on New Mexico Navajo lands have been let. There is no known current coal activity on Arizona Indian lands other than the Peabody operation.

Black Mesa has achieved a type of fame by having its name appear on bumper stickers. However, how much generally is known about it is another matter. By way of review, it is a rather distinctive physiographic feature, especially towards the northeast where it is bounded by an escarpment with a relief of about 1,500 feet between the elevations 6,000-7,500 feet. The mesa surface slopes to the southwest where the less imposing southwest edge is at the elevation range 5,500-6,000 feet, the general locale of the famous Hopi mesas. Black Mesa constitutes about 3 percent of the land area of Arizona and is larger than the state of Delaware. The general peripheral distance of the Mesa exceeds 160 miles and it is roughly equidimensional in shape, about 60 miles long in both NE-SW and NW-SE directions. Coal is exposed on all sides and in interior canyons of Black Mesa, which indicates that the coal resources of this area could be far larger than are currently defined.

The Mesa is an erosional remnant of once more extensive coal-bearing strata similar in age and closely related to the larger coal resources of the greater Rocky Mountain region. Since coal accumulation during the latter part of the Cretaceous Period of geologic time (70-135 million years ago), earth forces and subsequent erosion have warped and destroyed coal resources and related strata. Black Mesa represents the largest, most significant remnant of this history that is preserved in Arizona. This warping flexed Black Mesa's strata into gentle, elongate, low-amplitude folds. While erosion has stripped strata from the fold crests, these same strata tend to be preserved in the fold troughs. The Peabody coal reserves are preserved in one of these troughs, called the Maloney Syncline.

The thickest remnant of Cretaceous strata preserved in Black Mesa is about 1,700 feet thick at the northeast end of the Mesa. Southwestward, erosion has worn or truncated these strata into a crude, tapering wedge. Because coal is confined to the Cretaceous-aged rocks, it is not found more than 1,700 feet below the surface.

The Cretaceous rocks have been subdivided into five formations, three of which are notably coal-bearing. From the bottom (oldest), these are known as the Dakota Sandstone (coal-bearing), Mancos Shale, Toreva Formation (coal-bearing), Wepo Formation (coal being exploited), and the locally present highest unit, the Yale Point Sandstone. Coal from each of the coal-bearing formations has been mined on a small scale and was utilized before the introduction of natural gas as fuel for power plants in Hopi and Navajo tribal communities.

Although coal mining on Black Mesa dates back into prehistoric times, large-scale mining didn't begin until the 1970s. Prior to this time the record indicates that ten small underground mines had been operative in providing fuel for local use and for limited shipment to Holbrook, Winslow, and Flagstaff. Although the overall total production from these mines probably was less than 300,000 tons, they serve a useful function because they afford some experience with the characteristics of relatively fresh coal from each of the three coal-bearing formations.

Williams (1951) suggested that Black Mesa coal would not be produced on a large scale until three problems were overcome: (1) transportation costs, (2) need for a large market, and (3) adequate water supply. In 1966, the Peabody Coal Company announced plans to initiate a large stripping operation at the north end of the Mesa. Contracts with two power plants call for the delivery of about 400 million tons of coal over a span of 35 years, an average of 11 million tons each year. In one case coal is supplied through a slurry pipeline 275 miles long to the Mohave plant just across the Colorado River in Nevada, in the other it's supplied by rail to the Navajo plant in Page, Arizona. Figure 2 shows the total coal-mining, power-generating complex being developed in the Four Corners region.

Thus, a large market has been developed for power; transportation costs have been handled economically by pipelining and by moving the plants close to the fuel sources; and water requirements are supplied by groundwater that is pumped from an aquifer beneath the coal-bearing Cretaceous strata. This water is pumped at a rate of about 2,000 gallons per minute from four wells.

Peabody coal reserves occur within about 130 feet of the surface (this is the maximum stripping depth, which may change with time), and underlie about 14,000 acres of leased Tribal land (which is about 0.7 percent of Black Mesa's total area). It is estimated that about 16 million tons of strippable coal underlie each square mile of the Peabody lease. If one assumes that one square mile coal one foot thick weighs close to one million tons, one can calculate that an average of 16 feet of minable coal underlies each square mile of the Peabody lease. Several seams have been identified that range from 5 to 28 feet thick; none are of consistent thickness, though.

It has been stated that the coal resources of Arizona represent the greatest known concentration of conventional fuel energy materials within the state. This is easily demonstrated by using energy equivalents to compare Arizona's coal reserves and petroleum production. Conservatively, one ton of coal is the energy equivalent of four barrels of oil. The total all-time production of crude oil in Arizona is about 15 million barrels. In terms of coal equivalent this equates to less than four million tons of coal — an amount found beneath just ¼-square mile of the Peabody lease!

The coal being mined by Peabody comes from the Wepo Formation. There is no current exploitation of the other coal-bearing formations, the Dakota and Toreva. Table 1 summarizes the estimated coal resources of Black Mesa by formation. Recall that all coal occurs within 1,700 feet of the surface.

Although the coals from these three formations are bituminous, they differ in quality as regards ash and sulphur. Both the Dakota and Toreva coals are higher in ash and sulphur content than the Wepo formations, as summarized in Table 2.

Table 1 — Estimated Gross Coal Resources of Black Mesa

	Billions of short tons	Utilization
Wepo Formation	5.65	presently being mined
Toreva Formation	6.00	small mines—inoperative
Dakota Sandstone	9.60	small mines—inoperative

Table 2 — Quality and Heat Content of Black Mesa Coals

	Dakota Coal	Toreva Coal	Wepo Coal
Av. ash (%)	11.9	13.8	5.20
Av. sulphur	1.62	1.09	0.58
Av. BTU/lb	11,125	12,338	12,382

Indications are that the coal resources of Black Mesa are large and for the most part remain unexplored. The region is large and much of it is relatively uninhabited. There is a wide range of opportunity, within which discussion, exploration, and possible development might be undertaken, especially as regards mining style (surface or underground), location and size of operations, and transportation modes. Perhaps one or more of the various Tribal jurisdictions will find it in their best interest to learn more about this resource and thus encourage systematic and deliberate investigations that might be of assistance in establishing a possible format for the planning and management of some additional development of Black Mesa coal resources.

It seems likely that Arizona's large industries eventually will turn to coal as an energy fuel. As of this date, coal is shipped into Arizona from New Mexico and used to generate electrical power. However, can we rely upon New Mexico's continuing to ship its diminishing energy resources to an expanding list of Arizona's users?

It would appear to behoove Arizona's leaders to investigate seriously all possible avenues to the development, however limited, of additional Black Mesa coal resources for utilization within the state. However, it should be pointed out that at the

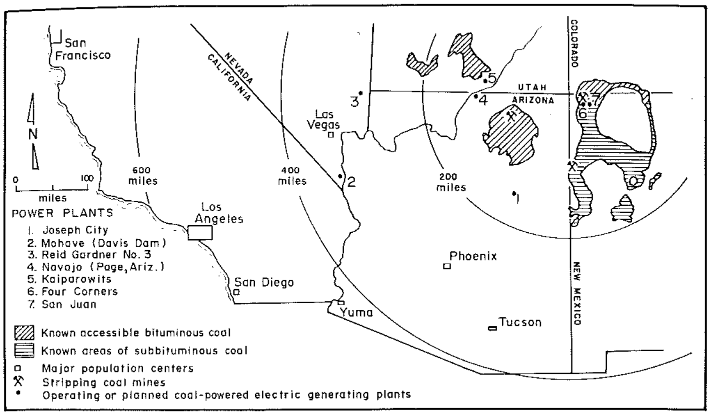

Figure 2. Operating and planned coal-fueled electrical generating plants and major coal fields in the Four Corners region.

present time there is no transportation available for shipment of Black Mesa coal to Arizona's population centers.

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Applied Remote Sensing Lab at the U of A

Remote sensing is the gathering of information from such devices as cameras, multispectral scanners, radar, and thermal infrared detectors located in aircraft or spacecraft.

Most of us are aware of the usefulness of conventional aerial photographs. Civil and mining engineers, cartographers, geologists, and others involved in the study of the earth's surface have been using aerial photographs for many decades. More recently, the technology of recording remotely-sensed data from various types of platforms has become sophisticated enough to warrant a special field of study commonly referred to as "Remote Sensing."

Many geologists, engineers, and students in the Tucson area have been utilizing remote sensing data available from the National Aeronautics and Space Administration (NASA) through the local administration of the Office of Arid Land Studies at the University of Arizona. The library of materials, which has steadily grown, has recently found a new home. The new location for viewing or using the wide variety of available imagery is the Arizona Bureau of Mines/College of Earth Sciences Remote Sensing Laboratory, Room 334 of the Geology Building on the University of Arizona campus, Tucson. This program is supported by a NASA grant to the Office of Arid Lands Studies.

The Applied Remote Sensing Program (ARSP) at the University of Arizona serves a three-fold purpose: (1) to maintain a library of satellite and high-altitude imagery, (2) to provide expertise in remote sensing techniques and applications, and (3) to cooperate with local, state, and federal agencies within Arizona in developing and utilizing remote sensing projects for planning purposes.

Because of the increasing interest in remote sensing techniques and their applications, personnel of the ARSP are often called upon to speak to university classes, governmental agencies, and private meetings. Visual displays of imagery and equipment, as well as visits to the lab, help interested parties become more knowledgeable with the program and its capabilities.

Although providing remote sensing expertise and maintaining a library are two important functions of the program, another major effort is developing proposals for projects and working with various agencies on those projects, most of which involve studies concerning land-use planning and agricultural and water-shed management. As stipulated in NASA's grant to the program, the results of completed projects are intended to be used for rational planning decisions.

Many of the non-agency users of remote sensing materials are prospectors and geologists from private industry. The modern "explorationist" still uses black and white and natural color photographs flown at conventional low altitudes for the bulk of his remote sensing imagery needs. Indeed, this conventional imagery is the most detailed scale to analyze and use as a base map for local studies. High altitude imagery from NASA research aircraft offers a medium, or intermediate, scale to study regional, gross geologic features. Satellite imagery generally has only limited application for the "explorationist." However, the area covered by a single satellite image affords an opportunity to study certain geologic features, especially those of structural origin, at a scale where the larger features (often missed in more detailed studies) are more easily defined.

Other remote sensing research concerning nonrenewable resource exploration involves color enhancement techniques. Certain tonal registers from film imagery or digital computer data from electronic imagery are enhanced to accentuate the desired feature. Present research suggests that certain rock types and rock alterations zones are discernable under restricted conditions. Once these techniques are refined, exploration targets in remote regions of the world may be defined prior to surface geologic studies. Contrary to rumors being circulated by some less informed prospectors, remote sensing satellite imagery is not yet quite able to pinpoint the location of hidden gold deposits or buried treasure.

Included in the ARSP library's NASA-derived imagery collection are photos taken from high altitude flying aircraft such as the U-2, or from satellite platforms. Most of the satellite coverage is from the Earth Resources Technology Satellite (ERTS) 1 and 2, now designated as LANDSAT 1 and 2. There is also limited Skylab, Gemini and Apollo coverage of Arizona. [*See pages 4 and 5.*]

High altitude flights cover the southern half of Arizona and an 18-mile wide corridor along the Colorado River between Lake Mead and Yuma. Both 9 in. by 9 in. color infrared (CIR) and natural color positive transparencies, and 70mm multispectral black and white (B & W) and CIR positive films are available for use.

LANDSAT imagery covering the entire state and portions of adjacent states and Mexico is available in 9 in. by 9 in. and 70mm B & W positive transparencies. Because the satellite passes over Arizona on an 18-day cycle, at an altitude of 500 nautical miles, there is a variety of dates from which to choose. *continued*

Remote Sensing *continued*

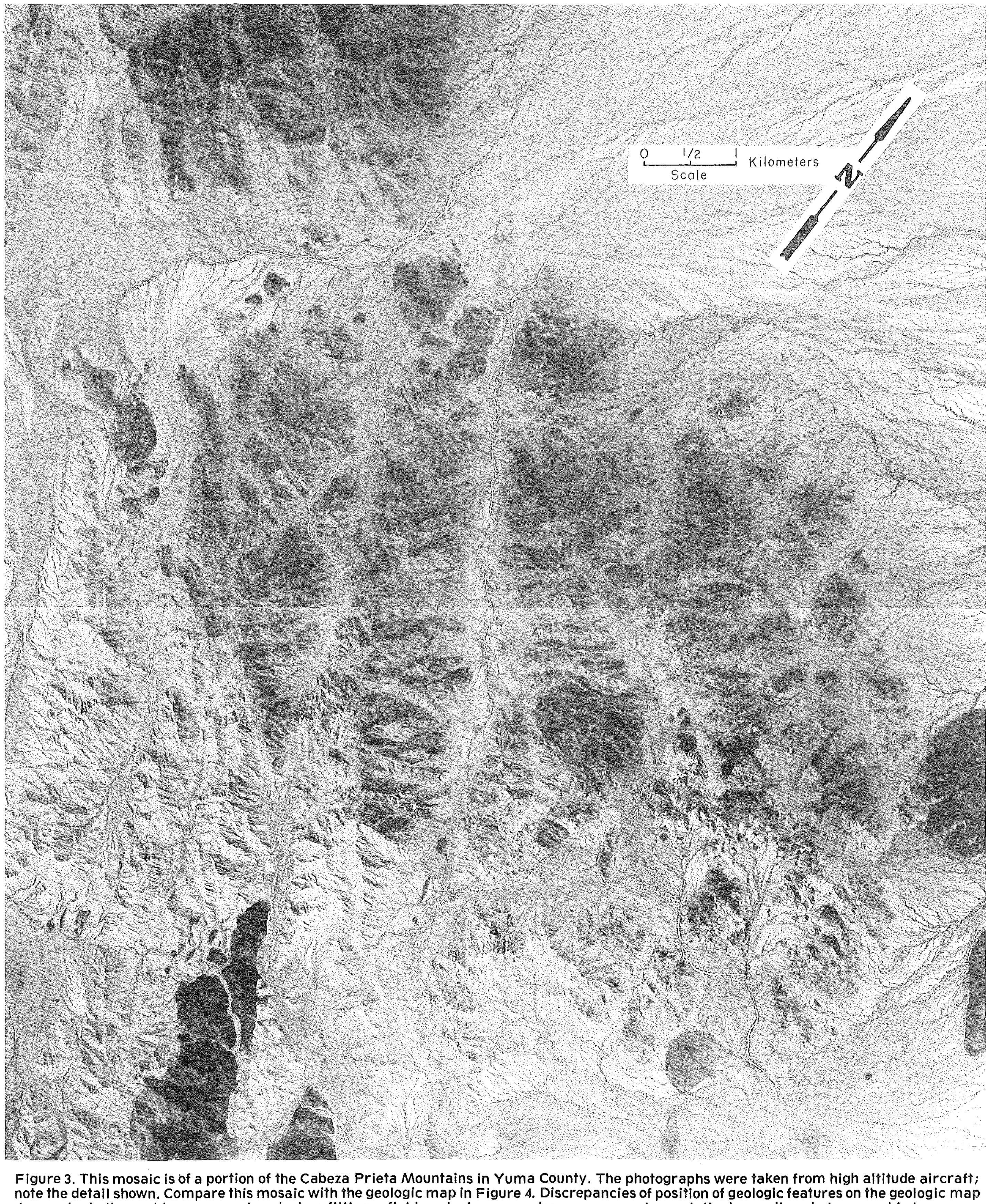


Figure 3. This mosaic is of a portion of the Cabeza Prieta Mountains in Yuma County. The photographs were taken from high altitude aircraft; note the detail shown. Compare this mosaic with the geologic map in Figure 4. Discrepancies of position of geologic features on the geologic map demonstrate the problems encountered when fitting a field geologic-reconnaissance survey to a relatively small-scale topographic base map such as the 2° Army Map Service sheet (scale of 1:250,000).

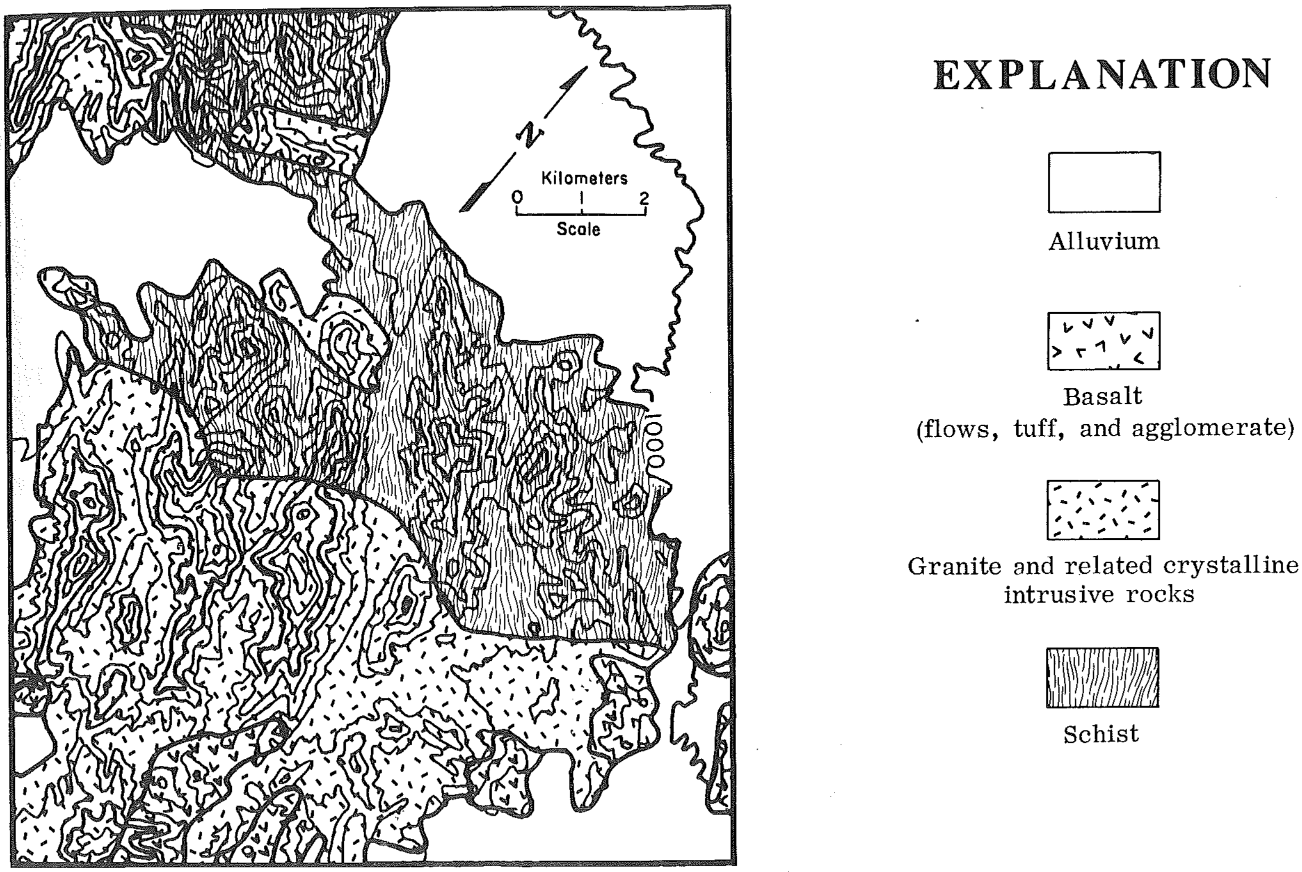


Figure 4. Geologic map of area shown in Figure 3. Data after E.D. Wilson (Geologic map of Yuma County, 1960); topographic base from Ajo 2° AMS topographic map; contour interval 200 feet.

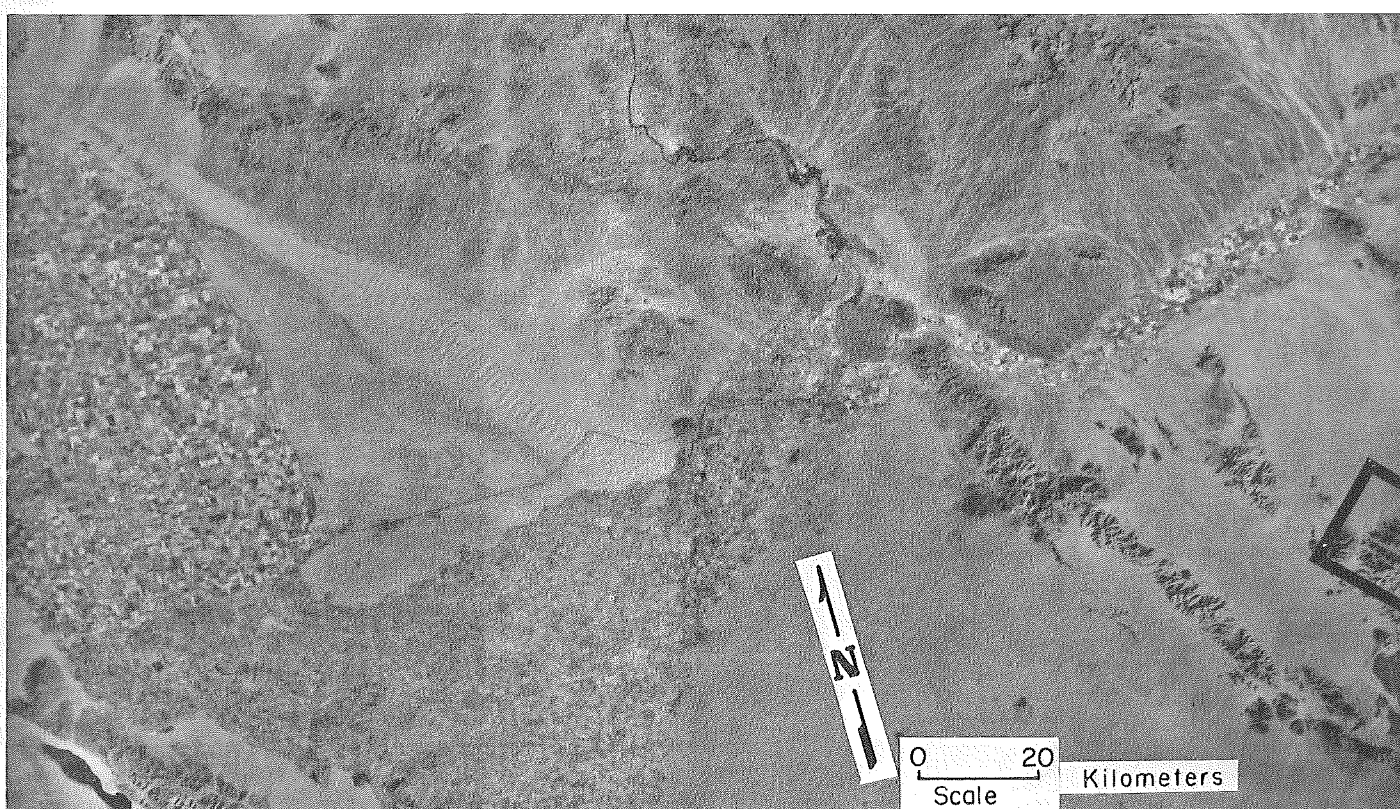
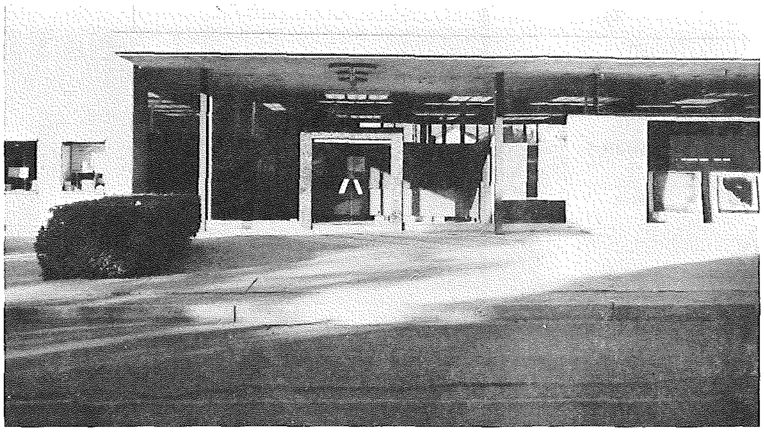
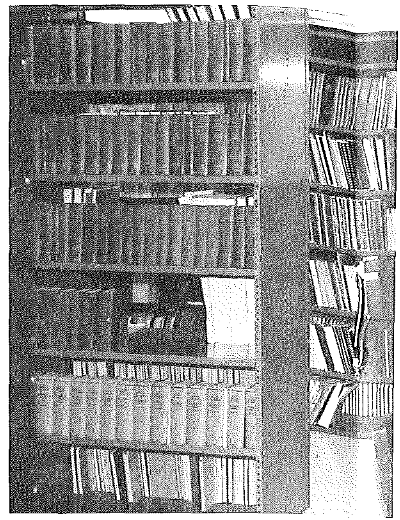


Figure 5. LANDSAT 1 Satellite imagery, band 7 (infrared). The outlined section along the right edge is the same area covered in Figures 3 and 4. Colorado River shows as a thin black line, dividing the photo above the north arrow. Arizona is on the right of the photo, California on the left, and Mexico on the lower left. The regional geologic features can be evaluated relative to the study area.

Continued page 8

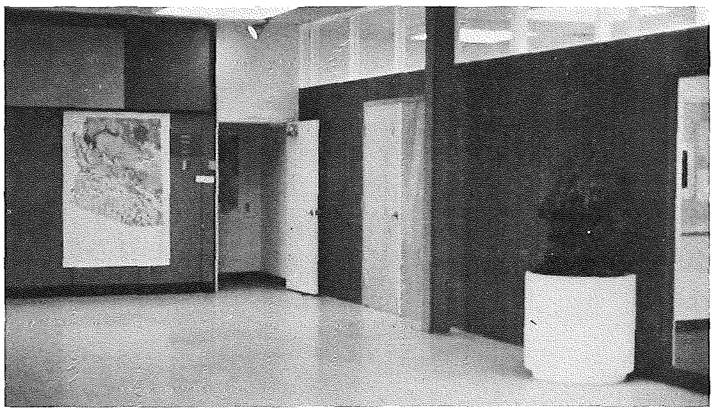


Entrance to the new quarters of the Geological Survey Branch and Publications Office of the Bureau, located at the southwest corner of Park Avenue and Second Street. Free parking facilities are on the far side of the building. Arid Lands Studies' display is in the window to the right; on the left the windows contain Bureau of Mines' displays. The photo is taken from the western edge of the University of Arizona campus, looking across Park Avenue; Second Street is to the right.

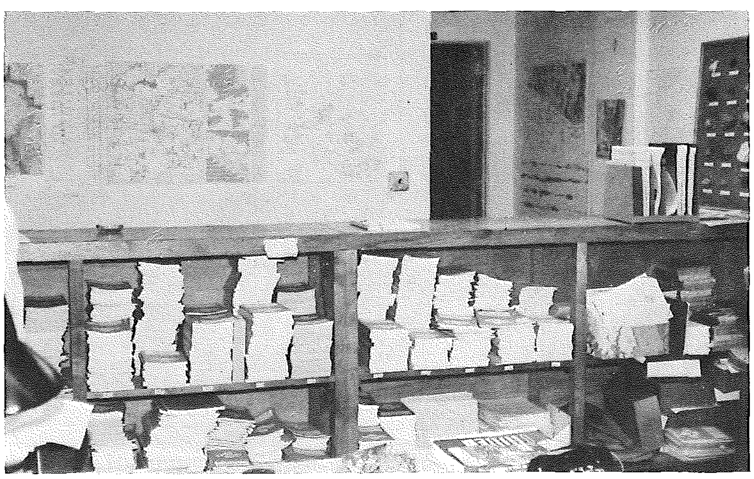


The library, containing over 22,500 publications, adjoins the publication map files is a microfiche reader and a

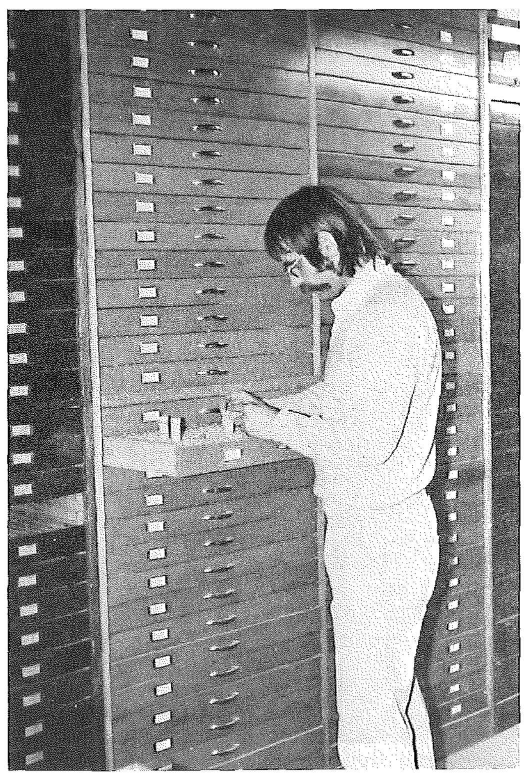
845 North Park

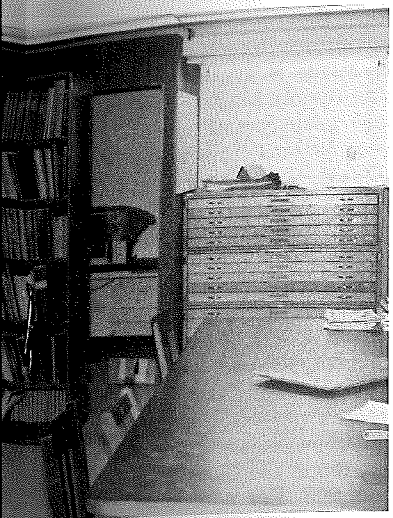


The open door in the center of this photo leads to the Bureau's downstairs quarters from the entrance lobby. The Creative Photography Center is at the extreme right.

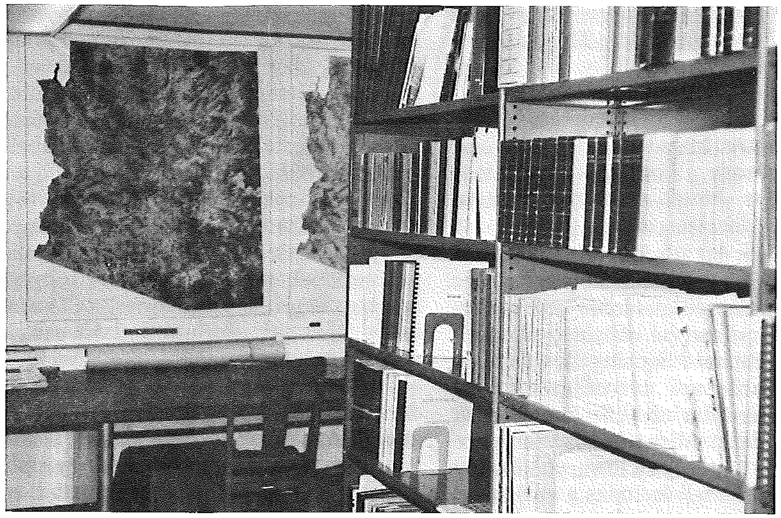


These stacks of publications, ready for sale, may be obtained at the foot of the entrance stairs.





22,500 bulletins, journals, and other
cations sales office. To the left of the
and a microfilm reader/printer.



The library's reading area is seen here from the stacks. The ABM library contains publications from U.S. Geological Survey, U.S. Bureau of Mines, adjoining state surveys' publications, geological and mining journals, open-file reports and maps, files on active and inactive mines, and much other material. Though check-out is not allowed, the facilities are open to the public for use, and copying can be arranged with local blueprint companies or with the Bureau.

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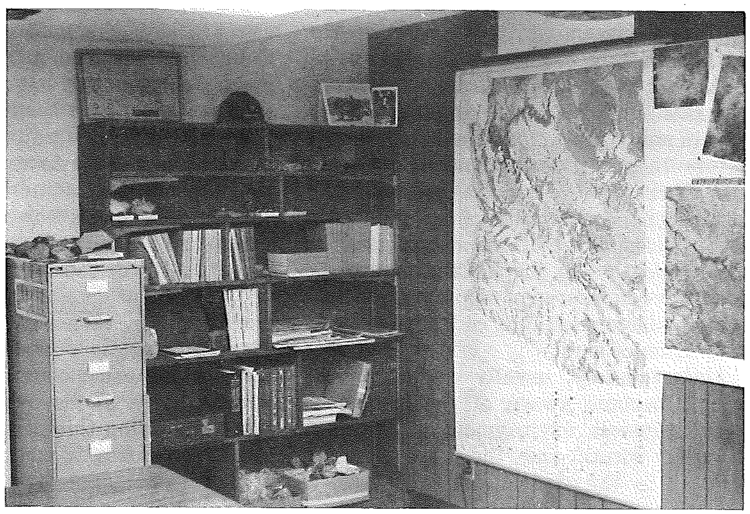
Avenue



Part of a typical geologist's office. Each office contains a drafting table, desk, and enough wall room for maps and photos.

Left: lab technician Tom McGarvin working in the well-cutting storage area. Vials of representative material from measured distances within well holes fill many large cabinets in the Bureau's well-cutting library. Above: core samples from numerous wells are also stored in the Bureau's storage area.

Dr. Dresher, Bureau director, continues to be in Room 134 of the Geology Building on the University of Arizona campus. Offices of mineralogist Bob O'Haire, mining engineer Dave Rabb, and metallurgist Sam Rudy remain in the basement of the Mines Building. Metallurgist Walt Fisher's office is in Room 125E of the Mines Building.

Phones for the Bureau offices are:
Director, W.H. Dresher . . [602] 884-1401
Geological Survey Branch 884-2733
Mineral Technology Branch . . . 884-1943
Publications Sales Office 884-2733

Remote Sensing *Continued*

The lab has received limited area coverage of Skylab imagery. This imagery is available in 5 in. by 5 in. and 70mm natural color positive transparencies. Southern Arizona, California, and Northern Mexico are included in Apollo and Gemini coverage. Both of the latter imagery-types have a 70mm positive transparency format.

Imagery can be used in the lab, and some coverage is available for circulation. Imagery indices are available and ordering information can be obtained through the Applied Remote Sensing Program.

Also available are microfilm catalogs and some microfilm of U.S. and foreign LANDSAT data. Microfilm readers are located in the University library. Viewing equipment in the lab includes a variety of stereoscopes, large light tables, and a color-combiner viewer for 70mm imagery.

The Applied Remote Sensing Laboratory publishes a newsletter several times a year, and Carolyn Sawtelle, the editor, will add your name to the mailing list upon request. Mail should be addressed to Applied Remote Sensing Laboratory, Geology Building, University of Arizona, Tucson AZ 85721; the phone number is (602) 884-1691.

An assistant is on hand in the lab to aid visitors in finding the necessary imagery and to furnish information. There is also a professional staff capable of applying remote sensing techniques to various fields of study including land-use and natural resources inventories.

Particular expertise of graduate student assistants J.S. Conn, John Stelling, and D.A. Miller include urban studies, land-use planning, plant ecology, plant geography, natural resources, and soils morphology. Dr. David A. Mouat, in charge of the lab, has a remote sensing background in geomorphology and plant ecology.

Although physically separated from the lab, the Geological Survey Branch of the Arizona Bureau of Mines is available to assist in interpreting remote sensing data as it pertains to the geology and nonrenewable resources of Arizona. Interested parties should contact John Vuich, a Bureau geologist who has considerable background using remote sensing data for engineering and economic geology studies.

A digitizer, densitometer, and zoom transfer scope are available for use in the Lab for Remote Sensing and Computer Mapping, another remote sensing laboratory on the University campus. Dr. Bill Rasmussen, a research professor in renewable natural resources, is in charge of the lab, which is located in the Bioscience East building, Room 203. For additional information concerning the use of this lab's equipment, call Dr. Rasmussen at (602) 884-3751.

Collapsing Soil—a Geologic Hazard

by Bruce J. Murphy

One of the consequences of urban growth and development in the semi-arid Southwest is an inevitable upset in the natural balance of geologic conditions.

Among the responsibilities of the geotechnical engineer is recognizing these effects and any resultant geologic hazards before they cause economic and human loss. Therefore, a thorough understanding of these natural conditions is essential in these natural conditions is essential in order that we may judiciously incorporate corrective measures in engineering structures and adopt building codes for the best utilization of land.

Unfortunately, usually the only time people become aware of the impact of their physical environment is when a disaster occurs and they are directly affected by the consequence.

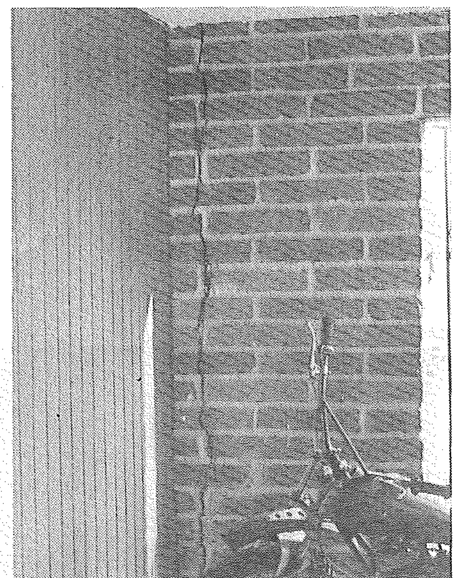
Continuing as we have in past issues of FIELDNOTES, the Geological Survey Branch of the Arizona Bureau of Mines is presenting a look at selected geologic hazards and how they affect Arizonans.

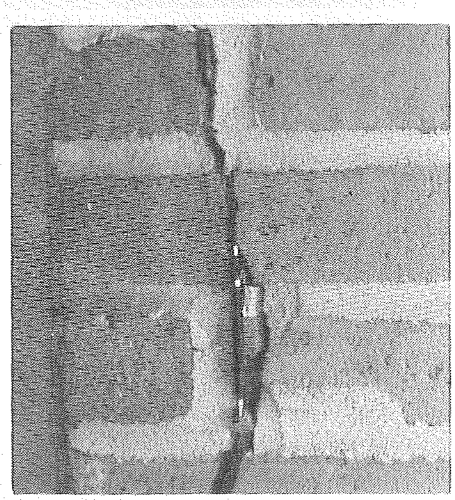
One that has affected many homeowners in southern Arizona is the problem of foundation failure resulting from collapsing soil sediments. Collapsing soil, or near-surface subsidence, can be related to two geologic processes: the failure of sediment that is subjected to rapid loss of volume upon wetting, load application, or both; and ground subsidence resulting from depression of the groundwater table due to groundwater withdrawal. The first process is generally localized, while the second may involve an entire valley. This article is primarily concerned with the problem of collapsing soils related to the first geologic process as it affects homes in the Tucson area.

Most homeowners find small, insignificant cracks in the walls and foundation of their residence due to building material and/or construction imperfections. These small cracks, while aesthetically unpleasing, are natural adjustments of the building materials to stress/strain relationships and are not normally considered serious. There are, however, many dwellings which have suffered severe settlement that has caused large cracks and separation of walls and foundations, resulting in thousands of dollars in damage. Questions often pondered by a homeowner who encounters serious structural failures in his own residence are: what is causing this particular problem?; are local officials aware of the seriousness of this phenomena?; how can it be fixed?; what could have been done in the original construction of the building to prevent this problem?

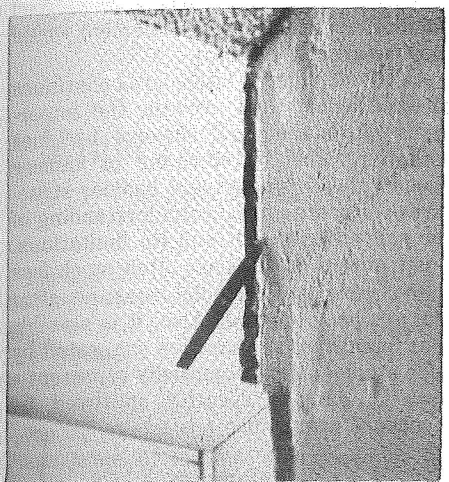
During the past 15 years, much research has been devoted to the mechanism and origin of collapsing soils, yet little of this valuable information has been applied to our own semi-arid environment. Though the exact reason for a soil to collapse is still poorly understood, most experts agree that moisture content, overburden load, and type of natural cementation (material that bonds the soil grains together) are chief factors causing instability.

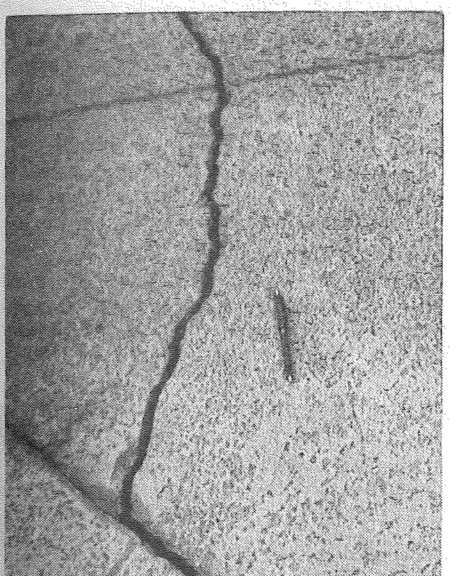
When water percolates through a sediment that has been undersaturated or devoid of liquid since its formation, the supporting material in the voids between





These photos of a house's brick wall show tensional cracks with up to 1-inch displacement.





Top: vertical and lateral displacement is caused by settlement.

Bottom: patio floor was extensively damaged by differential cracking.

the grains (usually clay) are easily weakened or dissolved. When a structural load is placed on this material (0.6 ton/sq. ft. for a normal house to 1.0-2.0 ton/sq. ft. for an industrial plant), the soil fabric must adjust to this new stress condition. The less stable soil compacts more easily and this volume loss translated vertically over many feet may result in visible cracking on the surface. This settling adjustment can be rapid, taking only a few days, or it may take several years to stabilize. The important step is to recognize the soil conditions within the area and adopt a suitable scheme to alleviate the problem.

The Tucson basin lies within the Basin and Range physiographic province which is characterized by numerous mountain ranges rising abruptly from broad, plain-like valleys. The Tucson basin is theorized to have formed during early/mid-Tertiary time (25 million years ago). During this time, massive blocks of rock moved vertically relative to one another, forming high mountainous areas and contrasting low valleys. These valleys were later filled to depths of 2,000-8,000 feet with weathered alluvial material from the uplands. During this basin-fill process, the Tucson basin was characterized by an internal drainage system. In the Pliocene Epoch (11-13 million years ago), apparently the Santa Cruz River cut northwesterly between the Tucson Mountains and the Santa Catalina Mountains. This changed the drainage system into a through-flowing system, and erosion of the basin began. The Santa Cruz drainage system, which is still actively eroding the basin today, formed broad river terraces and scoured alluvial fill along mountain fronts.

In other areas, collapsing soils have been associated with some recent erosional surfaces and river terraces, such as those found in the Tucson Basin. According to many workers, collapsing soils are geologically recent, loosely-packed (up to 40% void space), and generally undersaturated with water. Smith (1938) and Pashley (1966) have mapped the recent terrace deposits within the Tucson area and have classified them from oldest to youngest as the University, Jaynes, and Cemetery terraces. These terraces are topographically higher than the present floodplain (bottomland). (See fig. 6.) Some of these terrace sediments consist of low-density, organic-rich silts, sands, clays, and gravels. The low density is the result of small voids developed as these sediments were deposited in water-deficient environments. Soils like these are likely to experience consolidation when pressure is applied.

Consolidation tests indicate that the University terrace has been subjected to preconsolidation or prior loading whereas the younger terraces are either normally consolidated or slightly underconsolidated. Field observations indicate that the University terrace is the least prone to collapsing soil problems. On the other hand, the Cemetery terrace, and to a lesser degree the Jaynes terrace and the floodplain, are subject to the most severe settling within the Tucson area. Though the degree of foundation failure varies widely, problem-prone areas in the Tucson region are located on or near the Santa Cruz, Pantano wash, and Rillito floodplains and adjacent terraces (see photographs). Foundation settling of up to 2½ feet has been reported on some residential lots, and such major structures as the high-rise Home Federal Building have developed some settling problems requiring costly remedial measures.

For existing structures, two soil stabilization methods are generally practiced to compensate for a soil's inability to bear applied loads.

One remedial method is known as underpinning (fig. 7), an expensive and difficult operation that reinforces the foundation with a new support. Underpinning requires that the foundation be excavated and slowly raised by large hydraulic jacks. A new foundation of greater width and depth is then set under each of the existing footings.

The second method uses injection of a soil cement to fill voids and displace soil

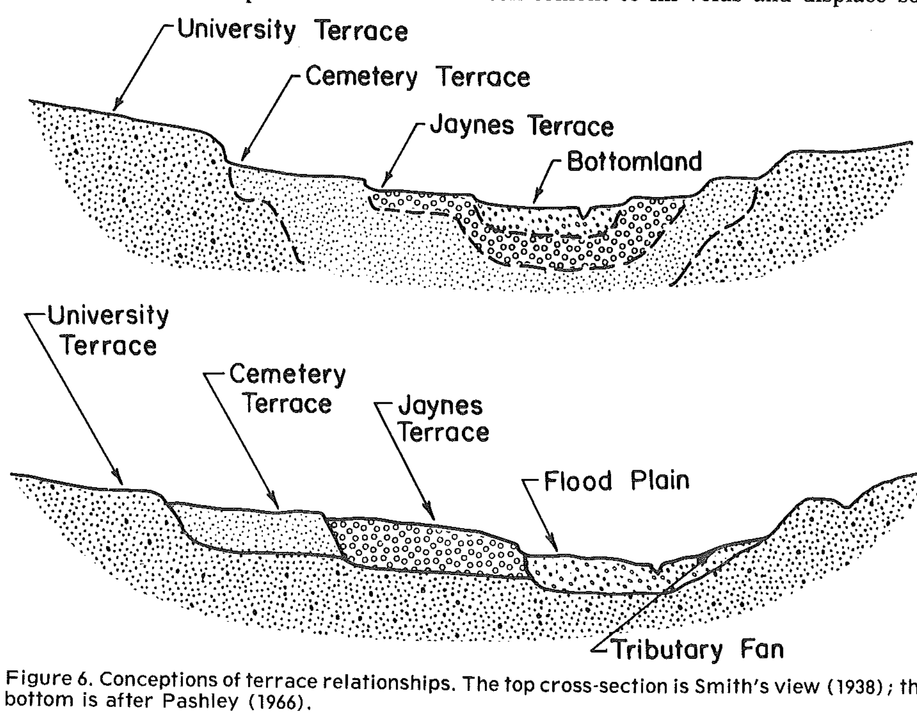


Figure 6. Conceptions of terrace relationships. The top cross-section is Smith's view (1938); the bottom is after Pashley (1966).

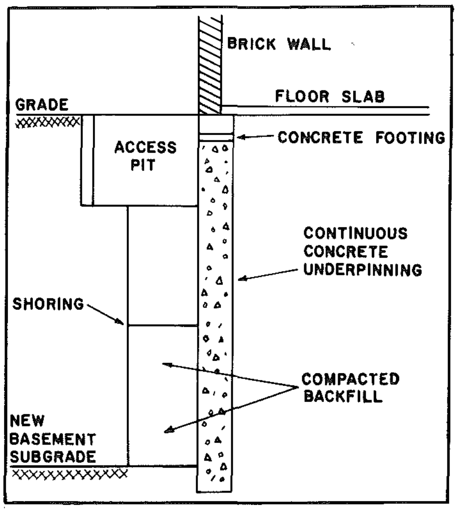


Figure 7. A cross section of the continuous underpinning method of stabilizing existing foundations.

grains (fig. 8). This method involves raising the foundation footings and injecting a low-moisture, non-plastic mixture of soil and cement down a grout pipe at specified depths. The process is repeated in several pipes until the volume of soil underneath the footings has been filled with properly-spaced balls of the soil/cement mixture. The increase in volume of the soil in the region where grouting cement is injected causes adjacent soil grains between the balls to compact. This

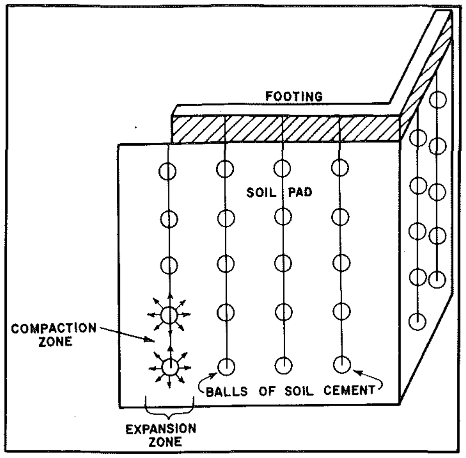


Figure 8. A demonstration of the soil-cement injection method of stabilizing damaged foundations.

tends to stabilize the soil along a linear zone surrounding the grout holes.

Both of these methods are relatively expensive, and the resulting soil stability depends upon the skill and experience of the contractor.

Perhaps the best solution, however, lies in the fact that collapsing soil problems can be avoided by recognition of this soil condition prior to construction, and qualified testing by soil and foundation experts can determine potential foundation problems. When these conditions are found to exist the structure should be built on a preconsolidated pad with a reinforced foundation; localized soil settlement would then be greatly reduced.

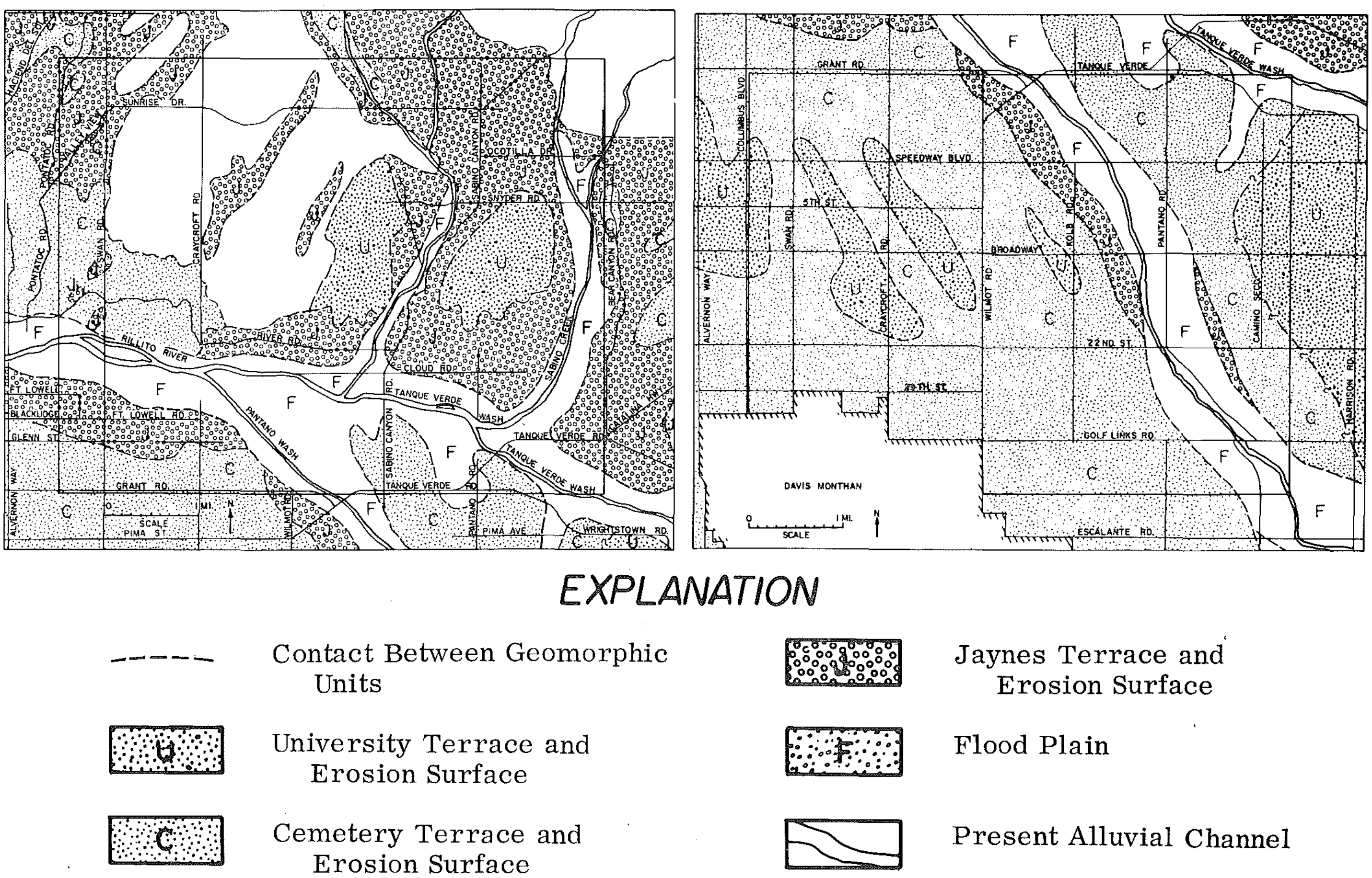
As the population of our area continues to experience rapid growth, the importance of detailed soil surveys becomes essential. The introduction of denser housing developments and heavier structures warrants a greater understanding of the soil environment and its limitations. Costs of such studies are often much less than the costs of remedial measures after damage has occurred. Also, it is possible that foundation preparation suggested by such studies might eventually represent a form of damage security approved by insurance companies.

References

Pashley, E.F., 1966. Structure and stratigraphy of the central, northern, and eastern parts of the Tucson basin, Arizona. University of Arizona, Ph.D. thesis.

Smith, G.E.P., 1938. The physiography of Arizona valleys and the occurrence of ground water. University of Arizona Agricultural Experiment Station, Technical Bulletin 77, 91 p.

These maps are of terraces and erosion surfaces within the Tucson area. The Cemetery unit appears to have the greatest potential for foundation failure.



Arizona Department of Mineral Resources

by John H. Jett
DMR Director

Though the Department of Mineral Resources was officially created on March 1, 1939, its true beginning was in February 1938 when the first council of the Arizona Small Mine Operators Association was organized. In order to understand the scope of the activities of the Arizona Department of Mineral Resources, it is necessary to review the reasons for its creation.

Between 1935 and 1937, as indicated in the Minerals Yearbook published by the U.S. Bureau of Mines, the number of small, producing mines in Arizona dropped from 2,200 to 1,200. This alarming drop was of grave concern to those interested in mining, and it gave impetus for the organization of the Arizona Small Mine Operators Association. Over the years the "small mine operator" classification has come to include prospectors, operators, exploration personnel, rockhounds, mineral collectors, and many others with an active interest in the mining industry of Arizona.

The initial growth of the organization was rapid and by August, 1939 there were 46 councils and 2,100 members. The basic organization consisted of a state headquarters for coordinating the work of the independent and autonomous councils which were located in various active mining camps and other communities.

The first annual state meeting was held in Prescott, in August, 1938; approximately 2,000 members were present. Discussion at this first state meeting indicated that the small mine owners' major problems were economic, and that to arrive at a solution a greater degree of study, research, and field technical assistance would be necessary than that possible with a volunteer group. It was believe that such a program would require the full time and effort of a paid, properly equipped and trained staff, but that the results of such work would benefit the entire state. As a result, a plan for a Department of Mineral Resources was drafted.

In February, 1939 State Representative Ben O'Neil of Ajo introduced a bill, sponsored by the Arizona Small Mine Operators Association, establishing a Department of Mineral Resources. This bill was passed unanimously by both houses of the Legislature. When Governor Robert T. Jones signed the bill on March 1, 1939, he characterized it as "the most constructive legislation that has been enacted."

The bill provided for the Department to be controlled by a board of governors, consisting of 5 members from various parts of the state appointed by the Governor for 5-year terms. The Board of Governors would serve without compensation, other than reimbursement for actual expenses of attending meetings. They would outline the policies of the Department and employ the director, who would in turn employ field and office staff consistent with the Department's appropriation and the policies of the board.

Charlie Willis became Chairman of the first board, and Sam Coupal was appointed the first director. With the exception of the years between 1944-51, Mr. Willis remained chairman until his death in 1968. The directors succeeding Coupal were, in order: Charles H. Dunning, R.I.C. Manning, Frank P. Knight, and the present director, John H. Jett. As required by the statutes, all were registered mining engineers.

During the Department's first year, four mining engineers were hired and trained as field engineers. All the diverse laws and regulations governing mining on lands within the state were compiled and studied. A major part of the effort during the first year was devoted to a resources survey in which information on many partially developed prospects, mines, and mineral deposits of the state was gathered. However, because of a continuing shortage of personnel, this project has not been completed. Also, a study was made of the problems of the "small miner," and extensive field service was provided to help prospectors and small miners with their individual problems.

Another early phase of the Department's work was the gathering of the basic economic information required from time to time for compiling reports and making studies. Every effort is made to keep this data up to date; its value has been proven many times when it was necessary to prepare briefs on mining subjects.

Surveys of special projects such as roads to serve isolated mining areas, custom milling plants, custom smelters, and numerous other mining-related problems, were made by the Department upon request. One interesting and important project was a study and survey made of dust conditions in the mining industry and the relationship to silicosis as a compensable industrial disease.

Many conferences were held in the early days with Dr. T.G. Chapman, then director of the Arizona Bureau of Mines, in order to more closely coordinate the work of the Department and Bureau. One of the more important results of these conferences was the publication of a series of information circulars on the less common metals and minerals.

Another phase of the cooperation between the Department and Bureau was the establishment of an ore testing department in the Bureu to serve the small mines. With the Department of Mineral Resources supplying field work, and the Arizona Bureau of Mines doing research, flow sheets were designed for better milling results, at only a small charge to the miner.

The work of the Department was carefully planned in its earlier years to avoid overlapping or duplicating the work of the Arizona Bureau of Mines. The Department's activities were limited to the economic side of mining and to field problems confronting the small miner and prospector.

The early work and cooperation between the two agencies clearly demonstrates their differences. The Bureau is of a scientific and research nature, and the Department is more or less promotional and concerned with problems that are more economic and technical than scientific in character.

It must be remembered that the Department was created as a service organization to the mining industry of the state; the only thing that has changed through the years is the *type* of service required to "promote the mineral industry" and assist interested or mineral-oriented people.

The call for strategic and critical minerals by the federal government during World War II found the Department well equipped and ready to give immediate service. During these war years mining became so complicated and was beset by so many restrictions and regulations that a liaison man from the Department was stationed in Washington. The Director of the Department became a consultant to, or member on several Federal agencies, including the War Production Board.

During the immediate post-war years, many new problems arose for the mineral industry that required new types of help from the Department of Mineral Resources. Problems that involved the Department included the critical materials stockpiling act; premium price plan for copper, lead, and zinc; federal government contract terminations with the small miners; demand for uranium; phasing-out of RFC loans; suspension of Copper Tariff; mining law revisions; and the developing interest in nonmetallic minerals.

In the 1950s, new problems included increased costs (without increased metal prices); the Korean war and its related shortages; and a change in public opinion toward mining, which created a need for public relations. Additional changes were increased uranium prospecting; emergence of manganese and tungsten as major metals; the decline of lead-zinc mining; availability of federal DMEA loans; revision of mining laws on state lands; and the establishment of the Mineral Museum as a full-time division of the Department. Toward the end of the 1950s, production of copper was curtailed, and much work was being done on long-range mineral policies, tariffs, and similar problems for submission to federal agencies. The government terminated the manganese stockpiling program, which closed the manganese mines. During thise years, the Department maintained field offices in Tucson, Prescott, and Kingman, as well as the main office in Phoenix.

During the 1960s, much time was spent on developing data for submission at congressional hearings on stockpiling of surplus minerals; tax laws; depletion; gold and other mineral subsidies; silver purchase act; laws, regulation, and administrative procedures pertaining to mineral rights on public lands; the Wilderness Act; import controls; gold, silver, and monetary policy; land withdrawals; and the creation of the Public land Law Review commission.

During these years the Department was called upon many times for assistance to state agencies on mining questions relating to property tax studies, park areas, right-of-way, industry development; economic research, history, employment, and use of State lands. Federal agencies called on the department with questions or problems relating to public lands, mining statistics, mine loans, exploration loans, old and new mines, mining costs, stimulation of copper production, use of water, and the study of strip and surface mining.

Although many of the problems of the small miner still exist, and a constant demand for field service is still being made, additional problems arose in the 1970s: awareness of "environment" and "ecology"; land-use planning; curtailment of copper smelter capacity; the closing of custom copper smelters and most of the lead-zinc smelters; land withdrawals; government rules and regulations; and inflation; all produced many additional hardships for the small miner.

The circumstances existing in 1939 that resulted in the creation of the Department of Mineral Resources have changed considerably. The number of small miners has decreased, but those individuals have been partially replaced by exploration companies. At this time there are more than 55 active exploration companies in Arizona. Even though the small miner has decreased in number, he is perhaps more important than ever; though fewer in number, he does a bigger job and still represents a major claim owner. This is why the Department continues to work very closely with the Arizona Small Mine Operators Association.

Mineral economics, proposed major revisions of the Federal Mining Laws, expanding markets for nonmetallics, and proposed restoration and reclamation of mined areas are all problems causing the explorationists to call for more help from the Department of Mineral Resources — in ways never imagined when the Department was created.

A new area of the mineral industry, and one of major importance because of the involvement of so much of the public, consists of the rockhound (hobbyist, or amateur mineralogist) and the recreational or weekend prospector. Both groups have a considerable economic impact on the state, and because they are not usually technically trained, they need considerable professional help. The Department of Mineral Resources is their representative within the state.

Publications of the Department of Mineral Resources

Publications of the Department of Mineral Resources are available free of charge; a complete list of the publications will be sent upon request. The mailing address is:

Arizona Dept. of Mineral Resources
Mineral Building
Fairgrounds
Phoenix, AZ 85007

Some of the publications are:

Laws and regulations governing mineral rights in Arizona;
Pertinent data for new mining operations;
Patenting a mining claim;
Environmental guidelines for exploration;
Annually revised lists of active mines within the state, exploration companies, land ownership, rockhound clubs, and many other subjects.

FIELDNOTES

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ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
845 NORTH PARK AVE.
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