FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

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BEDROCK SHOULDERS AND LAND USE

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INTRODUCTION

This article is prompted by the much publicized conflict between mineral explorationists and residential property owners near the Tucson Mountains (Fig. 1) in Pima County, Arizona (*Newsweek*, Oct. 15, 1973). Although much has been said and written about this problem, we have yet to see an explanation of the basic underlying factors involved, an explanation that might help us approach the future with added awareness. In our opinion, the missing element is an overview of the general geologic condition of southern Arizona. With this in mind, we here introduce the subject "Bedrock Shoulders and Land-Use."

In the area of the Tucson Mountains, the basic ingredients for land-use conflict–mineralization and picturesqueness–were expressed by G.M. Butler in a foreword to an Arizona Bureau of Mines bulletin written by Jenkins and Wilson in 1920: "... The complexity of their geology, the variety of their igneous rocks, and the diversity of their ore deposits all combine to make the Tucson and Amole Mountains a very rich field for students and scientists. The general public, also, find these mountains interesting because of their picturesqueness, the heavy growth of sahuaro cactus existing in portions thereof ..."

It is understandable that mineralization should attract those whose task it is to provide additional reserves of minerals and that picturesqueness should attract a diversity of land users whose immediate interest is surface use.

This Tucson Mountain example is complicated by the fact that certain lands

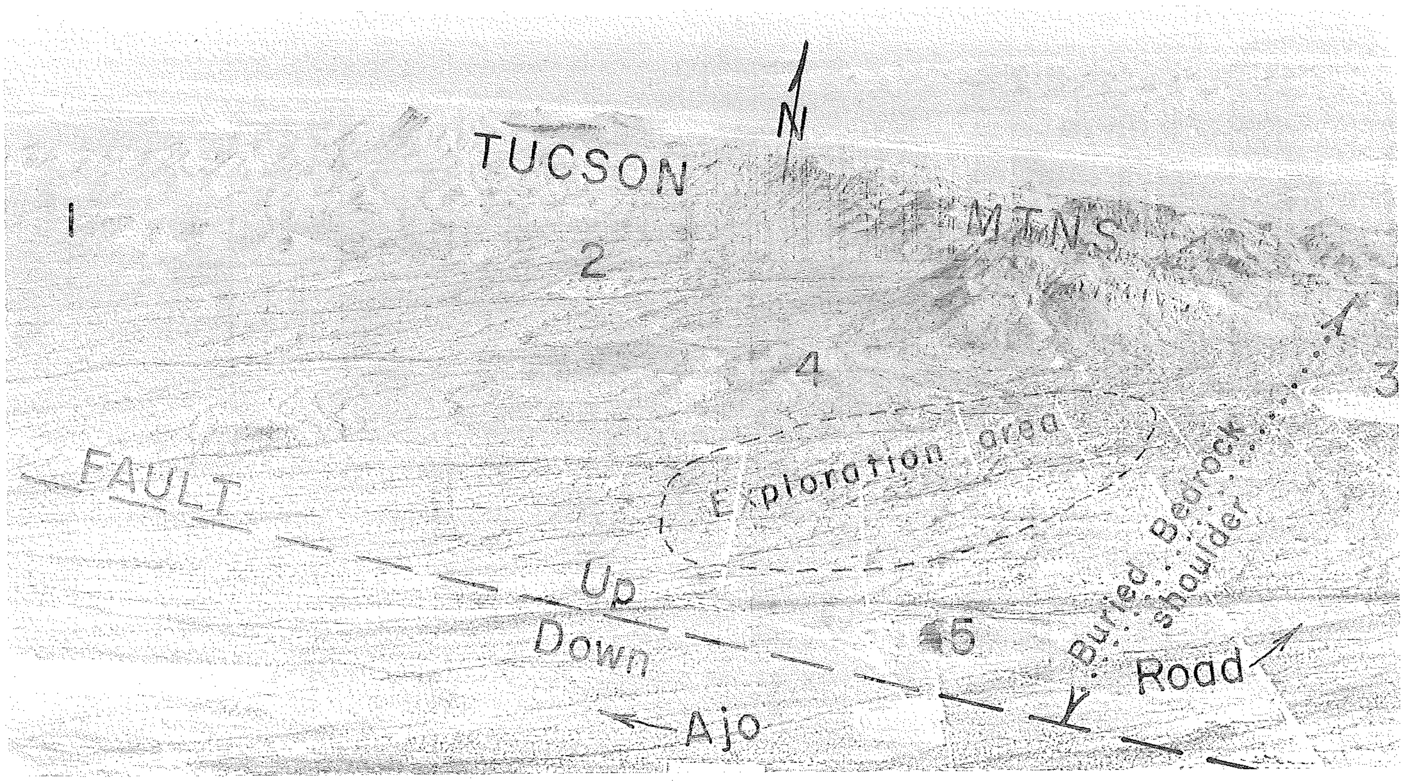


Figure 1
Panorama of the Tucson Mountain region showing the area of conflict between mineral exploration activities and scattered residential interests. Erosional retreat of the main mountain bedrock mass has left a shallowly buried bedrock shoulder. Locally, bedrock projects upward through the alluvium. Numbered features are (1) Desert Museum; (2) Old Tucson; (3) Tucson Estates; (4) Sedimentary Hills; (5) Snyder Hill.

were sold with mineral rights reserved to the Federal government. Perhaps this condition became obscured as these lands changed hands. However, as suggested by the excerpt, the area has long been known to be mineral in character and it is in just such areas that exploration interest might be anticipated.

Although the passage refers to the Tucson Mountains, technically, the scattered residences involved were not built in the mountains proper, but near them. Even so, given an understanding of the relationships between our desert valleys and mountains, the statement remains applicable, at least with regard to ore deposits. Perhaps we tend to think of mountains only as permanent, high standing topographic features because it is this aspect that is most conspicuous. However, it is that portion of a mountain which we usually do not see that is our major concern here.

In the paragraphs that follow, the subject of "bedrock shoulders" is briefly explored and extended to a larger region than just the area of the Tucson Mountains.

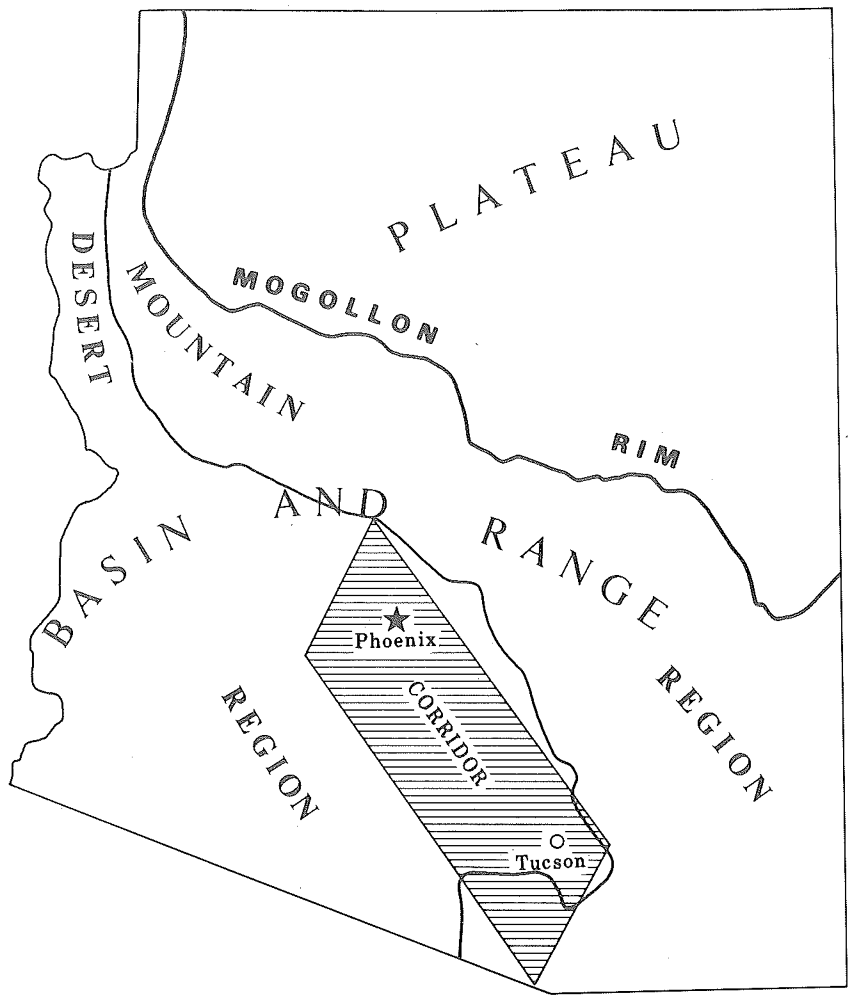


Figure 2
Location of corridor area with respect to physiographic subdivision of Arizona.

SOUTHERN ARIZONA MULTIPLE USE AREA

The land area shown in Fig. 2, lying within the Arizona portion of the Basin and Range Province, encompasses a belt or corridor between Phoenix and Tucson that is approximately 55 miles wide and 170 miles long, an area of about 9300 square miles in parts of Pima, Pinal, and Maricopa Counties. This corridor (Fig. 3), which includes the greater Phoenix and Tucson valleys, is bounded on the northeast by a nearly continuous mountain front and on the southwest by an arbitrary line connecting most of the westward extensions of cultivated lands and associated smaller communities. Within this region lies the largest area of interconnected valley surfaces in the State. Of the total land surface approximately 1/4 is "bedrock" exposed in hills and mountains and the remaining 3/4 is "alluvium."

In order to establish an idea of the multiple land use dimension of this region a few statistics are presented. The corridor, representing only 8% of the land area of the State, contains: (1) 63% of the population, (2) 50% of the groundwater pumped in 1971, (3) 50% of the State's cultivated acreage, (4) feedlot cattle that numbered one-half million in early 1973, (5) resources that produced 33% of Arizona copper production (18% of U.S. production) in 1971, (6) huge buried (cubic miles) volumes of minerals (sodium chloride-salt, and calcium sulfate-anhydrite and gypsum) formed in the past by the evaporation of huge volumes of water, (7) the largest active earth fracture system in Arizona, etc.

There are eleven known major copper properties within these confines. Eight are in operation, one is under development, and two are being evaluated. Of these eleven, the mineralization in eight is contained in bedrock that is buried beneath alluvial or valley fill materials. The three that are not actually buried beneath alluvium occupy the lower topographic regions of the associated mountains. Two of the three newest Arizona properties being readied for production are within the corridor. The rather clear implications, as regards copper exploration, have been stated many times – new discoveries, if they are to be made, will result only from exploration made difficult by the fact that remaining major targets are likely to be hidden from view by covering alluvial materials – the "easy" ones have been found. This is to say that the search, at least in much of southern Arizona, will tend to be conducted from valley surfaces and not from the surface expressions of the adjoining mountains. Exploration has literally been driven into the valleys where it must, at times, contend with a diversity of other potential land uses if it is to remain viable. (Responsible leaders perhaps should try to understand something of the uniqueness of the copper resource in Arizona before judging realistically the merits of exploration and mining as a land use (Titley, S.R.).

LAND FORMS – **Earth Materials—Geologic Processes—Geologic Time**

As indicated in Figure 2, the discussion area is within the so-called Desert Region of the Basin and Range geologic province. The designation "Desert Region" refers to the high percentage of alluvial desert surface interspersed between the small percentage of relatively low elevation bedrock mountain ranges (Figure 4). All or part of about 30 ranges are included within the corridor.

It is common knowledge that mountains are subject to destruction by natural forces, forces that largely act above ground, the forces of weathering and erosion. It also is common knowledge

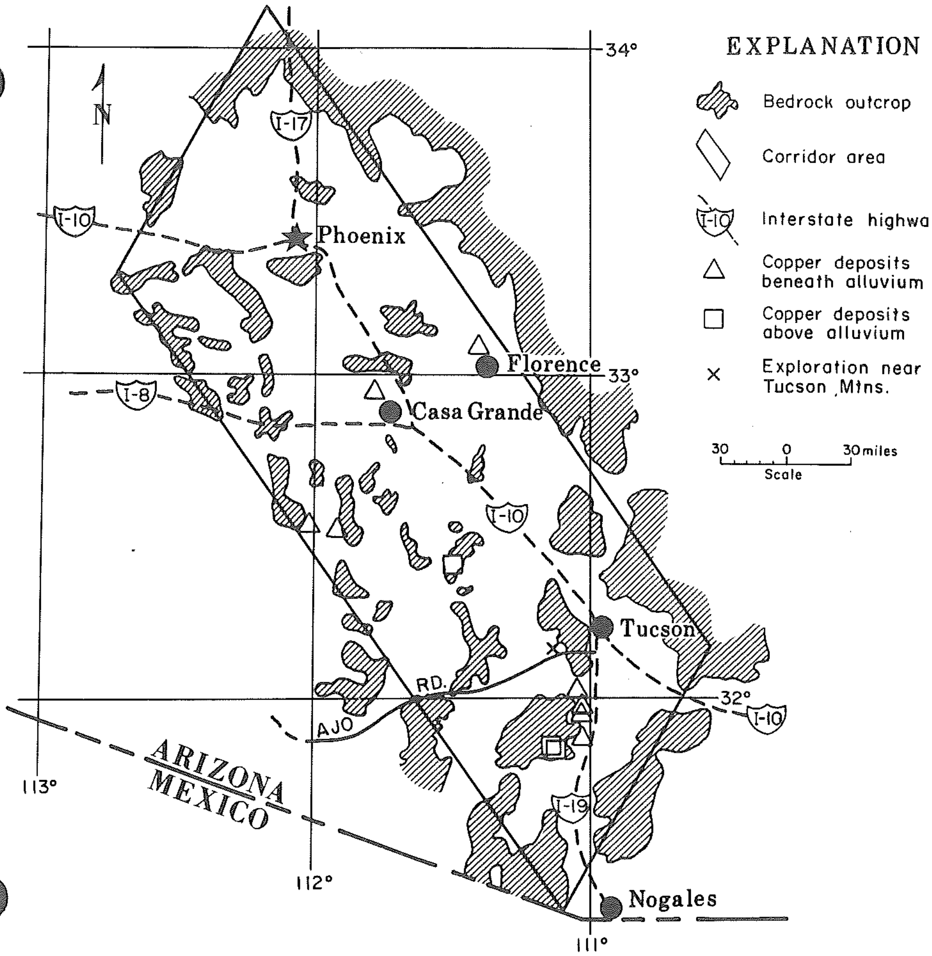


Figure 3
Corridor area showing bedrock (mountains) outcrops, position of copper deposits, and major towns and highways.

that mountains are worn down, but perhaps what is not so well understood is the extent to which they are often worn *back* by processes long active in the southwestern deserts. The mountain fronts that we see today are, more often than not, false or topographic fronts. The real, or structural fronts, often extend several miles outward toward the valley or basin centers. This means that portions of valleys actually overlie, at relatively shallow depths, eroded mountains. In such circumstances one can build a house, etc., that is on the one hand beside mountains while on the other it is above the rock mass, or root of the same mountain (Fig. 5C). In such circumstances, any characteristics noted in the surface rock exposures, including mineralization features, are subject to projection to the rocks that are shallowly buried.

The surface or topographic part of a mountain range can be likened to a head and the root that projects outward into adjacent valleys can be thought of as shoulders (Fig. 5C). These shoulder areas, though generally more or less buried, have an impact on land use that likely is not recognized or appreciated.

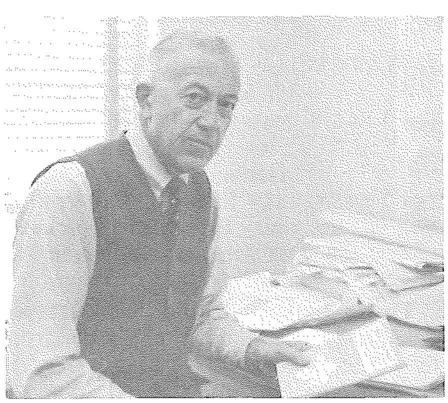
There are two basic categories of earth materials that need general definition, "bedrock" and "alluvium." Bedrock, as used here, refers to the substance of the mountains—the older, harder rock types. Alluvium is the relatively soft, younger sedimentary debris deposited in valleys and derived from the bedrock of adjacent or nearby mountains (Fig. 5B). Bedrock is the parent of alluvium. While some of the materials that have accumulated in valleys, such as salt deposits, are not alluvial, the younger upper portions of all of the valleys are alluvial—gravel, sand, silt, and clay, mixed in different proportions.

It is important to establish an historical sketch of the order in which various phenomena came into existence within the corridor region. A general simplified sequence of events would be, from older to younger: (1) origination of bedrock units, (2) mineralization, (3) mountain-valley making, (4) reshaping of the mountains and deposition of alluvium in the deeper structural valleys as well as over the thinner bedrock shoulder areas, and (5) an influx of Homo Sapiens who continue to try to create a satisfying existence for themselves. *Continued page 8*

NEW BULLETIN AVAILABLE

Bulletin 187, INDEX OF MINING PROPERTIES IN COCHISE COUNTY, is now available in the Arizona Bureau of Mines. The first in a planned series covering Arizona counties, this bulletin is designed to provide records concerning mining operations of note in Cochise County.

Arizona has been an important mineral-producing area for over one hundred years and many mines, ranging from major operations to small mines and prospects, have contributed to the total mineral output. The records of these operations are scattered in numerous publications of Federal and State agencies, in articles in various technical journals, in public and private reports, and in newspaper clippings. Many such sources are not readily available to individuals seeking information concerning these operations. Hopefully, this bulletin will bridge the "information gap."

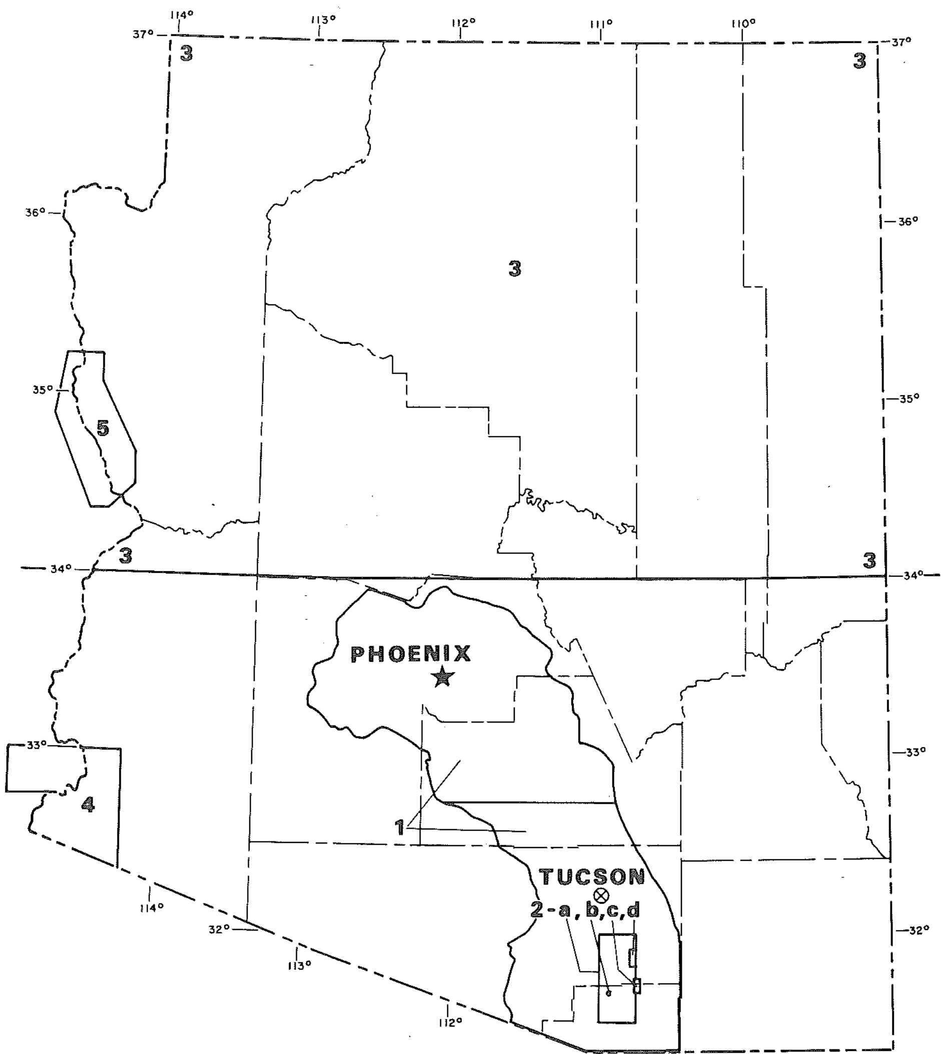


Mr. Stanton B. Keith, author of new bulletin.

The index does not attempt to name and describe every mining property that may exist in an area. The selection of those included had to be made arbitrarily on the basis that they had importance due to their production record or their special geologic or mineralogic character, or because their occurrence or characteristics might indicate possible hidden mineral resources. The identification of such areas of possible mineral resources is important not only for the material that might be extracted but also for planning the best use for the land involved.

This bulletin is priced at $1.00 per copy to non-residents of Arizona and is free to residents of the State.

NEW GEOLOGIC MAPS OF ARIZONA



KEY TO MAP

1. 1973. The U.S. Geological Survey has, thus far, released eleven new land resource, land hazard, and general land information maps that embrace the Phoenix-Tucson region. The individual maps and their index numbers are:

Map I-843-A Index and description of flood-prone area maps in the Tucson-Phoenix area, Arizona.

Map I-844-A Map of land status in the Tucson Area, Arizona – 1973

Map I-844-B Map of Irrigated Land In The Tucson Area, Arizona

Map I-844-C Map Showing Distribution and Estimated Thickness of Alluvial Deposits in the Tucson area, Arizona, 1972

Map I-844-D Map showing depth to water in wells in the Tucson area, Arizona, 1972.

Map I-844-E Ground-water recharge in the Tucson Area, Arizona

Map I-844-F Map showing distribution of recoverable groundwater in the Tucson Area, Arizona.

Map I-844-G Map showing potential for copper deposits in the eastern three-quarters of the Nogales 2° quadrange, Tucson, area, Arizona.

Map I-845-A Map of Land Status In The Phoenix Area – 1973.

Map I-845-B Map of Irrigated Land In The Phoenix Area, Arizona.

Map I-845-C Map Showing Distribution and Estimated Thickness Of Alluvial Deposits In The Phoenix Area, Arizona.

These maps should be ordered individually, by number and title, from the U.S. Geological Survey, Denver Distribution Section, Denver Federal Center, Denver, Colorado 80225. Each map costs 75 cents.

We encourage all Arizona citizens to avail themselves of every opportunity to become more familiar with their surroundings. In the present case, Tucson-Phoenix citizens now have available some new maps that are well done, colorful, and basic to awareness and good land management.

2. - a. Tectonic Map of the Santa Rita Mountains, Arizona, Plate 1.
- b. Geologic Map of the Montosa Canyon – Glove Mine Area, West Flank of the Santa Rita Mountains, Arizona, Plate 2.
- c. Geologic Map of the Adobe Canyon – Sawmill Canyon Fault Zone Area, East Flank of the Santa Rita Mountains, Arizona, Plate 3.
- d. Geologic Map of the Rosemont – Helvetia Area, North End of the Santa Rita Mountains, Arizona, Plate 4: or U.S.G.S. Professional Paper 748, Titled, Structural Geology of the Santa Rita Mountains, Southeast of Tucson, Arizona; by Harald Drewes, 1972.

3. 1972. J.H. Stewart, F.G. Poole, and R.F. Wilson; With a Section on Sedimentary Petrology by R.A. Cadigan; Stratigraphy and Origin of the Triassic Moenkopi Formation and Related Strata in the Colorado Plateau Region: U.S.G.S. Professional Paper 691, 5 Geologic plates.

4. 1973. R.E. Mattick, F.H. Olmsted, and A.A.R. Zohdy; Geophysical Studies in the Yuma Area, Arizona and California: U.S.G.S. Professional Paper 726-D, plates 1 and 3.

5. 1973. D.G. Metzger and O.J. Loeltz: Geohydrology of the Needles Area, Arizona, California, and Nevada: U.S.G.S. Professional Paper 486-J, plate 1.

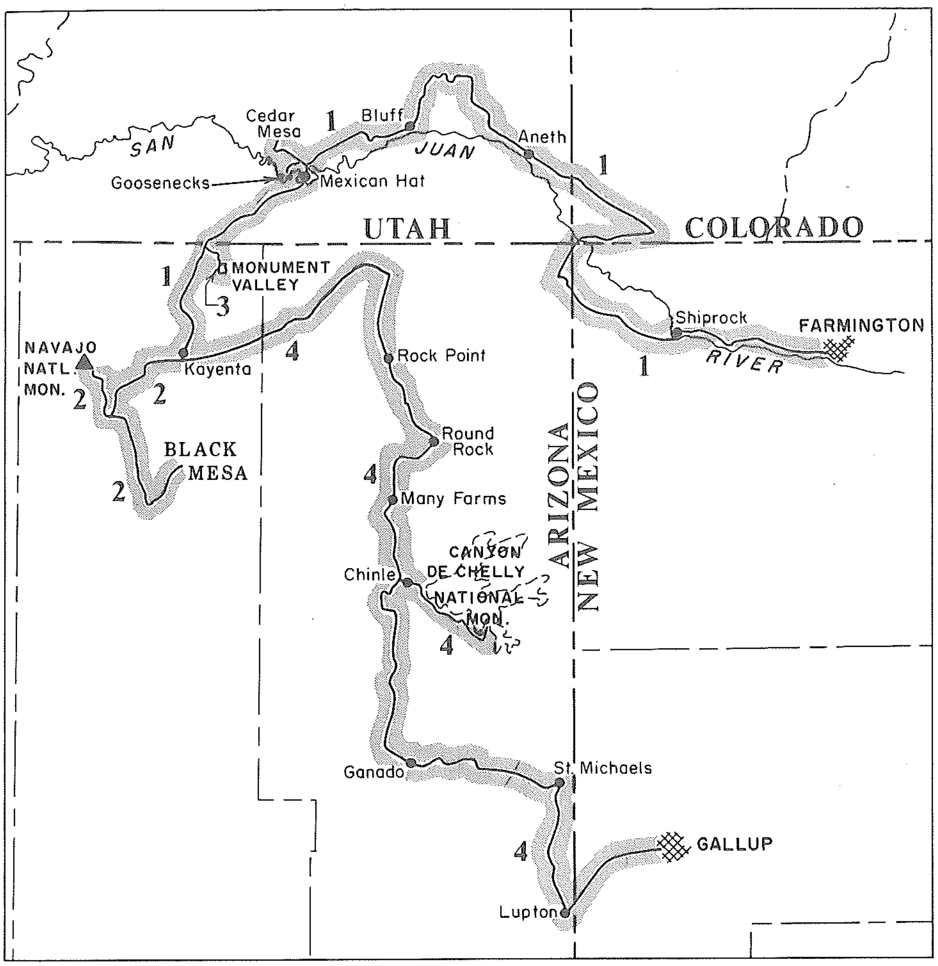
PUBLICATIONS

1973. Stanton B. Keith; Index of Mining Properties in Cochise County, Arizona: Arizona Bureau of Mines Bulletin 187, 98 p., 4 Tables, 10 Figures.

1973. Harald Drewes; Geochemical Reconnaissance of the Santa Rita Mountains, Southeast of Tucson, Arizona: U.S.G.S. Bulletin 1365, 67 p., plates.

1973. R.F. Marvin, T.W. Stern, S.C. Creasey, and Harald H. Mehnert; Radiometric Ages of Igneous Rocks from Pima, Santa Cruz, and Cochise Counties, Southeastern Arizona: U.S.G.S. Bulletin 1379, 27 p.

NEW ROAD LOGS



KEY TO MAP ROAD LOGS

1973. New Mexico Geological Society, Twenty-fourth Field Conference October 4-6, 1973; Guidebook of Monument Valley and Vicinity, Arizona and Utah:

1. D.L. Baars, Sidney R. Ash, William L. Chenoweth, H.L. James, Robert B. O'Sullivan, Jack A. Ellingson: Road Log from Farmington, New Mexico, to Kayenta, Arizona, via Shiprock, Four Corners, Aneth, Bluff, Cedar Mesa, Goosenecks, and Mexican Hat.
2. D.L. Baars, Sidney R. Ash, William L. Chenoweth, J.D. Strobell, Jr., H.L. James: Road Log from Kayenta, Arizona, to Black Mesa and Navajo National Monument.
3. D.L. Baars, Sidney R. Ash, H.L. James: Road Log of Monument Valley, Navajo Tribal Park.
4. D. L. Baars, Robert B. O'Sullivan, Sidney R. Ash, H.L. James: Road Log from Kayenta, Arizona, to Gallup, New Mexico, via Dinnehotso, Rock Point, Round Rock, Many Farms, Chinle, Canyon De Chelly, Ganado, St. Michaels, Hunters Point and Lupton.

1972. Harald Drews; Structural Geology of the Santa Rita Mountains, Southeast of Tucson, Arizona: U.S.G.S. Professional Paper 748, 35 p., 4 plates.

1972. T.G. Lovering; Jasperoid in the United States – Its Characteristics, Origin, and Economic Significance: U.S.G.S. Professional Paper 710, 164 p., (Arizona) pp. 90-93.

1972. J.H. Stewart, F.G. Poole, and R.F. Wilson; With a section on Sedimentary Petrology by R.A. Cadigan; Stratigraphy and Origin of the Triassic Moenkopi Formation and Related Strata in the Colorado Plateau Region: U.S.G.S. Professional Paper 691, 195 p., 5 plates.

1973. Donald A. Brobst and Walden P. Pratt, Editors; United States Mineral Resources: U.S.G.S. Professional Paper 820, 722 p.

1973. R.E. Mattick, F.H. Olmsted, and A.A.R. Zohdy; Geophysical Studies in the Yuma Area, Arizona and California: U.S.G.S. Professional Paper 726-D, 36 p., 5 plates.

1973. D.G. Metzger and O.J. Loeltz; Geohydrology of the Needles Area, Arizona, California, and Nevada: U.S.G.S. Professional Paper 486-J, 54 p., 3 plates.

1973. Ronald L. Hanson; (Arizona); Evaluating the Reliability of Specific-Yield Determinations: or U.S.G.S. Journal of Research, Volume 1 Number 3, May-June, pp. 371-376.

1973. F.E. Arteaga and S.E. Rantz; Application of the Source-Area Concept of Storm Runoff to a Small Arizona Watershed: or U.S.G.S. Journal of Research, Volume 1 Number 4, July-August, pp. 493-498.

1973. Journal of Research of the U.S. Geological Survey: U.S.G.S. Volume 1 Number 3, May-June, p. 251-376.

1973. Journal of Research of the U.S. Geological Survey: U.S.G.S. Volume 1 Number 4, July and August, pp. 377-499.

1973. Journal of Research of the U.S. Geological Survey: U.S.G.S. Volume 1 Number 5, September and October, pp. 501-625.

THESES ARIZONA STATE UNIVERSITY

1973. N.B. Cousins; Relationship of Black Calcite to Gold and Silver Mineralization in the Sheep Tanks Mining District, Yuma County, Arizona: MS Thesis, 43 p.

The above Thesis appeared in FIELDNOTES Vol. 3 No. 2. Because of a typographical error in Mr. Cousins' last name, we are reentering the above corrected entry in this issue of FIELDNOTES. For this error we offer our sincere apologies.

1973. Joseph Garnett Aylor, Jr.; The Geology of Mummy Mountain, Phoenix, Arizona: MS Thesis, 86 p.

NOTE

Publications and maps issued by agencies other than the Arizona Bureau of Mines must be ordered directly from the issuing agency. Arizona Bureau of Mines publications and maps may be purchased at, or ordered from, the Arizona Bureau of Mines, University of Arizona, Tucson, Arizona 85721.

PUBLICATIONS I

Bureau Director William H. Dresher and F. Catherine Cate, Editor of FIELDNOTES, have their hands full as publication time draws near four times each year. With the Bureau's numerous concerns and commitments both locally and state-wide, there is never a shortage of material but often difficulty deciding what to write, and when. Once the Director has selected material for the next issue, the Editor is responsible for "getting it all together" and to the printers — hopefully, on time!

Mrs. Judy Friedrichs has the exacting job of typing such publications as the bulletins on a typewriter which allows lines to be "justified" — flush at both margins — and lines perfectly centered and spaced within a given area. This time-consuming job is accomplished by meticulously counting each letter, word, and line and alloting the necessary space between words and letters.

IN PROGRESS


Distribution includes keeping up with an ever-growing mailing list. Bureau secretary Mrs. Roseanna Jizmejian is primarily responsible for answering requests for over 25 bulletins and 12 maps in print. In addition, she and Joseph LaVoie, with the help of assistant Bob Varga, handle the actual mailing of FIELDNOTES — almost a full-time job in itself for about two weeks each quarter.

Bureau publications begin with words, but writing is only part of the story – other parts include typing, editing, illustrating, and distributing them.

Since the second issue of FIELDNOTES was mailed to 1,374 readers in June, 1971 (based on responses to the trial mailing of the first issue), the mailing list has grown to approximately 3,660 at our September mailing.

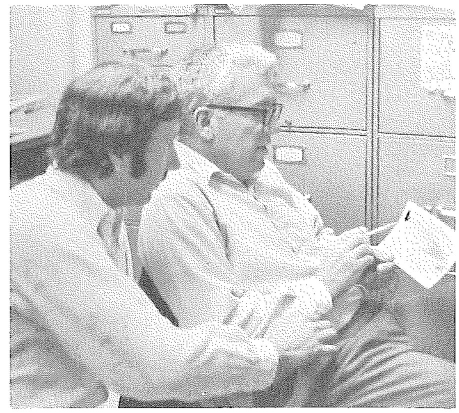
Like many growing enterprises, we recently enlisted the aid of computers to facilitate mailings similar to FIELDNOTES, and encountered a few headaches along the way. Once the transition is complete, it will be a tremendous benefit, but computers are only machines – not mind readers – and they cannot guess changes of address. If you, the readers, wish to continue receiving FIELDNOTES, you must notify us of changes of address.

The numerous illustrations and maps in FIELDNOTES and other Bureau publications are the handiwork of draftsman Joseph R. LaVoie. In addition, he does the layouts of material, and develops much of the film for photos.

BEDROCK SHOULDERS *Continued*

Figure 4

Sacaton Mountains in the Desert Region of the Basin and Range province. Note the irregular boundary between alluvium and granitic bedrock. Detached bedrock remnants are Inselbergs projecting up from a bedrock shoulder. Central Arizona College at right edge. Gila River and agricultural development in next valley to the north. See also the complex network of washes.



Authors Vuich and Peirce study photograph pertaining to their article.

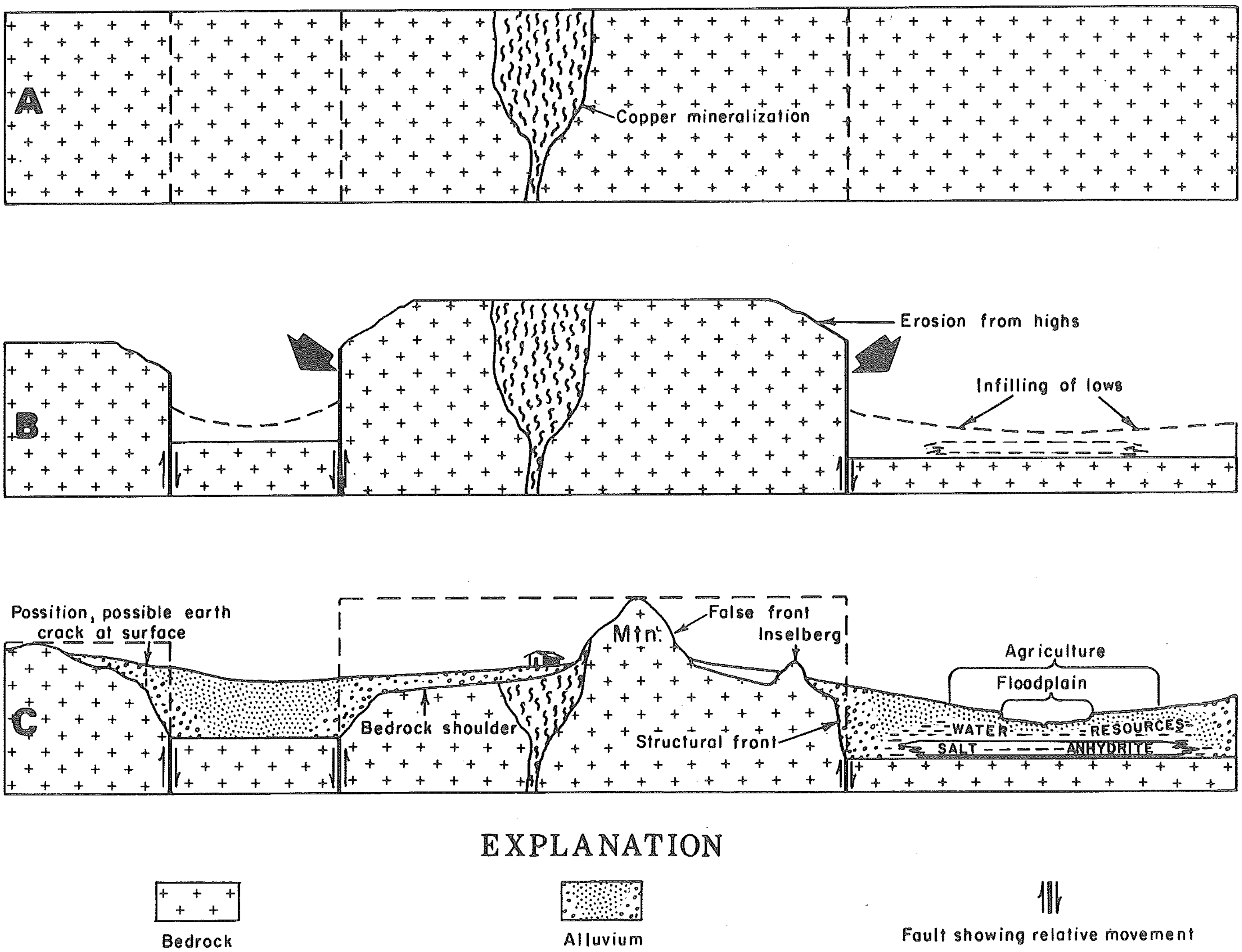


Figure 5

Generalized stages in the development of present land forms.

A. Bedrock mineralized before the stage of differential vertical movement.

B. Differential vertical movement and the initiation of erosion in high areas and deposition in the lows.

C. Present condition is a multiplicity of possible resources, both surface and subsurface.

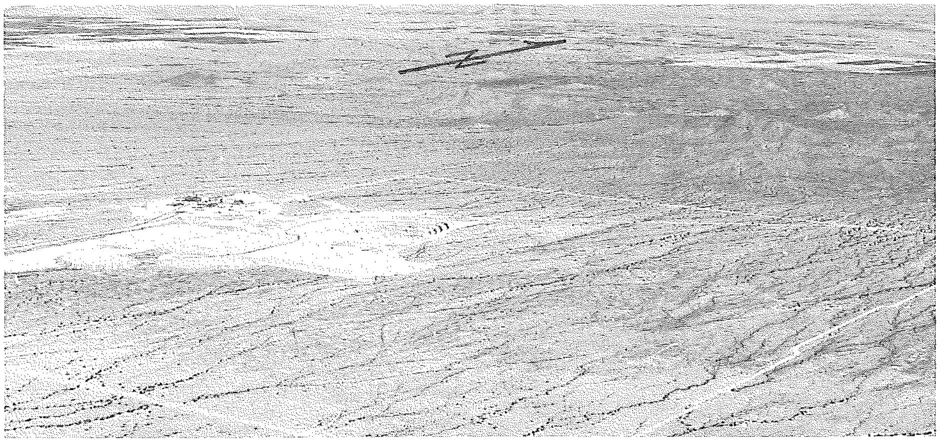


Figure 6

Casa Grande area — a newly developed open pit copper mine discovered in mineralized bedrock beneath an alluvial cover. Note that development is on a valley surface away from the bedrock mountains. Mineralization is contained within a bedrock shoulder. Agricultural development is closer to the valley center where slopes are minor, soils are better, and water supply is more abundant.

It is to be emphasized that the mineralizing event occurred after the formation of most of the bedrock units now preserved within the corridor. Because of this, these units have a metallic mineral occurrence potential. Where they have in fact been mineralized is the principal question that faces the explorationist. The "where" question is now being directed at the shoulder zones (Fig. 6).

The development of the present mountain-valley type of topography was initiated about 15-20 million years ago during the Basin and Range disturbance. Much of the western United States was affected by this mountain- and valley-making episode so that what we see in southwestern Arizona is but a part of a more extensive phenomenon. We can document thousands of feet of differential vertical displacement along certain faults that form structural boundaries between the original valleys and mountains. A mountain is relatively uplifted or raised and a valley relatively down-dropped or depressed. It is very important to understand that the present topographic boundaries (what we now see at the surface) are not the original structural, or fault, boundaries. Since the essential completion of the major faulting several million years ago, the mountain blocks have been subjected to reshaping by the forces of weathering and erosion. The resulting debris collected in the adjacent basins, at least until the development of the Colorado River drainage system. It is the bedrock geometric form or habit, resulting from this modification, that has a major impact on land use possibilities (Fig. 5C).

Figure 5 depicts a basic structural pattern often used to explain the origin of basins and ranges. Also shown are the subsequent erosional and depositional modifications. It is to be noted that with time a mountain face retreats from its original structural front in such a way as to leave a relatively gentle, outward facing slope cut on mountain bedrock. The shoulder thus produced is buried by a relatively thin cover of alluvium that slowly thickens toward the valley center but thickens quickly when the original structural front is reached. The overall effect is to narrow the mountain and to extend the valley surface so that the valley, at least its extended portion, comes to overlie the "root" of the mountain. It is firmly established that the topographic fronts of a number of mountains have retreated as much as 7-8 miles from their original structural fronts. This retreat is not always complete because bedrock remnants (inselbergs), detached from the topographic mountain fronts, often project above the alluvium (See Figs. 1, 4, & 5C). Where this happens one should suspect: (1) that bedrock likely is close to the surface between the remnant bedrock and the topographic mountain front, and (2) that the structural front lies still farther out in the valley. Various topographic and geologic maps depict these inselbergs so that it is possible to obtain some idea as to shoulder dimensions. The modern topographic boundaries between mountains and valleys (bedrock and alluvium) are very irregular (Fig. 4).

Determination of the areal extent of bedrock shoulder areas and their varying depths of burial are matters worthy of continued research. Regarding depths to buried bedrock shoulders, the greatest thickness of alluvium thus far removed within the corridor to reach mineralization is about 600 feet in the case of at least one open pit mine near Tucson. If adequate records are available, wells drilled for numerous reasons, especially water, are potential sources of information useful in gaining quantitative data about bedrock depths. Various geophysical surveying techniques also are useful in delineating shoulder extent.

In addition to mineral aspects, these buried shoulders have a decided influence on other phenomena. Most of the water supplies of our desert regions are stored beneath the ground surface in the thick alluvial "sponges." By contrast, the thin alluvium above bedrock shoulders is often water deficient. As depicted in Fig. 5C, the buried structural front marks a break-off point between relatively thick and thin alluvium. It is often theorized that in some cases the dewatering of the thick alluvium facilitates a settling action that results in an earth crack at the ground surface above the break-off point (Fig. 7).

It is likely that attempts will be made to suggest that future mineral exploitation will not take place beyond certain depths. If a limiting depth could be determined, a line representing this thickness of alluvium theoretically could be drawn around any mountain, which could then give guidance useful to planners. However, in the face of unknowns concerning future technological, economical, and political (world) trends, the establishment of a finite limiting depth would necessarily be arbitrary and subject to change.

CONCLUSIONS

As often has been suggested, rocks and their associated minerals have long since been fixed in place. Civilization as we know it is dependent, for better or for worse, upon discovery of presently unknown resources—the addition to our reserves. In Arizona, where most of the Nation's naturally occurring copper now appears to be, there is an increasing tendency for an expanding population to settle on valley surfaces below which bedrock is shallowly buried—the habitat of potential mineral reserves.

Anticipation and *recognition* are qualities to be encouraged in our planning and policy making entities. Like a tree, humankind is deeply rooted in the earth. Whereas a tree is fixed in position, we have been granted flexibility (choices) through technology. It is this flexibility that has given rise to alternative uses of land and a need for planning. Most of our planning is related to surface uses where there are alternatives.

However, singly or as a group, it would seem wise for us to give a thought now and then as to where the fixed earth material reserves of the future will come from, both locally and worldwide. At times it might seem as though resources exploitation is the enemy, especially when it is near at hand. However,

Figure 7
This zone of earth cracking may be above a shoulder edge that marks the west buried structural front of the Picacho Mountains that are to the left of this picture. Agricultural developments are to the right (or west).

multiple land-use seems the only wise answer and it is with this in mind that planners and policymakers should be encouraged to formulate concepts that include a concern for the *total*, inevitable needs of our progeny. Oversimplifications born of ignorance and expediency are ever present forms of injustice that can be combated with but two weapons—knowledge and concern.

REFERENCES

Jenkins, O.P. and Wilson, E.D., A geological reconnaissance of the Tucson and Amole mountains: Univ. Ariz. Bur. Mines Bull. 106, p. 3 (1920).

Titley, S.R., Copper ming and Arizona land use planning – a geologist speaks: Univ. Ariz. Bur. Mines Fieldnotes, Vol. 2, No. 4 (1972).

WHAT IS THE BUREAU?

In 1915 the Arizona Bureau of Mines was created by an Act of the State Legislature to render technical services to residents in the development of the State's mineral resources. The Bureau was placed under the authority of the Arizona Board of Regents and has always been closely associated with the College of Mines of the University. The Dean of the College of Mines is also the Director of the Bureau.

Under the enabling legislation the Bureau conducts scientific investigations and provides services in the fields of geology, metallurgy and mining in response to public inquiries and the requirements of agencies of the State government. These services include:

1. Development and dissemination of technical and nontechnical information.
2. Original field and laboratory investigations of geological topics and mineral resources studies.
3. Information services on metallurgical problems referred to the Bureau, and laboratory metallurgical research and tests on metallic and nonmetallic mineral materials.
4. Advice and information for owners and/or operators of mining properties concerning the techniques and economics of mine development, materials handling, sampling, assaying, mining methods and costs, equipment selection and operation, marketing of mineral products, and other subjects related to mining.
5. Classification, free of charge, of mineral and rock specimens that originate within Arizona. When desirable, qualitative tests for the important chemical elements are made. This service also includes an assessment of the economic value and possible market for the materials submitted. A $2.00 per sample charge is made for those samples originating outside of Arizona. Spectrographic analysis, X-ray studies, detailed microscopic determinations, and the preparation of thin sections are done at established rates, a schedule of which will be furnished upon request.

In order to carry out these functions, two operational subdivisions have been established in the Bureau.

GEOLOGICAL SURVEY BRANCH

This branch is charged with the responsibility of acquiring, disseminating and applying basic geologic data that are designed to (a) enhance our understanding of Arizona's general geologic and mineralogic history and to assist in determining the short and long range influence these have on human activity and the relative merits of alternate land-use plans, and (b) to assist in developing an understanding of the controls influencing the location of metallic and nonmetalic mineral resources and mineral fuels in Arizona.

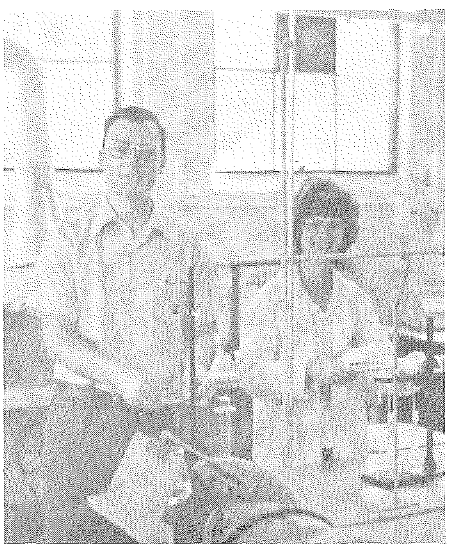
The Geological Survey Branch of the Bureau is the geological survey of the State of Arizona and, as such, is coordinated with the surveys of 49 of the states (Rhode Island is the only state without a geological survey). The Director of the Bureau is a member of the Association of American State Geologists

(AASG) inasmuch as he acts as the State Geologist for Arizona. Currently the Director of the Arizona state survey is the liaison representative of AASG for the eight western states in their interactions with the natural resource-oriented agencies of the federal government in Washington, D.C.

The principal function of a state geological survey is to develop an information base on the geologic setting and mineral, water and energy resources of their state. The value of such a survey is this repository of information as well as the expertise of its staff in providing rapid answers to questions concerning the resources of the state. The publications of the Bureau reflect topical areas of the data base which is available. The services available from the Bureau reflect the expertise of the staff.

MINERAL TECHNOLOGY BRANCH

This branch conducts research and investigations into, and provides information about, the development of Arizona's mineral resources, including the extraction, refinement, and utilization of metallic and nonmetallic mineral



Dr. Walter W. Fisher, Metallurgist, with his new laboratory technician, Mrs. Mariann Hill, who joined the Bureau staff in November. Mrs. Hill is an atomic absorption spectrograph operator.

deposits. These activities are directed toward the efficient recovery of Arizona's mineral resources as well as insuring that the recovery methods will be compatible with the environmental aspects of the state.

The mineral technology branch of the Arizona Bureau of Mines accepts samples for ore tests under the following conditions:

1. Requests for testing must be approved by the Director of the Arizona Bureau of Mines, Tucson. The reason for this regulation is, due to the time required to make tests, the Bureau must have some evidence that the test is justified and that the sample submitted is as representative as possible of the ore to be treated. A sample for such studies may vary from several pounds to several tons. The essential factor is it must be representative. The Bureau recognizes that in some cases testing may be desirable to determine the possibilities of treating an ore before a prospect or ore body is really developed, even though at that time sufficient ore is not in sight to warrant erection of a mill.
2. The Bureau of Mines will furnish a metallurgist to make the tests without charge, except for assays and materials, which will be supplied at cost. A deposit is required before tests are started to cover the cost of assays and materials and the Bureau will estimate the amount of deposit required for each sample submitted.
3. In order to serve as many as possible with the current facilities of the Bureau, the time that can be devoted to the samples from one property is limited to one week.
4. With its present facilities the Bureau cannot undertake the testing or treatment of an ore beyond the laboratories of the Bureau of Mines.
5. The order of testing samples will be the order in which they are delivered to the laboratories of the Bureau of Mines at Tucson.

Discussions of mining and ore treatment problems on material originating from within the State of Arizona will be welcome at any time.

SOLUTION MINING

Solution mining is a relatively simple but exciting technique by which mineral resources can be recovered from mineralized rock that is too deep and/or too low grade for conventional mining. Solution mining of copper from deep, low grade deposits is accomplished by pumping acid solutions underground where copper is leached from the deeply buried mineralized rock. Such deep, low-grade deposits could be rendered permeable by one of several methods: hydrofracking by an old-field-tested technique, "clean" nuclear explosives as suggested by the U.S. and U.S.S.R. Plowshare Program, or by taking advantage of the natural permeability of shear zone areas in some certain localities—a slow but successful reversal of the genesis of the ore deposit. Also, one phase of solution mining, called "washing", has been employed to create huge cavities in salt deposits which serve as high-pressure storage reservoirs for natural gas, LPG (liquid petroleum gases) and/or other petroleum products.

The U.S. Bureau of Mines investigations indicate that a dilute sulfuric acid containing sodium chloride or nitric acid is effective on ore in which the principal copper mineral is chalcopyrite, a variety that dissolves too slowly in conventional leaching conditions.

The Lawrence Livermore Laboratory experiment on a 10-ton batch of San Manuel ore (copper mineral: chalcopyrite) showed that the introduction of oxygen in very dilute sulfuric acid under pressure resulted in a surprisingly fast dissolution of the copper. The dissolution is achieved by conducting the experiment under a hydrostatic pressure simulating conditions deep underground, far below the ground water table. The essential point in the Livermore approach is solution circulation, induced and maintained by the high-pressure oxygen injection. The important facts are solution mining can be accomplished safely and economically without environmental problems such as open pit mining, mine and mill waste disposal and air pollution. Smelting would be unnecessary because copper could be won directly from the solution by electrolysis or hydrogen percipitation.

Precautions must be taken, however, against the probability of exchanging one pollution problem for another. Air pollution problems can disperse and blow away much easier than similar problems in ground water. Before any ore deposit is scheduled for in-place leaching underground, geologic studies and hydrologic surveys must establish that there is no danger of contaminating ground water supplies in the area. Studies by Lawrence Livermore Laboratories, Kennecott and McAlester Feed (at Zonia) have proven it is possible to control ground water contamination by judicious pumping to maintain hydraulic gradients with solution flow in the desired direction.

It should be emphasized that every situation is different and a separate evaluation must be made for each case.

NOTES FOR BEGINNING MINERALOGISTS

For beginning students and/or amateur prospectors, some suggested handy items to aid in mineral identification are:

(1) A sample pick or geologist's hammer with one sharpened point for digging and one flat hammer head for breaking and chipping rocks.

(2) A Mineralogist's hand lens or magnifying glass. A seven or ten power magnification is most commonly used.

(3) A small piece of non-glazed porcelain called a streak plate to determine if and what color a mineral leaves when scratched on the plate.

(4) A small magnet to test the magnetic characteristics of certain minerals.

(5) A small pocket knife, used to test hardness. Also, one may add a small piece of window glass (with smooth, sanded edges) to help determine the hardness of some minerals.

(6) A small plastic bottle of dilute (1:7) muriatic acid, well stoppered and labeled, because acid is always dangerous to clothing and eyes. This acid, also called hydrochloric acid (HCL), is useful in identifying carbonates: when the acid touches the carbonate mineral, bubbles of a gas, carbon dioxide, evolve. When the acid dissolves soluble copper minerals (usually blue or green color), the copper in solution can then be precipitated on an iron nail.

(7) As you become more proficient and involved, you may wish to add a gold pan or frying pan for panning ores, an ultra-violet or black-light source to test for fluoroluminescent minerals, a small laboratory-style microscope, flame-testing equipment, reagents and equipment for blow pipe analysis and perhaps a mineralogy handbook such as Dana's Mannual of Mineralogy, revised by Hurlbut, John Wiley and Sons, Publishers. Two Arizona Bureau of Mines publications, Bulletin 175, FIELD TESTS FOR COMMON MINERAL ELEMENTS by Roseveare, and Bulletin 165, ONE HUNDRED ARIZONA MINERALS by Moore, provide valuable descriptions of relatively simple field tests and list additional equipment.

SOLUTION MINING

The emphasis on land use in the future is careful geologic and hydrologic study before any mining venture is attempted.

FIELDNOTES Mailing List
New Request ( ) Change of Address ( )
(please attach old label)

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(Name)

____
(Street or Box No.)

____
(City) (State) (Zip)

____
(Business or Professional Affiliation)

FIELD NOTES
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