FIELD NOTES FROM THE ARIZONA BUREAU OF MINES

Vol. 5 No. 3 Earth Science and Mineral Resources in Arizona *Sept. 1975*

GEOLOGY AND LAND-USE PLANNING

by John S. Vuich
Assistant Geologist

Geologic hazards, mining, environment, land-use planning, urban sprawl, ecology — these stimulating, often controversial, and occasionally inflammatory words have been in our working vocabulary for a number of years. Common usage of these words has increased with people's growing awareness of their physical environment as they occupy more and more land. For instance, Arizona's phenomenal growth rate is creating a prime example of urban sprawl and also giving our state's population an accelerated course in the semantics of environmental problems.

As we advance our knowledge of the environment, and simultaneously inhabit available space at an alarming rate, land-use planning becomes a necessity if we are to live in harmony with our surroundings.

The Geological Survey Branch of the Arizona Bureau of Mines is concerned with land-use planning issues. Past editions of FIELDNOTES contain feature articles relating to natural resource exploration, energy, and a series on land-use planning; we have been striving in the last few months of consolidate these topics into a single, workable volume. Specifically, we are in the process of putting together a bulletin that will both discuss the importance of geology in land-use planning and cite examples of applied geology.

We recognize that this is a good time...time as appropriately expressed in the following lines, adapted with extreme literary license from Lewis Carrol:

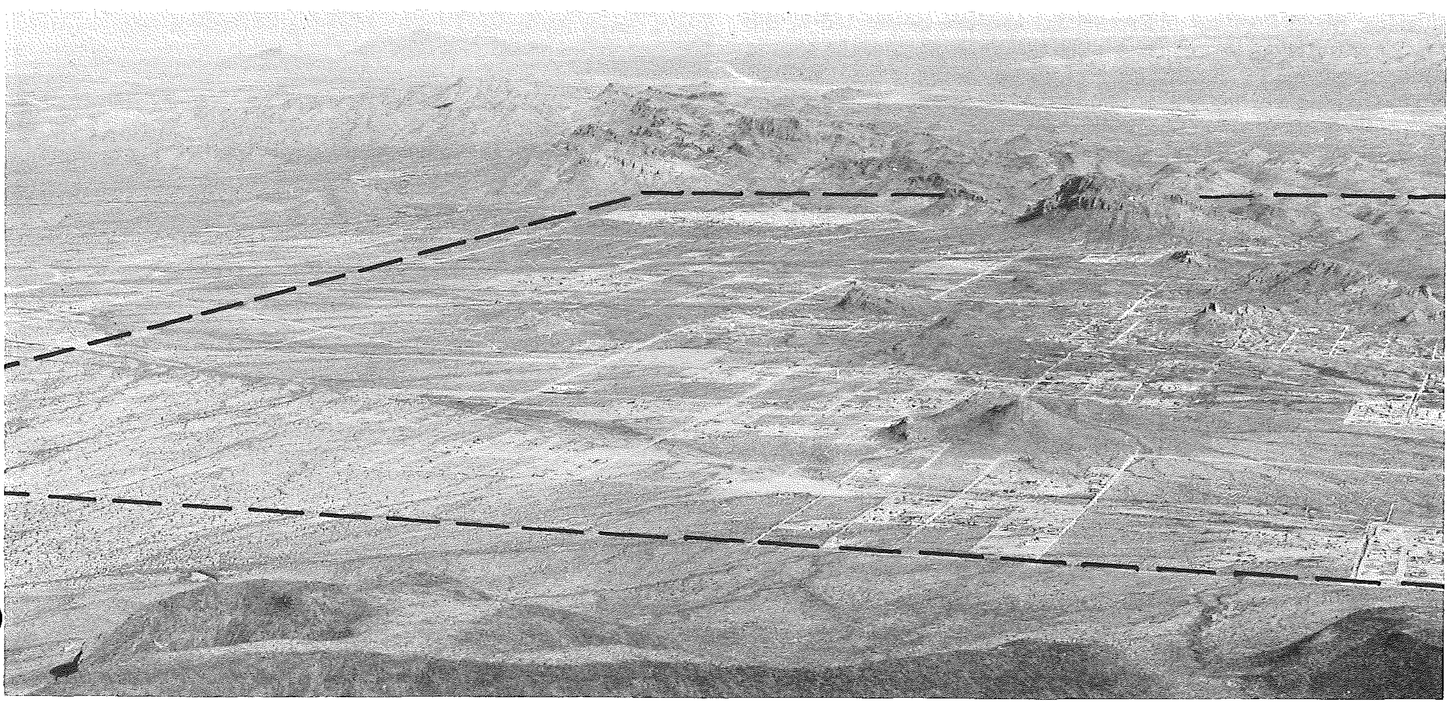
"The time has come," the Biosphere said,
"To speak of many seers,
of geologists, ecologists, and miners,
of environmentalists and engineers."

Land-use problems are not caused by, or solved by, one profession alone. Specialists in many fields will have to tax their abilities and work in cooperation toward a common goal before we can develop a functional land-use program.

Those who usually make the decisions on land use — legislators, developers, architects, realtors, and planners — rarely have geologists among their numbers. But, why *should* we include geologists or consider geology?

The reason is found in the key word *land*. Land is not limited in its connotations to acreage for homesites, a location for urban expansion, or any other single purpose. Land includes the surface of the earth and its natural resources. Natural resources are not necessarily contained only on the surface but in the substance of the land, and thus land includes the dimension of depth to its meaning. In a broader sense, *land* can be defined as a part of our physical environment.

How many of us have considered what the physical environment is? If not animal or vegetable, it must be mineral substance. Again, we must be speaking solely of inorganic matter, i.e., the whole earth. Geology is the science of the earth: its surface, its



This aerial photograph shows much of the area within the southern portion of the Tucson Mountains under study for the land-use and geology bulletin. View is northwesterly from Black Mountain.

atmosphere, its interior, its resources, and therefore should be considered fundamental to land-use planning.

A major problem in planning for good land use involves the lack of adequate input of applied geologic principles. True, geologic information is available for planning, and some reference to the geologic factors is occasionally found in zoning ordinances. The difficulties arise, however, when there are no qualified people to interpret the available geologic information. That is, much of the geologic data available is not in a form to be easily understood by the non-geologist planner.

There are two approaches that hold promise in solving this dilemma. The first would be to have geologists on planning boards, as construction project-code examiners, and as legislators. An alternative to the first solution would at least require the inspection, endorsement, and interpretation of land-use planning proposals by qualified geologic consultants. A second method is to have geologists prepare pertinent geologic information in such a form that it can be interpreted by non-geologists. Realistically, a compromise of the two methods would be the more beneficial and functional solution.

The Geological Survey Branch of the Arizona Bureau of Mines can assist in the latter case by preparing and interpreting geologic material for use by non-geologists. Thus, the purpose of our bulletin-in-progress is to perform just such a task. As the bulletin's main theme, geologic factors fundamental to land-use planning are discussed relative to physical environmental conditions common to the Southwest desert region. We believe that it will even be more helpful to planners because we cite examples of geology's role in familiar working situations.

A primary consideration in choosing the study area was the matter of logistics. The area had to be close to Bureau offices, to allow inspection of any particular location on short notice and also keep field expenses to a minimum. An ideal location was found in the south Tucson Mountain region, 6 miles southwest of downtown Tucson.

The area is divided into political jurisdictions of city, county, and Indian Reservation land. There are urban, suburban, and semi-rural living conditions. Besides private residences and business establishments, there are farming and mining areas. A river channel and flood plain contrasts with nearby steep, rocky hillsides. Sheet flooding and rock fall zones can be defined in the study area. Also of significance is the fact that much of the area is being developed at a relatively rapid pace.

The bulletin will begin as a standard geologic report. A geologic base map is being prepared, with accompanying text to describe the regional geology. After this data is presented, the format will change; the text will become explanatory, illustrated with many drawings and photographs. Several interpretive maps will be included, indicating areas of potential mineral resources, geologic hazards, and other geology-dependent factors of importance in land-use planning. This bulletin's objective is to be clear, concise, and of immediate benefit to non-geologists and geologists alike. If this bulletin lives up to its greatest expectations, it will be a primary guide in all major land-use decisions in southern Arizona. To be effective, it needs adequate exposure to planners, developers, and legislators.

FIELDNOTES has a much larger distribution than that which we anticipate for our bulletin on geology and land-use planning. Perhaps, therefore, this is an appropriate place to voice some opinions on the importance of geology in land-use planning. It has been said that a geologist's greatest frustration is not in trying to sell a particular recommendation based on a geologic study but to sell the idea of why the geology (physical environment) should be considered at all.

Figures 1 through 5 show a few reasons why a basic understanding of geology is important.

Did the contractor consider digging 8 feet into bedrock (Fig. 1) to place a sewer line? Who eventually absorbs the costs if it is an oversight?

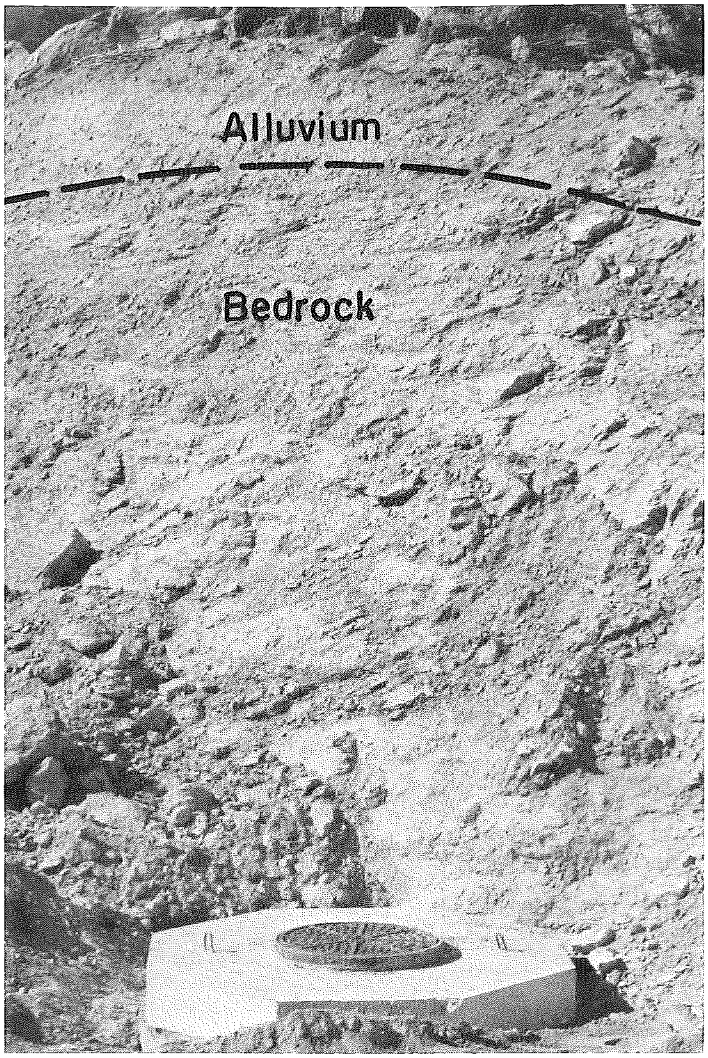


Fig. 1. Sewer line cover emplaced in hard bedrock. Note the large boulders and relatively thin alluvial cover 8 feet above.

Sometimes we neglect to estimate the amount of bank erosion that may occur on a "safe" floodplain (Fig. 2). Will this form of remedial measure actually save easements and residential property?

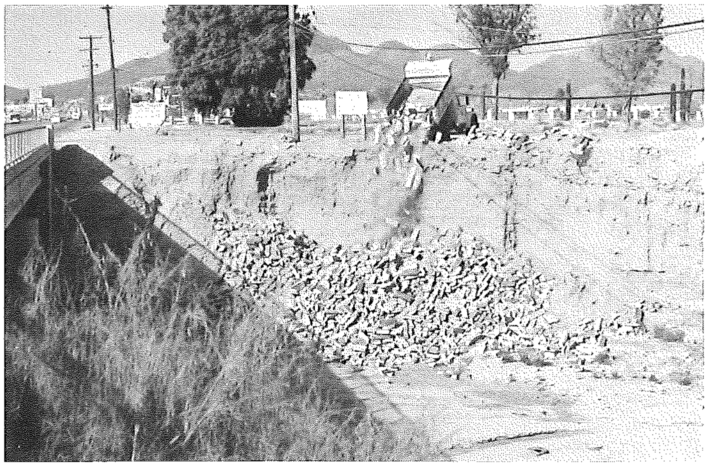


Fig. 2. A truck dumps rip-rap material in an attempt to forestall stream under-cutting which commonly caves large portions of Santa Cruz channel bank. An easement on the flood plain parallels this bank just a few feet away.

A seemingly firm, rock surface (Fig. 3) is still subject to destructive erosion when disturbed by human activity. You can't blame this erosion on off-road vehicle trails or prospectors. It's on a road within a mobile home subdivision.

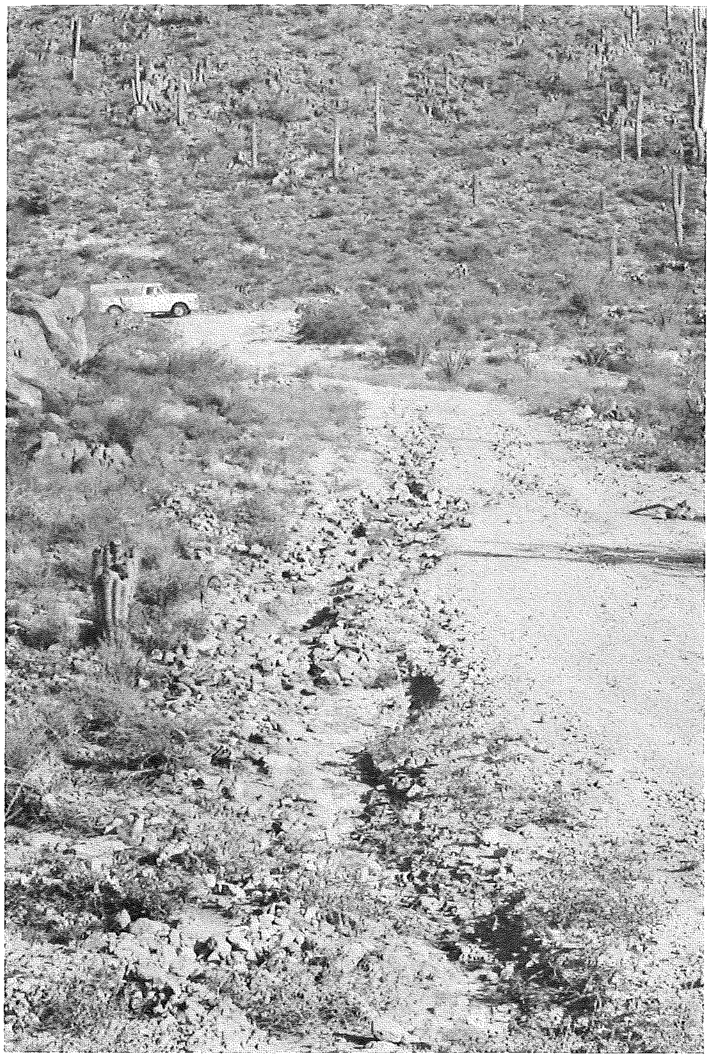


Fig. 3. This gully-cutting form of destructive erosion on a subdivision road was caused by human activity (bulldozer grading?).

Stream channel modification (Fig. 4) is common in many subdivisions. What changes can we expect on downstream flow rate, stream velocity, and groundwater recharge capability?

Fig. 4. Stream channel modification such as this one shown above is common to new subdivisions.

In Figure 5 we see one more example of domestic residences encroaching on an old mining district whose production history is recorded fact. This mineralized area has also been subject to a sporadic continuance of mineral exploration ventures. Has anyone proved that the area is void of any potentially economic mineral deposits? Perhaps all these residents have staked their own backyard with mineral claims and are not the least bit concerned. We all should be concerned, however; proposed land-use applications would have some of the unpatented land pictured here reserved for recreation and public use.

In conclusion, I would like to leave you with this analogy as a point to ponder: would we readily accept a ride (prior to F.A.A. certification) in an airplane designed by an accountant who never sought the advice of an aeronautical engineer? Yet, today we are developing land, legislating zoning ordinances, planning for future development and construction, and writing environmental impact statements, often without the advice of a geologist.

Can we really be getting (1) the most benefit of the land to (2) the most people for (3) the greater duration with (4) the least cost and (5) the least damage to the environment? Figure 6 illustrates just one of the many conflicts a geologist has in convincing the public why we must use geology in land-use planning.

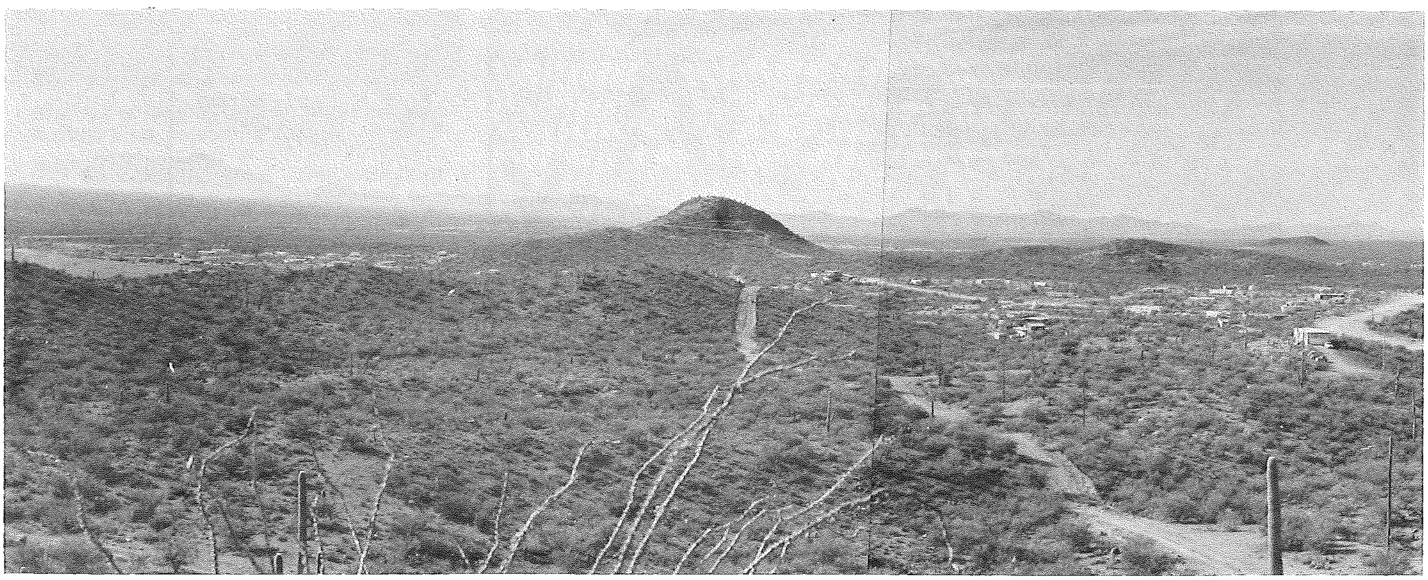


Fig. 5. Residential development encroaches on an old mining area.

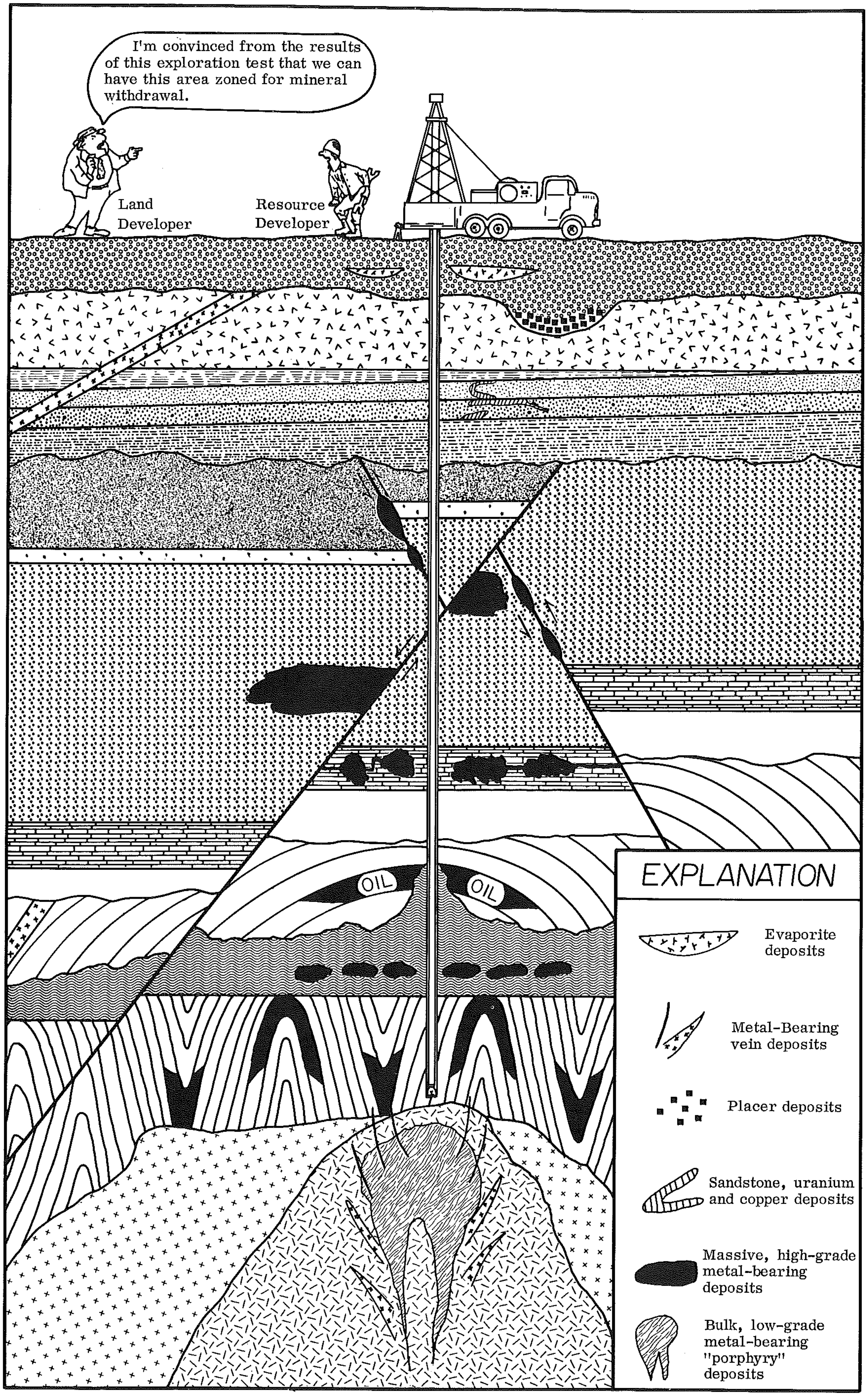


Fig. 6. "To reason without data," (or with inconclusive data), "is nothing but delusion." With apologies to Arthur Holmes.

Salt — An Arizona Resource

by H. Wesley Peirce
Geologist

It was November of 1968 when Gerald J. Grott, the brains and driving force behind the Southwest Salt Co., decided to risk hard cash in a costly drill hole near Luke Air Force Base northwest of Phoenix. The hole was the culmination of much searching effort on his part for clues as to the whereabouts of salt/rock salt resources as close to Phoenix as possible.

Well, he found it — many *cubic miles* of natural, high-purity rock salt. Grott's first hole topped the salt just 880 feet below the surface; the salt continues for several thousands of feet in depth.

The Geological Survey Branch of the Arizona Bureau of Mines has more than a little interest in the development of this salt. As Mr. Grott will be the first to tell you, it played a significant role in preliminaries leading up to his discovery.

The discovery of the deposit is a fascinating contribution to knowledge of Arizona's geologic history, and the salt itself is a valuable natural resource. Both aspects are of interest to the Bureau.

Presently, the largest markets for the dried, ground, and sized product are in the cattle feeding and water softening industries, though there are numerous lower-volume users. Prior to Grott's discovery, all salt products were imported into Arizona.

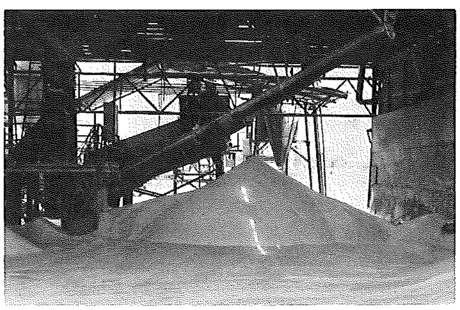


Fig. 7. Cal Gas' railroad tanker propane loading and unloading facility. Product goes into or comes from solution cavities in salt via pipeline. White Tank Mountains and agricultural land in background.

Processing involves pumping water into the salt to dissolve it, then pumping the resulting brine into solar evaporation ponds. The cavern-like areas created by the dissolving process have attracted another industry to the state — an energy industry. Since the salt walls do not dissolve in contact with hydrocarbons, these large caverns are ideal for storage of propane, a form of liquid petroleum gas (LPG).

Propane vaporizes at normal pressures, and so it is widely used as a fuel for heating where the more common energy sources (natural gas and electricity) are not readily available. Also, it serves as a back-up generating fuel for power companies normally dependent on now-scarce natural gas.

Cal Gas has made an agreement with Southwest Salt whereby the salt company processes the brine produced by the dissolving process, and the energy company leases the newly-created storage space. Cal Gas' facilities are now operational and include an intriguing self-contained system for loading and unloading railroad tank cars via a short-distance pipeline to the underground storage cavities. This Arizona installation now serves as Cal Gas' western distribution center.

Fig. 8. Brine from solutioning of a storage cavity enters evaporation pond.

Because of the large size of the salt deposit, coupled with its strategic location with respect to railroads, pipelines, and Arizona's largest urban center, it would indeed be difficult to predict the extent of its ultimate development. But since

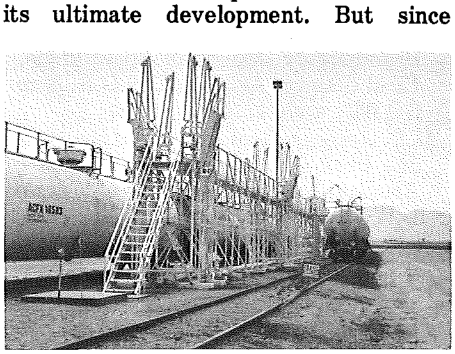


Fig. 9. Harvested, dried, and screened salt ready for bulk loading.

Arizona is an energy importer, and we *can* predict probable future energy materials shortage, it behooves State officials to plan ahead.

Energy planning must consider materials storage; it therefore seems likely that the salt will one day figure strongly in energy logistics for Arizona, if not for an even larger region of the western United States.

Uranium Resource Study Continues

For almost a year, the Geological Survey Branch of the Arizona Bureau of Mines has been studying the uranium potential of the Mogollon Rim area of Arizona.

As reported in the September 1974 issue of FIELDNOTES, the U.S. Geological Survey awarded a one-year grant in response to a proposal submitted by H. Wesley Peirce, a Bureau geologist. The proposal was to study certain rock formations that are exposed along the Mogollon Rim of east-central Arizona between Oak Creek Canyon south of Flagstaff and Whiteriver south of Show Low. Northward, these rocks are buried beneath the Mogollon Slope and have been encountered by petroleum exploration companies in scattered test drilling.

The U.S. Geological Survey awarded similar grants to several other states as part of a major effort to learn more about the nation's uranium potential, especially the potential that exists in rocks that remain buried beneath large regions.

Because uranium is radioactive and surface occurrences can be detected by almost anyone carrying or flying the proper instruments, the easily found deposits are already known. This means

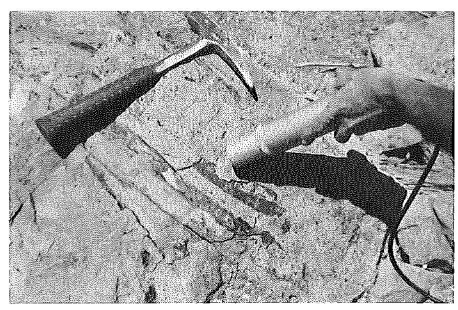


Fig. 10. Hand of Nile Jones holds scintillator probe against conglomeratic material to check radioactivity level contained in uraniferous plant debris that has been carbonized.

that new reserves will be difficult to find, and it will take a combination of scientific know-how, good luck, time, and money to find them if they are to be found. Obviously, most of the rocks of the world are

Continued page 11

Use of Sewage Effluent in Mineral Processing

by Walter W. Fisher
Assistant Metallurgist

The first official step toward use of sewage effluent by mining companies in the Tucson area was made in August of this year. The four copper mining companies located south of Tucson signed letters of intent with the Metropolitan Utilities Management Agency to share the cost of an engineering study, which will investigate the feasibility of using treated sewage effluent in their milling operations (*Tucson Daily Citizen*, August 6, 1975).

For several years there has been considerable interest and unofficial discussion on using municipal waste water, but the agreement between MUM and the mining companies is the first official action.

The Mineral Technology Branch of the Arizona Bureau of Mines began laboratory investigations about three years ago (FIELDNOTES, Vol. 4, No. 3, p.1) to explore the feasibility of using sewage effluent for flotation recovery of copper-molybdenum sulfides. The results of preliminary lab tests encouraged the Bureau to apply to the Water Research and Technology Office at the University of Arizona for a grant to study "the use of clear-water sewage effluent in mineral processing." Serious testing of sewage effluent as make-up water for copper milling operations began in July 1973.

The initial study was aimed primarily at defining the problems to be encountered if sewage effluent were substituted for fresh water in copper recovery operations. Two major problems were identified by this work. First, the untreated sewage effluent causes excessive foaming, which is detrimental to flotation. Second, unknown contaminants in the untreated effluent cause a large decrease in molybdenum recovery, though they do not appreciable affect the copper recovery. Since molybdenum is a valuable by-product of the mining operation, such drastic loss of recovery is unacceptable.

As the first phase of the laboratory study neared completion in mid-1974, a series of informal discussions between representatives from the City of Tucson, Pima County, Anamax Mining Co., Duval Corp., Cyprus Pima Mining Co., ASARCO, Inc., and the Arizona Bureau of Mines were held to explore the possibility of utilizing sewage effluent in the mining and milling operations. The major issue in the discussions was the quality of water required for milling operations. After considerable discussion, it was decided that the question of water quality could

Continued page 11

Arizona's Geologic Maps

The following maps are U.S. Geological Survey Geologic Quadrangle Maps (GQ), Miscellaneous Geologic Investigation Maps (I), and Mineral Investigation Field Studies (MF), covering Arizona, that have been published since 1947.

The preliminary numbers on the following list were assigned to simplify the index map, which shows the areas covered by these maps.

NOTE

The maps are sold by the U.S. Geological Survey and can be ordered from:

Map Sales Office
U.S. Geological Survey
Bldg. 41, Federal Center
Denver, CO 80225

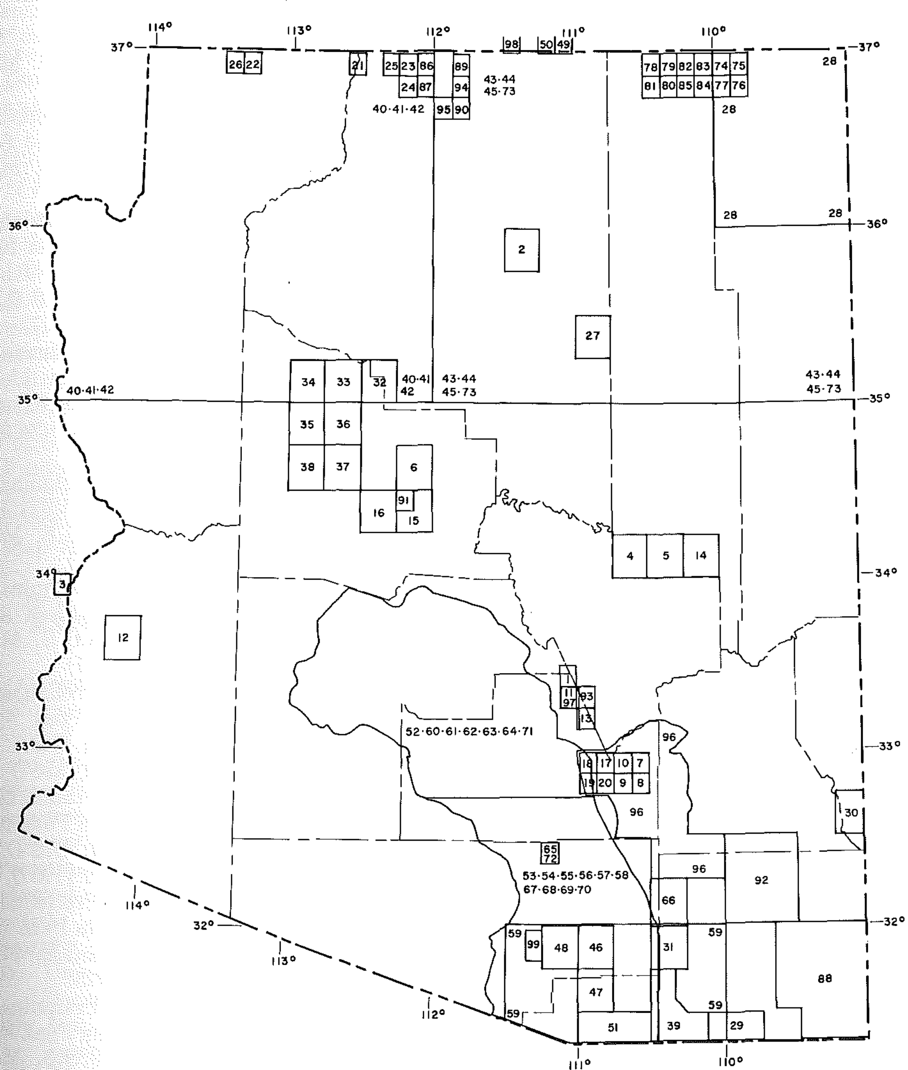
U.S.G.S. Geologic Quadrangle Maps — GQ Series

1. *D.W. Peterson:* Geology of the Haunted Canyon Quadrangle, Arizona; U.S.G.S. Map GQ-128, scale 1:24,000 (1960)
2. *J.P. Akers, J.H. Irwin, P.R. Steven, and N.E. McClymonds,* (with a section on uranium deposits by W.L. Chenoweth, Atomic Energy Commission): Geology of the Cameron Quadrangle, Arizona; U.S.G.S. Map GQ-162, scale 1:62,500 (1962)
3. *W. Hamilton:* Geologic map of the Big Maria Mountains NE Quadrangle, Riverside County, California and Yuma County, Arizona; U.S.G.S. Map GQ-350, scale 1:24,000 (1964)
4. *T.L. Finnell:* Geologic map of the Chediski Peak Quadrangle, Navajo County, Arizona; U.S.G.S. Map GQ-544, scale 1:62,500 (1966)
5. *T.L. Finnell:* Geologic map of the Cibecue Quadrangle, Navajo County, Arizona; U.S.G.S. Map GQ-545, scale 1:62,500 (1966)
6. *C.A. Anderson and S.C. Creasy:* Geologic map of the Mingus Mountain Quadrangle, Yavapai County, Arizona; U.S.G.S. Map GQ-715, scale 1:62,500 (1967)
7. *M.H. Krieger:* Geologic map of the Brandenburg Mountain Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-668, scale 1:24,000 (1968)
8. *M.H. Krieger:* Geologic map of the Holy Joe Peak Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-669, scale 1:24,000 (1968)
9. *M.H. Krieger:* Geologic map of the Lookout Mountain Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-670, scale 1:24,000 (1968)
10. *M.H. Krieger:* Geologic map of the Saddle Mountain Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-671, scale 1:24,000 (1968)
11. *D.W. Peterson:* Geologic map of the Superior Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-818, scale 1:24,000 (1969)
12. *F.K. Miller:* Geologic map of the Quartzsite Quadrangle, Yuma County, Arizona; U.S.G.S. Map GQ-841, scale 1:62,000 (1970)
13. *H.R. Cornwell, N.G. Banks, and C.H. Phillips:* Geologic map of the Sonora Quadrangle, Pinal and Gila Counties, Arizona; U.S.G.S. Map GQ-1021, scale 1:24,000 (1971)
14. *E.J. McKay:* Geologic map of the Show Low Quadrangle, Navajo County, Arizona; U.S.G.S. Map GQ-973, scale 1:62,000 (1972)
15. *C.A. Anderson and P.M. Blacet:* Geologic map of the Mayer Quadrangle, Yavapai County, Arizona; U.S.G.S. Map GQ-996, scale 1:62,500 (1972)
16. *C.A. Anderson and P.M. Blacet:* Geologic map of the Mount Union Quadrangle, Yavapai County, Arizona; U.S.G.S. Map GQ-997, scale 1:62,500 (1972)
17. *M.H. Krieger:* Geologic map of the Winkleman Quadrangle, Pinal and Gila Counties, Arizona; U.S.G.S. Map GQ-1106, scale 1:24,000 (1974)
18. *M.H. Krieger:*- Geologic map of the Crozier Peak Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-1107, scale 1:24,000 (1974)
19. *M.H. Krieger:* Geologic map of the Black Mountain Quadrangle, Pinal County, Arizona; U.S.G.S. Map GQ-1108, scale 1:24,000 (1974)
20. *M.H. Krieger:* Geologic map of the Putman Wash Quadrangle, Pinal County, Arizona, U.S.G.S. Map GQ-1109, scale 1:24,000 (1974)

U.S.G.S. Miscellaneous Geologic Investigations Maps — I Series

21. *R.H. Morris:* Photogeologic map of the Fredonia NE Quadrangle, Coconino and Mohave Counties, Arizona; U.S.G.S. Map I-247, scale 1:24,000 (1957)
22. *G.H. Marshall:* Photogeologic map of the Hurricane Cliffs 2NE Quadrangle, Coconino County, Arizona; U.S.G.S. Map I-252, scale 1:24,000 (1957)
23. *J.P. Minard:* Photogeologic map of the House Rock Springs NW Quadrangle, Coconino County. Arizona; U.S.G.S. Map I-253, scale 1:24,000 (1957)
24. *J.S. Pomeroy:* Photogeologic map of the House Springs SW Quadrangle, Coconino County, Arizona; U.S.G.S. Map I-254, scale 1:24,000 (1957)
25. *K. McQueen:* Photogeologic map of the Shainrump NE Quadrangle,

GEOLOGIC MAPS OF ARIZONA



Coconino County, Arizona; U.S.G.S. Map I-255, scale 1:24,000 (1957)

26 *J.S. Pomeroy:* Photogeologic map of the Hurricane Cliffs 2 NW Quadrangle, Mohave County, Arizona; U.S.G.S. Map I-293, scale 1:24,000 (1959)

27. *J.H. Irwin, J.P. Ackers, and M.E. Cooley:* Geology of the Leupp Quadrangle, Arizona; U.S.G.S. Map I-352, scale 1:62,500 (1962)

28. *R.B. O'Sullivan and H.M. Beikman:* Geology, structure, and uranium deposits of the Shiprock Quadrangle, New Mexico and Arizona; U.S.G.S. Map I-342, scale 1:250,000 (1963)

29. *P.T. Hayes and E.R. Landis:* Geologic map of the southern part of the Mule Mountains, Cochise County, Arizona; U.S.G.S. Map I-418, scale 1:48,000 (1964)

30. *R.B. Morrison:* Geologic map of the Duncan and Canador Peak Quadrangles, Arizona and New Mexico; U.S.G.S. Map I-442, scale 1:48,000 (1965)

31. *S.C. Creasey:* Geologic map of the Benson Quadrangle, Cochise and Pima Counties, Arizona; U.S.G.S. Map I-470, scale 1:48,000 (1967)

32. *M.H. Krieger:* Reconnaissance geologic map of the Ash Fork Quadrangle, Yavapai and Coconino Counties, Arizona; U.S.G.S. Map I-499, scale 1:62,500 (1967)

33. *M.H. Krieger:* Reconnaissance geologic map of the Picacho Butte Quadrangle, Yavapai and Coconino Counties, Arizona; U.S.G.S. Map I-500, scale 1:62,000 (1967)

34. *M.H. Krieger:* Reconnaissance geologic map of the Turkey Canyon Quadrangle, Yavapai County, Arizona; U.S.G.S. Map I-501, scale 1:62,500 (1967)

35. *M.H. Krieger:* Reconnaissance geologic map of the Camp Wood Quadrangle, Yavapai County, Arizona; U.S.G.S. Map I-502, scale 1:62,500 (1967)

36. *M.H. Krieger:* Reconnaissance geologic map of the Simmons Quadrangle, Yavapai County, Arizona; U.S.G.S. Map I-503, scale 1:62,500 (1967)

37. *M.H. Krieger:* Reconnaissance geologic map of the Iron Springs Quadrangle, Yavapai County, Arizona; U.S.G.S. Map I-504, scale 1:62,500 (1967)

38. *M.H. Krieger:* Reconnaissance map of the Huachuca and Mustang Mountains, southeastern Arizona; U.S.G.S. Map I-509, scale 1:48,000 (1968

40. *I. Zietz and J.R. Kirby:* Transcontinental geophysical survey (35° - 39° N) magnetic map from 112° W longitude to the coast of California; U.S.G.S. Map, I-532-A, scale 1:1,000,-000 (1968)

41. *Compiled by the United States Air Force Aeronautical Chart and Information Center:* Transcontinental geophysical survey (35°-39°N) Bouquer gravity map from 112° W longitude to the coast of California; U.S.G.S. Map I-532-B, scale 1:1,000,000 (1968)

42. *J.E. Carlson and R. Willden:* Transcontinental geophysical survey (35°-39°N) geologic map from 112° W longitude to the coast of California; U.S.G.S. Map I-532-C, scale 1:1,000,000 (1968)

43. *I. Zietz and J.R. Kirby:* Transcontinental geophysical survey (35°-39°N) magnetic map from 100° to 112° W longitude; U.S.G.S. Map I-533-A, scale 1:1,000,000 (1968)

44. *Compiled by the United States Air Force Aeronautical Chart and Information Center:* Transcontinental geophysical survey (35°-39°N)Bouquer gravity map from 100° to 112° W longitude; U.S.G.S. Map I-533-B, scale 1:1,000,000 (1968)

45. *J.E. Carlson and R. Willden:* Transcontinental geophysical survey (35°-39°N) geologic map from 100° to 112° W longitude; U.S.G.S. Map I-533-C, scale 1:1,000,000 (1968)

46. *H. Drewes:* Geologic map of the Sahuarita Quadrangle, southeast of Tucson, Pima County, Arizona; U.S.G.S. Map I-613, scale 1:48,000 (1971)

47. *H. Drewes:* Geologic map of the Mount Wrightson Quadrangle, southeast of Tucson, Santa Cruz and Pima Counties, Arizona; U.S.G.S. Map I-614, scale 1:48,000 (1971)

48. *J.R. Cooper:* Geologic map of the Twin Buttes Quadrangle, southwest of Tucson, Pima County, Arizona; U.S.G.S. Map I-745, scale 1:48,000 (1973)

49. *F. Peterson and B.E. Barnum:* Geologic map of the southeast Quarter of the Cummings Mesa Quadrangle, Kane and San Juan Counties, Utah, and Coconino County, Arizona;

U.S.G.S. Map I-758, scale 1:24,000 (1973)

50. *F. Peterson and B.E. Barnum:* geologic map of the southwest quarter of the Cummings Mesa Quadrangle, Kane and San Juan Counties, Utah and Coconino County, Arizona; U.S.G.S. Map I-759, scale 1:24,000 (1973)
51. *F.S. Simons:* Geologic Map and Sections of the Nogales and Lochiel Quadrangles, Santa Cruz County, Arizona; U.S.G.S. Map I-762, scale 1:48,000 (1974)
52. *E.S. Davidson:* Index and description of flood prone area maps in the Tucson-Phoenix area, Arizona; U.S.G.S. Map I-843-A, scale 1:500,000. (1973)
53. *Compiled by U.S. Department of Agriculture and Arizona Water Commission:* Map of land status in the Tucson area, Arizona-1973; U.S.G.S. Map I-844-A, scale 1:250,000 (1973)
54. *Compiled by U.S. Department of Agriculture and Arizona Water Commission:* Map of irrigated land in the Tucson area, Arizona; U.S.G.S. Map I-844-B, scale 1:250,000 (1973)
55. *M.E. Cooley:* Map showing distribution and estimated thickness of alluvial deposits in the Tucson area, Arizona; U.S.G.S. Map I-884-C, scale 1:250,000 (1973)
56. *W.R. Osterkamp:* Map showing depth to water in wells in the Tucson area, Arizona; U.S.G.S. Map I-844-D, scale 1:250,000 (1973)
57. *W.R. Osterkamp:* Ground water recharge in the Tucson area, Arizona; U.S.G.S. Map I-844-E, scale 1:250,000 (1973)
58. *W.R. Osterkamp:* Map showing distribution of recoverable ground water in the Tucson area, Arizona; U.S.G.S. Map I-844-F, scale 1:250,000 (1973)
59. *Compilation of geology, production, and mineral occurrences by M.G. Johnson, W.J. Keith, and J.R. Bergquist:* Map showing potential for copper deposits in the eastern three-quarters of the Nogales 2° Quadrangle, Tucson area, Arizona; U.S.G.S. Map I-844-G, scale 1:250,000 (1973)
60. *Compiled by U.S. Bureau of Land Management, U.S. Department of Agriculture, and Arizona Water Commission:* Map of land status in the Phoenix area, Arizona—1973; U.S.G.S. Map I-845-A, scale 1:250,000. (1973)
61. *Compiled by U.S. Geological Survey, U.S. Department of Agriculture, and Arizona Water Commission:* Map of irrigated land in the Phoenix area, Arizona; U.S.G.S. Map I-845-B, scale 1:250,000 (1973)
62. *M.E. Cooley:* Map showing distribution and estimated thickness of alluvial deposits in the Phoenix area, Arizona; U.S.G.S. Map I-845-C, scale 1:250,000. (1973)
63. *W.R. Osterkamp:* Map showing depth to water in wells in the Phoenix area, Arizona; U.S.G.S. Map I-845-D, scale 1:250,000 (1973)
64. *Compiled by U.S. Bureau of Reclamation and U.S. Department of Agriculture:* Arability map of the Phoenix area, Arizona; U.S.G.S. Map I-845-E, scale 1:250,000 (1973)
65. *Compiled by U.S. Geological Survey:* Map of slopes and their environmental significance in the Marana Quadrangle, Arizona; U.S.G.S. Map I-846-A, scale 1:24,000 (1973)
66. *Harald Drewes:* Geologic map and sections of the Happy Valley Quadrangle, Cochise County, Arizona; U.S.G.S. Map I-832, scale 1:48,000 (1974)
67. *L.R. Kister:* Dissolved-solids content of ground water in the Tucson area, Arizona; U.S.G.S. Map I-844-I, scale 1:250,000 (1974)
68. *R.T. Moore, W. Jones, and J.W. Peterson:* Map showing nonmetallic mineral deposits in the Tucson area, Arizona; U.S.G.S. Map I-844-J, scale 1:250,000 (1974)
69. *W.R. Osterkamp:* Map showing ground water velocities in the uppermost saturated alluvial deposits of the Tucson area, Arizona; U.S.G.S. Map I-844-K, scale 1:250,000 (1974)
70. *W.R. Osterkamp and R.L. Lamey:* Map showing chemical quality of ground water for public supply in the Tucson area, Arizona; U.S.G.S. Map I-844-L, scale 1:250,000 (1974)
71. *H.H. Schumann:* Land subsidence and earth fissures in alluvial deposits in the Phoenix area, Arizona; U.S.G.S. Map I-845-H, scale 1:250,000 (1974)
72. *B.N. Aldridge and D.E. Burkham:* Delineation of flood hazards in the Marana Quadrangle, Pima County, Arizona; U.S.G.S. Map I-846-B, scale 1:36,000 (1974)
73. *E.H. McGarock and E.J. Edmonds:* Availability of ground water for irrigation, municipal, or industrial use in the Navajo and Hopi Indian Reservations, Arizona, New Mexico and Utah; U.S.G.S. Map I-878, scale 1:375,000 (1974)

U.S.G.S. Mineral Investigations Field Studies Maps — MF Series

74. *I.J. Witkind and others:* Preliminary geologic map of the Dinnehotso NW Quadrangle, Arizona-Utah; U.S.G.S. Map MF-92, scale 1:24,000 (1956)
75. *I.J. Witkind and others:* Preliminary geologic map of the Dinnehotso NE Quadrangle, Arizona-Utah; U.S.G.S. Map MF-93, scale 1:24,000 (1956)
76. *I.J. Witkind and others:* Preliminary geologic map of the Dinnehotso SE Quadrangle, Arizona; U.S.G.S. Map MF-94, scale 1:24,000 (1956)
77. *I.J. Witkind and others:* Preliminary geologic map of the Dinnehotso SW Quadrangle, Arizona; U.S.G.S. Map MF-95, scale 1:24,000 (1956)
78. *T.J. Witkind and others:* Preliminary geologic map of the Boots Mesa NW Quadrangle, Arizona — Utah; Quadrangle, Arizona-Utah; U.S.G.S. Map MF-84, scale 1:24,000 (1957)
79. *I.J. Witkind and others:* Preliminary geologic map of the Boots Mesa NE Quadrangle, Arizona-Utah; U.S.G.S. Map MF-85, scale 1:24,000 (1957)
80. *I.J. Witkind and others:* Preliminary geologic map of the Boots Mesa SE Quadrangle, Arizona; U.S.G.S. Map MF-86, scale 1:24,000 (1957)
81. *I.J. Witkind and others:* Preliminary geologic map of the Boots Mesa SW Quadrangle, Arizona; U.S.G.S. Map MF-87, scale 1:24,000 (1957)
82. *I.J. Witkind and others:* Preliminary geologic map of Agathla Peak NW Quadrangle, Arizona-Utah; U.S.G.S. Map MF-88, scale 1:24,000 (1957)
83. *I.J. Witkind and others:* Preliminary geologic map of the Agathla Peak NE Quadrangle, Arizona-Utah; U.S.G.S. Map MF-89, scale 1:24,000 (1957)
84. *I.J. Witkind and others:* Preliminary geologic map of the Agathla Peak SE Quadrangle, Arizona; U.S.G.S. Map MF-90, scale 1:24,000 (1975)
85. *I.J. Witkind and others:* Preliminary geologic map of the Agathla Peak SW Quadrangle, Arizona; U.S.G.S. Map MF-91, scale 1:24,000 (1958)
86. *J.D. Wells:* Preliminary geologic map of the House Rock Spring NE Quadrangle, Coconino County, Arizona; U.S.G.S. Map MF-188, scale 1:24,000 (1958)
87. *J.D. Wells:* Preliminary geologic map of the House Rock Spring SE Quadrangle, Coconino County, Arizona; U.S.G.S. Map MF-189, scale 1:24,000 (1959)
88. *J.R. Cooper:* Reconnaissance geologic map of the Southeastern Cochise County, Arizona; U.S.G.S. Map MF-213, scale 1:125,000 (1959)
89. *R.G. Peterson and D.A. Phoenix:* Preliminary geologic map of the Paria Plateau NE Quadrangle, Coconino County, Arizona, U.S.G.S. Map MF-214, scale 1:24,000 (1959)
90. *R.G. Peterson:* Preliminary geologic map of the Emmett Wash NE Quadrangle, Coconino County, Arizona; U.S.G.S. Map MF-215, scale 1:24,000 (1959)
91. *C.A. Anderson:* Preliminary geologic map of the NW 1/4 Mayer Quadrangle,

Yavapai County, Arizona; U.S.G.S. Map MF-228, scale 1:24,000 (1959)

92. *J.R. Cooper:* Reconnaissance map of the Willcox, Fisher Hills, Cochise, and Dos Cabezas Quadrangles, Cochise and Graham Counties, Arizona; U.S.G.S. Map MF-231, scale 1:62,500 (1960)

93. *N.P. Peterson:* Preliminary geologic map of the Pinal Ranch Quadrangle, Arizona; U.S.G.S. Map MF-81, scale 1:24,000 (1961)

94. *R.G. Peterson:* Preliminary geologic map of the Paria Plateau SE Quadrangle, Coconino County, Arizona; U.S.G.S. Map MF-196, scale 1:24,000 (1961)

95. *R.G. Peterson and J.D. Wells:* Preliminary geologic map of the Emmett Wash NW Quadrangle, Coconino County, Arizona; U.S.G.S. Map MF-197, scale 1:24,000 (1961)

96. *S.C. Creasey, E.D. Jackson, and R.A. Gulbrandsen:* Reconnaissance geologic map of parts of the San Pedro and Aravaipa Valleys, south-central Arizona; U.S.G.S. Map MF-238, scale 1:125,000 (1961)

97. *D.W. Peterson:* Preliminary geologic map of the western part of the Superior Quadrangle, Pinal County, Arizona; U.S.G.S. Map MF-253, scale 1:12,000 (1962)

98. *F. Peterson:* Geologic map of the Southwest Quarter of the Gunsight Butte Quadrangle, Kane and San Juan counties, Utah and Coconino County, Arizona; U.S.G.S. Map MF-306, scale 1:24,000 (1973)

99. *Harald Drewes and J.R. Cooper:* Reconnaissance geologic map of the west side of the Sierrita Mountains, Palo Alto Ranch Quadrangle, Pima County, Arizona; U.S.G.S. Map MF-538, scale 1:24,000 (1973)

Theses on Arizona Geology and Mines

The following M.S. and Ph.D. theses from the three Arizona universities have been published since the compilation of the most recent Arizona bibliography, Arizona Bureau of Mines bulletin 190. Unless mentioned otherwise, the locations are all within Arizona.

Permission for copying must be requested through the Dean of the Graduate College of the respective university, as coded below:

UA: University of Arizona
Tucson, AZ 85721

ASU: Arizona State University
Tempe, AZ 85281

NAU: Northern Arizona University
Flagstaff, AZ 86001

Alexander, William J.: Reconnaissance geology and geomagnetics of western Flagstaff, Coconino County; NAU, M.S., 67 p. (1974)

Arnold, Leavitt Clark: Structural geology along the southeastern margin of the Tucson Basin, Pima County; UA, Ph.D., 99 p. (1971)

Baldwin, Evelyn Joan: Environments of deposition of the Moenkopi Formation in north-central Arizona; UA, Ph.D., 208 p. (1971)

Balla, John Coleman: The relationship of Laramide stocks to regional structure in central Arizona; UA, Ph.D., 132 p. (1972)

Benfer, Jon Alan: The petrology of the eastern phase of the Toroweap Formation, Walnut Canyon; NAU, M.S., 85 p. (1971)

Bladh, Katherine Laing: Petrology of the O'Leary Peak volcanics, Coconino County; UA, M.S., 129 p. (1972)

Blake, David William: Geology, alteration, and mineralization of the San Juan Mine area, Graham County; UA, M.S., 85 p. (1971)

Boyce, Joseph Michael: The structure and petrology of the older Precambrian crystalline rocks, Bright Angel Canyon, Grand Canyon; NAU, M.S., 88 p. (1972)

Boyer, Jeffrey Allen: Hydrogeology of the Carefree Ranch area; UA, M.S., 75 p. (1974)

Briscoe, Melanie: An investigation of the invertebrate paleontology of the Tsegi and Naha Formations in Tsegi Canyon; NAU, M.S., 77 p. (1974)

Brook, Doyle Kenneth, Jr.: Relative ages of strata-form sulfide ore and wall rock determined by a structural analysis of the Copper Queen Mine, Yavapai County; UA, M.S., 60 p. (1974)

Brown, Calvin C.: Geologic influence on blasting; UA, M.S. (1972)

Burgert, Barratt L.: Petrology of the Cambrian Tapeats Sandstone, Grand Canyon; NAU, M.S., 156 p. (1972)

Butler, William Charles: Permian conodonts from southeastern Arizona; UA, Ph.D., 130 p. (1972)

Call, Richard D.: Analysis of geologic structure for open-pit slope design; UA, Ph.D. (1972)

Carrigan, Francis J.: A geologic investigation of contact metamorphic deposits in the Coyote Mountains, Pima County; UA, M.S. (1971)

Chakarun, John Douglas: Geology, mineralization and alteration of the Jhus Canyon area, Cochise County; UA, M.S., 89 p. (1973)

Cheeseman, Raymond J.: The geology of the Webb Mountain district, Gila Bend Mountains, Maricopa County; NAU, M.S., 69 p. (1974)

Condit, Christopher D.: The geology of Shadow Mountain, Coconino County; NAU, M.S., 71 p. (1973)

Dalton, Russell O.: Stratigraphy of the Bass Formation; NAU, M.S., 140 p. (1972)

Davis, Jerry: Geothermometry, geochemistry, and its alterations at the San Manuel porphyry copper ore body, San Manuel; UA, Ph.D. (1974)

Dodge, Constance Nuss: An analysis and comparison of pebbles from the Chinle and Morrison Formations, Arizona and New Mexico; UA, M.S., 49 p. (1973)

Durning, William Perry: Geology and mineralization of Little Hill Mines area, northern Santa Catalina Mountains, Pinal County; UA, M.S., 91 p. (1972)

Earl, Thomas A.: A hydrogeologic study of an unstable open-pit slope, Miami, Gila County; UA, Ph.D. (1973)

Edmiston, Robert C.: Thermal gradients and sulfide oxidation in the Silver Bell mining district, Pima County; UA, M.S. (1971)

Evans, Thomas J.: A stratigraphic study of the Toroweap Formation (Permian) between Sycamore and Oak Creek Canyons; UA, M.S., 111 p. (1971)

Fouts, James Allen: Petrology and chemistry of some diabase sills in central Arizona; UA, Ph.D., 158 p. (1974)

Frank, Thomas Russell: Geology and mineralization of the Saginaw Hill area, Pima County; UA, M.S., 136 p. (1970)

Fredericksen, Rick Stewart: The secondary dispersion of tungsten in some southern Arizona tungsten districts, UA, M.S., 152 p. (1974)

Gambell, Neil Austin: A heavy mineral reconnaissance of a portion of the Copper Basin mining district, Yavapai County; NAU, M.S., 69 p. (1973)

Gottesfeld, Allan Saul: Paleoecology of the Chinle Formation in the Petrified Forest National Park; UA, M.S., 87 p. (1971)

Gould, James E.: Lineation analysis from aerial photographs of the Sierrita Mountains, Pima County; UA, M.S. (1973)

Graybeal, Frederick Turner: The partition of trace elements among coexisting minerals in some Laramide intrusive rocks in Arizona; UA, Ph.D., 220 p. (1972)

Hampf, Andrew William: Geology of the Golden Rule Mine area, Cochise County; UA, M.S., 91 p. (1972)

Harrison, Jessica Ann: The mammals of the Wolf Ranch local fauna, St. David Formation, Cochise County; UA, M.S., 81 p. (1972)

Hastings, David A.: Analysis of geophysical data from the Point of Pines area, San Carlos Indian Reservation; UA, M.S. (1972)

Hazenbush, George Cordery: Stratigraphy and micropaleontology of the Mancos Shale (Cretaceous), Black Mesa Basin; UA, Ph.D., 182 p. (1972)

Hendricks, John D.: Younger Precambrian basaltic rocks of the Grand Canyon; NAU, M.S., 122 p. (1972)

Hereford, Richard: Cambrian-Devonian stratigraphy and Cambrian petrology in northern Yavapai County; NAU, M.S., 137 p. (1971)

Himes, Marshall David: Geology of the Pima Mine, Pima County; UA, M.S., 92 p. (1972)

Iberall, Eleanora Roberta: Paleoecological studies from fecal pellets, Stanton's Cave, Grand Canyon, UA, M.S., 67 p. (1972)

Jacobs, Louis L.: Small mammals of the Quiburis Formation, southeastern Arizona; UA, M.S., 77 p. (1973)

Janbeck, Tayseer T.: The recharge-discharge aspects of Green Valley, Pima County; UA, M.S. (1971)

Jansen, Louis: Geology of the Sus Hills, Pima County; UA, M.S. (1973)

Jones, William: Geology of the northern portion of the Ajo Mountains, Pima County; UA, M.S. (1974)

Kendorski, Francis S., III: Influence of jointing on engineering properties of San Manuel Mine rock; UA, M.S. (1971)

Klosterman, Michael J.: Structural analysis of olivine in pallistic meteorites; ASU, M.S. (1972)

Kluth, Charles F.: Geology of the Elden Mountain area, Coconino County; NAU, M.S., 89 p. (1974)

Kurupakorn, Somchai: Preliminary investigation of Upper Sabino Canyon Dam, Pima County; UA, M.S. (1973)

Laime, Roger Pierre: Geological-geochemical relationships between porphyry copper and porphyry molybdenum ore deposits; UA, Ph.D., 326 p. (1974)

Laney, Robert Lee: Weathering of the granodioritic rocks in the Rose Canyon Lake area, Santa Catalina Mountains; UA, Ph.D., 201 p. (1971)

Lausten, Charles Dean: Gravity methods applied to the geology and hydrology of Paradise Valley, Maricopa County; ASU, M.S., 137 p. (1974)

Lewis, Norman M.: The geology of the Little Rock Candy Mountain area, Yavapai County; NAU, M.S., 78 p. (1973)

Liming, Richard Brett: Geology and kinematic analysis of deformation in the Martinez Ranch area, Pima County; UA, M.S., 86 p. (1974)

Loghry, James Davy: Characteristics of favorable cappings from several southwestern porphyry copper deposits; UA, M.S., 112 p. (1972)

Lynch, Daniel James: Reconnaissance geology of the Bernardino volcanic field, Cochise County; UA, M.S., 78 p. (1972)

Lytle, Jamie Laverne: A microenvironmental study of an archaeological site; UA, M.S., 66 p. (1971)

McCabe, Kirk W.: Geology and botany of Stoneman Lake area, Coconino County; NAU, M.S., 104 p. (1971)

McCurry, Wilson G.: Mineralogy and paragenesis of the ores, Christmas Mine, Gila County; ASU, M.S. (1971)

Malone, Gary Bruce: The geology of the volcanic sequence in the Horse Mesa area; ASU, M.S. (1972)

Marshall, Donald R.: Gravity gliding at Gray Mountain, Coconino County; NAU, M.S., 83 p. (1972)

Masri, Fahad Isa: The electro-osmotic permeability of tailings from an Arizona porphyry copper mine; UA, M.S. (1973)

Merrill, Robert Kimball: The late Cenozoic geology of the White Mountains, Apache County; ASU, Ph.D. (1974)

Moores, Richard Charles III: The geology and ore deposits of a portion of the Harshaw District, Santa Cruz County; UA, M.S., 98 p. (1972)

Murry, Kent Stephen: Geology of the Woody Mountain volcanic field, Coconino County; NAU; M.S., 89 p. (1973)

Norby, Rodney Dale: Conodont biostratigraphy of the Mississippian rocks of southeastern Arizona; ASU, M.S. (1971)

Packard, Frank Alton: The hydraulic geometry of a discontinuous ephemeral stream on a bajada near Tucson; UA, Ph.D., 127 p. (1974)

Pickens, Caroline Mae: The Dakota Formation, Black Mesa Basin; ASU, M.S. (1974)

Prout, John W.: The silver-lead deposits of the Mowry Mine, Mowry, Santa Cruz County; UA, M.S. (1967)

Qahwash, Abdellatif A.: An electrical resistivity survey in the Avra Valley, Pima County; UA, M.S. (1972)

Qahwash, Abdellatif A.: An application of mathematical models for determining the optimum pattern of a geophysical exploration program; UA, Ph.D. (1974)

Racey, Jan Stewart: Conodont biostratigraphy of the Redwall Limestone of east-central Arizona; ASU, M.S. (1974)

Reid, Sue Ann: Microfauna from selected Pennsylvanian (Naco) sections in south-central Arizona; UA, M.S., 299 p. (1972)

Sanders, David E.: Massive calcite in the Vulture Mountains near Wickenburg, Maricopa County; NAU, M.S., 106 p. (1974)

Sauck, William August: Compilation and preliminary interpretation of the Arizona aeromagnetic map; UA, Ph.D., 147 p. (1972)

Savely, James P.: Orientation and engineering properties of jointing in the Sierrita Pit; UA, M.S. (1972)

Schern, Edward Michael: The occurrence of copper in clays in altered plagioclase phenocrysts; ASU, M.S., 66 p. (1975)

Schloderer, John Peter: Geology and kinematic analysis of deformation in the Redington Pass area, Pima County; UA, M.S., 60 p. (1974)

Schmidt, Eberhard Adalbert: A structural investigation of the northern Tortilla Mountains, Pinal County; UA, Ph.D., 248 p. (1971)

Scott, Phyllis Wilk: Hydrogeological-structural analysis of the Woody Mountain well field area, with geophysical interpretations, Coconino County; NAU, M.S., 79 p. (1974)

Shakel, Douglas Wilson: The geology of layered gneisses in part of the Santa Catalina forerange, Pima County; UA, M.S., 233 p. (1974)

Shank, Douglas Carl: Environmental geology in the Phoenix Mountains, Maricopa County; ASU, M.S., 137 p. (1974)

Sherwonit, William Edward: A petrographic study of the Catalina gneiss in the forerange of the Santa Catalina Mountains; UA, M.S., 165 p. (1974)

Smith, Jeffrey William: The petrology of the Mississippian Redwall Limestone in northern Yavapai County; NAU, M.S., 88 p. (1974)

South, David Long: Sulphide zoning at the Lakeshore copper deposit, Pinal County; UA, M.S., 102 p. (1972)

Spatz, David Moore: Geology and alteration-mineralization zoning of the Pine Flat porphyry copper occurrence, Yavapai County; UA, M.S., 148 p. (1974)

Stevenson, Gene M.: Stratigraphy of the Dox Formation, Precambrian, Grand Canyon; NAU, M.S., 225 p. (1973)

Stewart, James Conrad: Geology of the Morningstar Mine area, Greaterville Mining District, Pima County; UA, M.S., 79 p. (1971)

Tanenbaum, Ronald J.: Geological engineering survey of the Tucson Basin, Pima County; UA, M.S. (1972)

Thayer, David W.: Pennsylvanian *Lepospondyl* amphibians from the Swisshelm Mountains, Cochise County; UA, M.S., 66 p. (1973)

Totten, David Kenneth, Jr.: Biostratigraphy of some last Paleozoic rocks in the Naco Hills area near Bisbee; UA, M.S., 128 p. (1972)

Tougan, Omar I.: Hydrological and mechanical characteristics of soil in the area of salt deposits, northwest Phoenix; UA, M.S. (1971)

Turner, Christine E.: Facies of the Toroweap Formation, Marble Canyon; NAU, M.S., 120 p. (1974)

Van Devender, Thomas R.: Late Pleistocene plants and animals of the Sonoran Desert: a survey of ancient packrat middens in Southwest Arizona; UA, Ph.D., 179 p. (1973)

Van Fleet, John M.: Geomorphology of the Box Canyon drainage basin, Santa Rita Mountains, Pima County; UA, M.S., 47 p. (1973)

Vice, Daniel Hoy: The geology and petrography of the Babocamari Ranch area, Santa Cruz-Cochise Counties; ASU, M.S., 152 p. (1974)

Vidal, Jose Rabasso: Geology of an Upper Paleozoic sequence in north-central Canelo Hills, Santa Cruz County; UA, M.S., 54 p. (1971)

Vuich, John Steven: A geologic reconnaissance and mineral evaluation of the Wheeler Wash area, Hualpai Mountains, Mohave County; UA, M.S., 77 p. (1974)

Wadell, James Sanders: Sedimentation and stratigraphy of the Verde Formation (Pliocene), Yavapai County; ASU, M.S. (1972)

Wallick, Edward I.: Isotopic and chemical considerations in radio-carbon dating of ground water within the arid Tucson Basin; UA, Ph.D., 184 p. (1973)

West, Robert Elmer: A regional Bouquer gravity map of Arizona; UA, Ph.D., 186 p. (1972)

Wilkins, Joe: An induced polarization study at Meteor Crater; UA, M.S. (1974)

Wyman, Richard V.: The relationship of ore exploration targets to regional structure in the Lake Mead metallogenic province; UA, Ph.D. (1974)

Uranium Project *continued*

buried from view. "What is where?" is a question that never goes away, at least for geologists. In the present case, as regards uranium potential, we are searching for new frontiers, large regions that possibly could represent the exploration frontiers of the not too distant future.

Exploration frontiers frequently begin with ideas that are encouraged by interpretations permitted by favorable geologic parameters, parameters that range from the certainty of fact to the illusion of fiction. Ideas are pursued until they either result in a discovery or are discouraged by a new piece in the puzzle. However, there are many exploration interests, large and small, and each has ideas shaped by a combination of experience, philosophy, and economic facts of life.

This present study, spurred by a few non-exploited uranium mineral occurrences along the Mogollon Rim, seeks to evaluate their geologic habitat (relationship to enclosing rocks) and to wonder about the possible extent of this habitat into the subsurface beneath the Mogollon Slope. Field investigations are being conducted by geologists Nile Jones and Ralph Rogers, under the supervision of the project's Principal Investigator, Dr. Peirce.

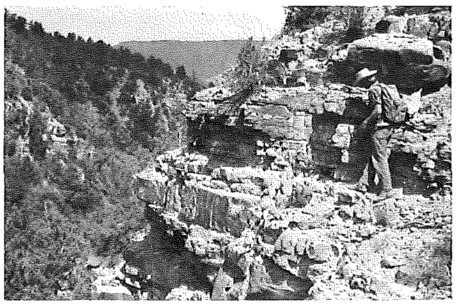


Fig. 11. Ralph Rogers examines attributes of strata that occur in the upper part of the Pennsylvanian Naco Formation exposed in walls of tributary to Fossil Creek Canyon.

Preliminary data suggest that the uraniferous minerals occur in channel-fill conglomerates in which plant debris (now carbonized fossils) became entrapped. The geology of these conglomerates is a point of emphasis.

Thus, the mode of deposition postulated in this study differs from earlier theories on uranium ore genesis, which postulated hydrothermal deposits. Although some uranium deposits are of igneous or hot-water origin, such as those associated with pegmatites and possibly those in the Precambrian rocks of the Sierra Ancha mountains, these earlier theories fell from favor for the Plateau-type and roll-front deposits when it was pointed out that they showed no marked hot-water-associated alteration. Also, the preservation of plant fossils and low-rank coals in these deposits is evidence against hydrothermal origin.

Sewage Effluent *continued*

not be answered with the available information. The most important point, however, was that the use of municipal waste water was being openly considered.

In July of 1974 the Bureau began the second phase of its work with sewage effluent. This phase of the laboratory study was designed to find methods for improving the quality of sewage effluent and to determine modifications of the flotation process so that sewage effluent would be acceptable to the mining companies. While this work was in progress, additional discussions were held in late 1974 between the Bureau and the mining companies to discuss the problem of extrapolating laboratory results to full-scale operations. The consensus was that sewage effluent should first be tested in a small pilot plant before full-scale use would be acceptable. Consequently, early in 1975, at the request of the mining companies, the Bureau staff prepared an engineering cost estimate for a 24-ton-per-day flotation pilot plant to operate for a period of two years. This estimate was prepared as a guideline to help the mining companies determine their future involvement in using sewage effluent in their operations.

The laboratory study on the use of sewage effluent in the flotation recovery of copper-molybdenum sulphides was completed in June of this year. Although the results are not conclusive, they suggest several areas of research for treating sewage effluent and optimizing the flotation process that could ultimately make use of Tucson's waste water a reality. A report of these results is currently being prepared for publication.

There are other areas of mineral processing where municipal waste water may find application, and consequently, the Bureau recently began the third phase of work with sewage effluent to determine the effect it may have on processes such as leaching, solvent extraction and metal recovery. In addition to the laboratory work, the Bureau is conducting a survey of current and past mineral processing use of sewage effluent. Although the magnitude of effluent use is small compared to that proposed for the Tucson area, our preliminary survey has identified six operations that are currently using some form of sewage effluent. The combined experience of these operations may provide some of the solutions for sewage effluent use in the Tucson area.

Geologic Hazards Study Begins

A grant to study geologic hazards in the rapidly developing area northwest of Tucson has been awarded to the Geological Survey Branch of the Arizona Bureau of Mines. The Water Resources Division of the U.S. Geological Survey awarded $30,000 for the study of geologic hazards in a portion of the Tucson Urban Basin Pilot Program area.

Specific hazards to be mapped include potentially unstable slopes, areas in which rockfalls may be expected, and areas of

Continued page 12

Geological Survey Branch and Publications Office Move

The Geological Survey Branch and the publications sales office of the Arizona Bureau of Mines have moved to new quarters at 845 North Park Avenue, Tucson.

During the latter part of August, the geologic staff, library, sales office, and well cutting storage facilities were moved from the Geology and Mines buildings to the former "College Shop" building on the western edge of the University of Arizona campus.

Dr. Dresher, the Bureau's director, and the Mineral Technology Branch, consisting of the mineralogical, mining, and metallurgical facilities, remained in their former quarters.

The new Geological Survey Branch offices are located in the basement, and the entrance is at the east side of the building, on Park Avenue. Parking is available to the west. The first floor of the building is shared by the University's Department of Arid Lands Studies and the new Center for Creative Photography.

The new mailing address for the geologic staff and the publications office is:

Arizona Bureau of Mines
University of Arizona
845 North Park Avenue
Tucson, Arizona 85719

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

Geologic Hazards *continued*

soils which are subject to piping and collapsing.

The area to be studied is bounded roughly by Eloy to the north, the Catalina Mountains to the east, Magee Road to the south, and the town of Silverbell to the west.

The project is headed by R.T. Moore, Principal Geologist, and Bruce J. Murphy, Assistant Field Geologist.

FIELD NOTES
Volume 5 No. 3 *Sept. 1975*
State of Arizona
Governor . . . . Hon. Raul Castro
University of Arizona
President . . . . John P. Schaefer
Arizona Bureau of Mines
Director . . . . William H. Dresher
Editor . . . . Judi Goodpaster
ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

ARIZONA BUREAU OF MINES
THE UNIVERSITY OF ARIZONA
845 NORTH PARK AVE.
TUCSON, ARIZONA 85719

INE 1852

[redacted]