FIELDNOTES

From The State Of Arizona
Bureau Of Geology And Mineral Technology

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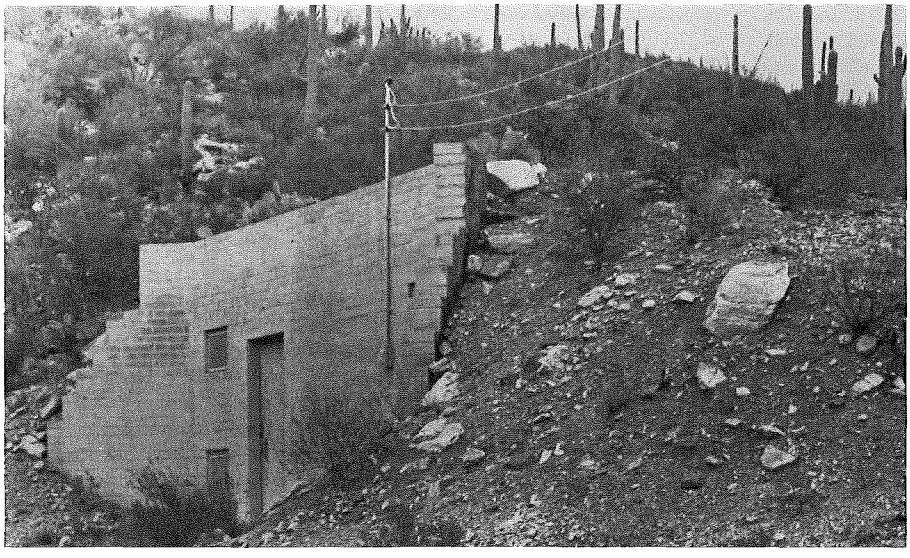
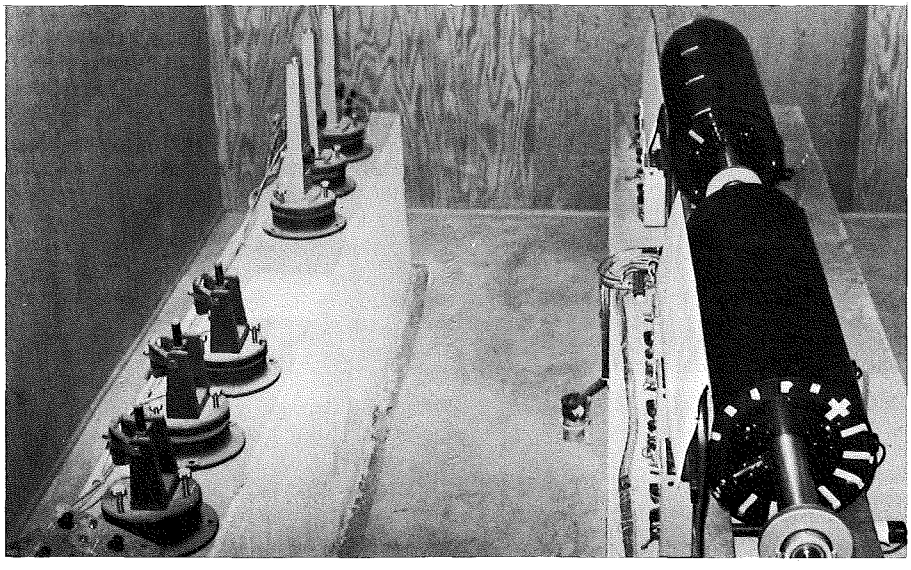
Bureau receives earthquake-recording equipment

by Marc Sbar





Jan. 1, 1978, the recording equipment of the Tucson Seismograph Station (TUC) will be transferred from its onsite location in the Catalina Mountains to the Bureau of Geology and Mineral Technology. The station's signals will also be recorded in a modified form at the Department of Geosciences of the University of Arizona. Since its inception, the TUC station has been operated by the U.S. Geological Survey, which will continue to fund the station's operation under the new configuration.

Seismographs are very sensitive recorders of ground motion. As such they record earthquakes and a variety of other phenomena: sonic booms, quarry and mining blasts, and nuclear explosions. The sensor is called a *seismometer.* Its operation is centered around an inertially stable mass suspended on a spring to detect ground motions. These masses will tend to remain stable when the ground moves, so that a change in distance between reference points on the ground and the masses occurs. These changes are then converted to electrical signals by a transducer consisting of a coil in a magnetic field. The coil is fixed to the mass and the magnet to the earth. To detect the total motion of the ground, three seismometers are needed: two perpendicular horizontal sensors and one vertical sensor. The system used by the World Wide Network of Standard Seismographs (WWNSS) includes three low-frequency seismometers and three high-frequency seismometers.

A variety of methods can be used to record the electrical output of the seismometers, ranging from digital tape recorders to a smoked drum scribed by a pen. The system employed by the

Dr. Sbar recently joined the University of Arizona's Geosciences Dept. as an Assistant Professor. Previously he was a research associate at Columbia University's Lamont-Doherty Geological Observatory. His areas of specialization are seismology and tectonics.

Above. Seismometer vault for the Tucson seismograph station in the foothills of the Catalinas. The vault is covered with earth to minimize temperature variations.
Below. Seismic recording system as currently operating at the Bureau of Geology and Mineral Technology.

Also in this FIELDNOTES

Geothermal Pipeline
Publication announcements
Oil and Gas Conservation Comm.

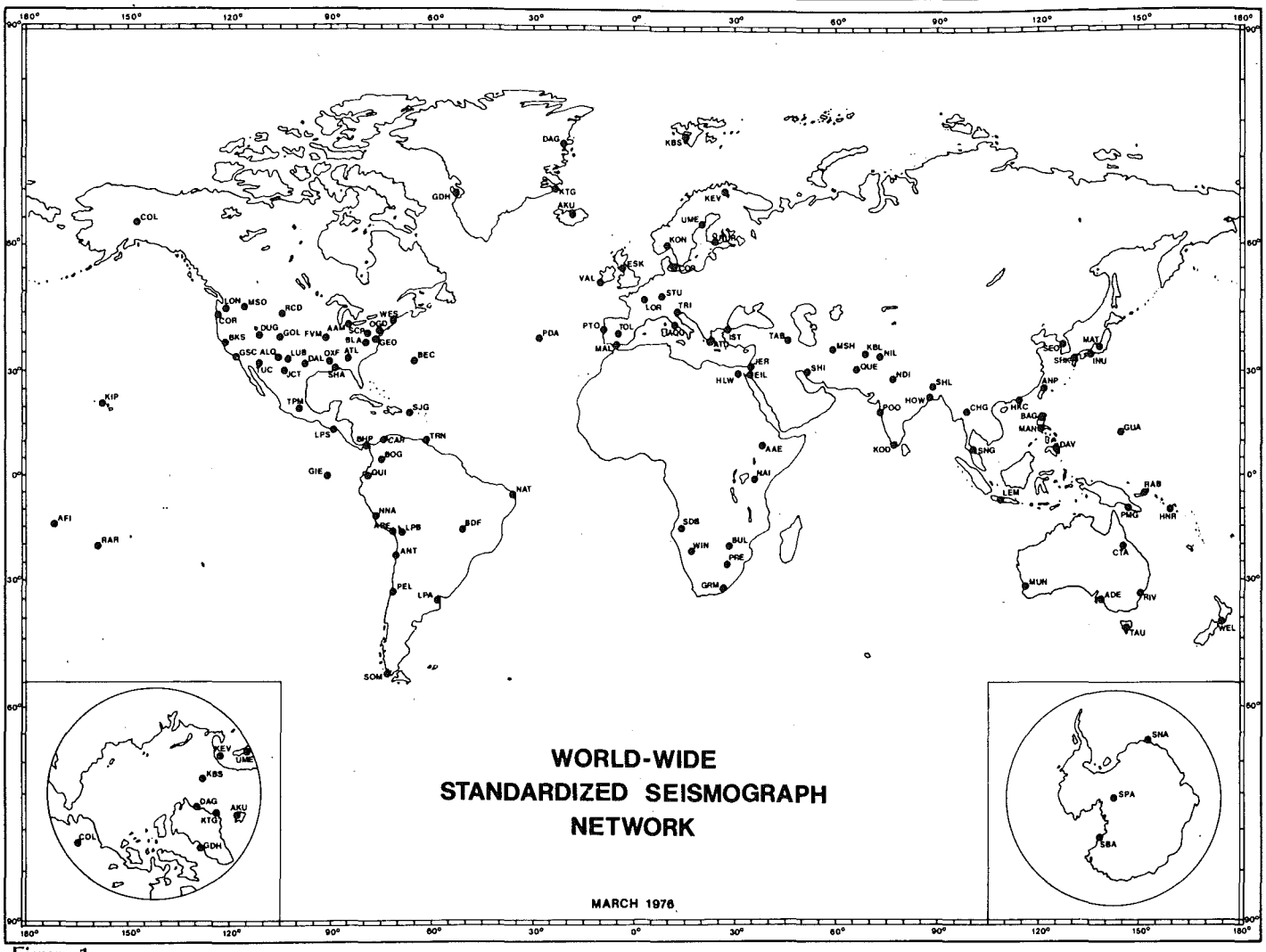


Figure 1

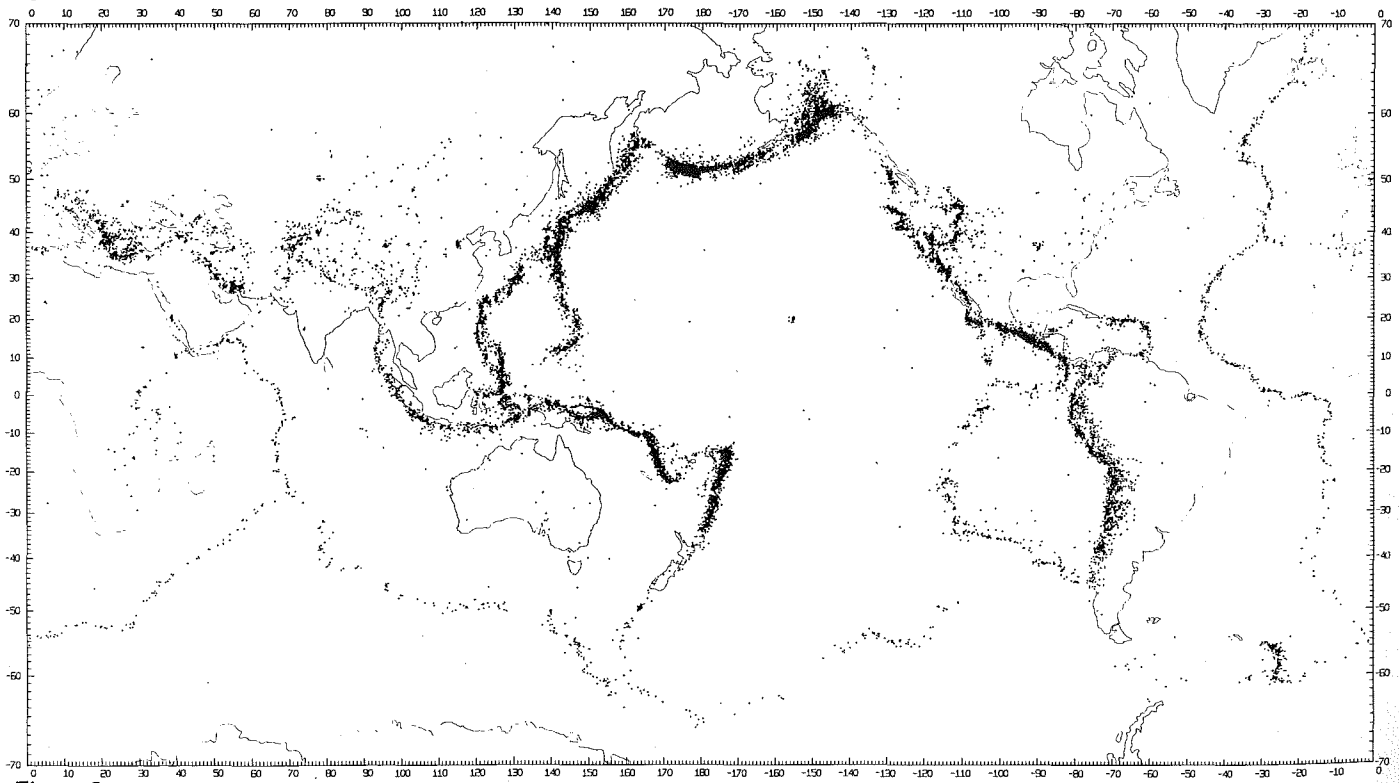


Figure 2

continued from page 1

WWNSS is extremely reliable and relatively inexpensive; it incorporates a *galvanometer* or coil, free to rotate, suspended in a magnetic field. A mirror is attached to the axis of the coil, thus the angle of rotation of the mirror is proportional to the current produced by the seismometer. To record the signal, a light beam is reflected from the mirror onto a drum on which photographic paper is mounted – this permanent record is a *seismogram*. The entire system, consisting of seismometer, galvanometer, and recorder, is called a *seismograph*.

The TUC station is presently part of the World Wide Network of Standard Seismographs established in the early 1960s (Figure 1). The network consists of approximately 112 continuously operating stations throughout the world. The primary function of the network is the detection of nuclear explosions, since one of the requirements of any nuclear testing treaty from the United States' point of view is the ability to identify Soviet nuclear explosions. The existence of the WWNSS also makes it possible to accurately plot the locations of earthquakes occurring anywhere in the world of a magnitude as small as 4.5 on the logarithmic Richter scale.

The influx of new, high-quality data from the WWNSS led to a significant increase in our understanding of global seismicity. World seismicity maps (such as that in Figure 2) and studies of earthquake source mechanisms unavailable before the network's installation provided some of the fundamental building blocks for the development of plate tectonic theories in the mid to late 1960s. Over the last few years, the WWNSS has been supplemented by the addition of about twenty digital recording stations at selected sites throughout the world.

A seismograph station has been operating in Tucson continuously since 1909 when the U.S. Coast and Geodetic Survey established a magnetic observatory here. At that time the seismometers were located at the site of the present magnetic observatory; when the WWNSS station was installed, they were moved into the foothills of the Catalina Mountains to reduce the background noise. The instrumentation also changed with time as newer, more sensitive seismometers were developed. In 1962 the WWNSS equipment used today was installed, but recording of the signals was done near the vault in the mountains. This fall the signals from the seismometers will be transmitted over telephone lines from the vault to the Bureau's Geological Survey Branch offices through FM (frequency modulation) telemetry.

The short-period seismographs at TUC magnify the ground motion by 200,000 at their peak sensitivity for signals between periods of 1 second to 0.5 second (frequency of 1Hz to 2Hz). These short-period instruments are most sensitive to local earthquakes and the seismic waves that travel *within* the earth, such as compressional and shear waves. An example of the local earthquake is a magnitude 2.5 shock in eastern Arizona, shown in Figure 3a.

The long-period seismographs record at magnifications of 1500 to 3000 in the period range 10 seconds (0.1Hz) to 100 seconds (0.01Hz). These extremely low-frequency or long-period signals are observed primarily in seismic waves that travel over the *surface* of the earth. An example is the magnitude 7.4 earthquake from south of Honshu, Japan, which is shown in Figure 3b.

The signals received at the Department

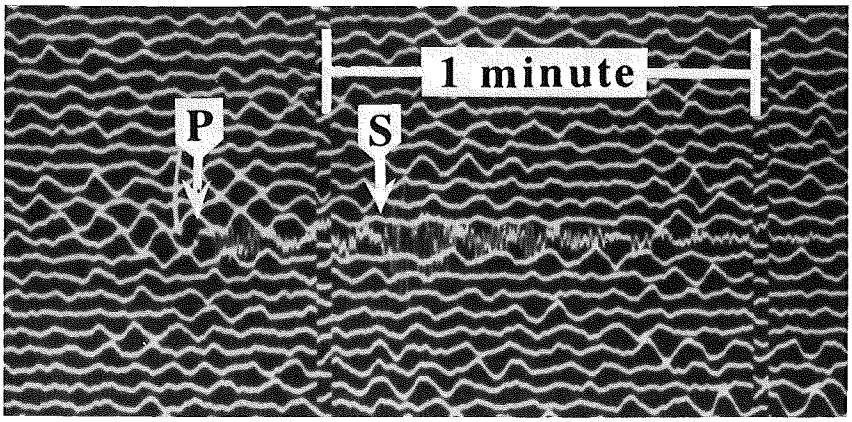


Figure 3A. Magnitude 2.5 earthquake in eastern Arizona as recorded at Tucson.

Figure 3B. Magnitude 6.7 earthquake from New Hebrides as recorded at Tucson. The upper diagram shows P and S waves which travel through the earth. The lower figure shows surface waves which travel at a slower velocity and arrive later.

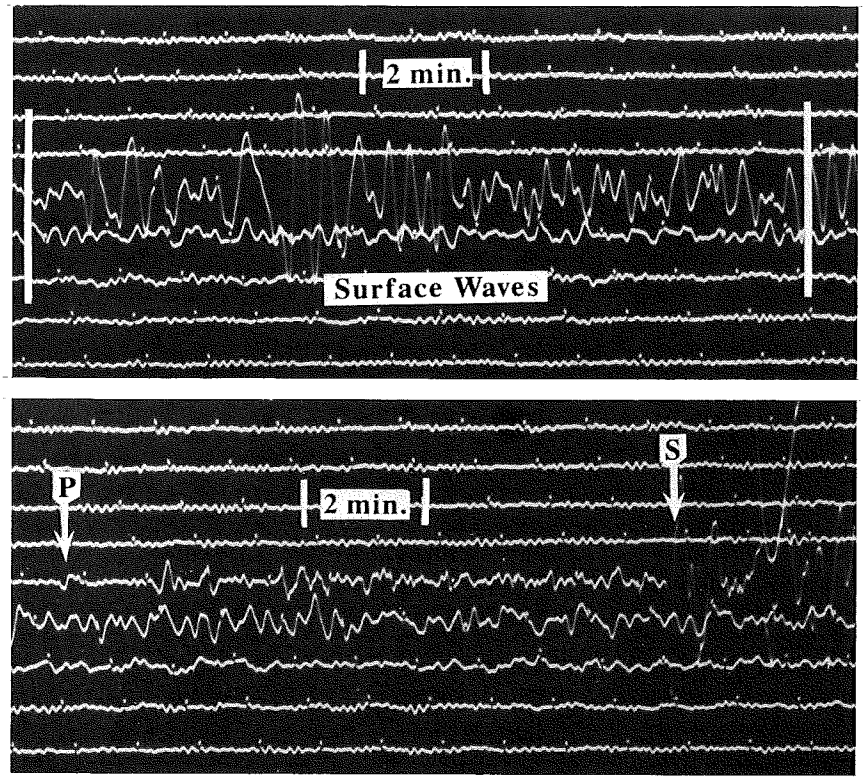


Figure 1. World Wide Network of Standard Seismographs; station locations with identifying call letters.

Figure 2. Earthquake epicenters from 1961 to 1967 in the depth range 0 to 11 km. Compiled from U.S.G.S. data.

of Geosciences will be modified to complement the standard WWNSS records. The short-period bandwidth will be extended to encompass the range 1Hz to 20Hz. The recorders will probably operate at a lower sensitivity near 1Hz than the WWNSS station. The second set of recorders at the Department will cover the band between the WWNSS instruments – 0.2 second (5Hz) to 10 seconds (0.1Hz).

A high-precision crystal clock will provide an accurate time base for all recordings. The clock will be checked daily against standard time broadcast from Ft. Collins, Colorado, since accurate timing is needed to compare seismic arrivals at different stations.

What can we do with all this hardware? The primary function of the station is to produce reliable data for nuclear explosion identification and the world-wide geophysical community. Copies of all the WWNSS records are available on microfilm. The seismogram library at the Department of Geosciences, for example, contains microfilm copies of TUC records from 1963 to 1976 and records from twenty selected WWNSS stations from 1965 to 1976. These will be used for both instruction and research.

Readings of seismic arrivals on the TUC station will routinely be made by the geophysics students and staff. These readings will be forwarded to the U.S.G.S. to be used in the location of earthquakes throughout the world. It is of greater importance to us, at this time, to keep a close watch on the earthquakes in Arizona and the Southwest. This data can then be channeled into hazard evaluations throughout the state and research projects on the seismicity of this region.

We need to know more precisely where earthquakes occur throughout Arizona and which faults are seismically active. We also wish to learn why earthquakes occur here and study their relationship to the tectonics and deformation in other parts of the West.

Recorders will be on public display at both the Bureau of Geology and Mineral Technology (Geological Survey Branch), and the Department of Geosciences. A magnitude 5.5 earthquake from almost anywhere in the world will record on these instruments. So we should see several earthquakes a week from around the world and probably about the same number from California.

FIELDNOTES SUBSCRIPTIONS

If you wish to receive FIELDNOTES, please write to Publications, Bureau of Geology and Mineral Technology, 845 N. Park, Tucson AZ 85719.

If you are presently a subscriber and are moving soon, please send us your old mailing label with your new address.

GEOTHERMAL PIPELINE

W. Richard Hahman Sr.

New ERDA Geothermal Project

A new geothermal energy project for the State of Arizona has been funded by the Energy Research and Development Administration. This second project is administered through the New Mexico Energy Institute at New Mexico State University. The Arizona agencies involved are the Office of Economic Planning and Development and the Bureau of Geology and Mineral Technology. The initial phase of this project is somewhat theoretical in nature, but later stages will have a significant role in the planning of geothermal development in the five participating states in the Southwest region. Similar agencies in the five states (Arizona, Colorado, Nevada, New Mexico, and Utah), working independently, will supply their information to the New Mexico Energy Institute.

The following quotation from the technical proposal by the New Mexico Energy Institute is an explanation of the project: " . . . to conduct operations research on the potential for development of geothermal energy resources in the Southwestern U.S., for ERDA and the Four Corners Regional Commission. The Institute, working together with a team from each State . . . will assess the present status of exploration and development, and will prepare a hierarchy of scenarios for the development of geothermal resources in the region. These scenarios will be capable of interrogation for assessing the probable effects of future economic or policy changes, and will display changes in the rate of resource development which are sensitive to economic, technical, legal or other institutional constraints to development." I was pleased to discover that Webster defines scenario as "an account or synopsis of a projected course of action or events."

The principal investigator for the Bureau of Geology and Mineral Technology is Dr. William H. Dresher, the Director. The principal investigator of scenarios is Dr. Donald H. White of the Chemical Engineering Department of the University of Arizona. Dr. David Wolf, Visiting Professor of Chemical Engineering, University of Arizona, considered Israel's foremost authority on solar energy, will be assisting in the various phases of the scenario preparation. I am the principal investigator of the geology section. This geothermal energy project will utilize data development from the initial geothermal energy project discussed in Summer 1977 FIELDNOTES.

Los Alamos Scientific Laboratory

Recently the hot dry rock geothermal energy program being developed by LASL in the Jemez Mountains near Los Alamos, New Mexico, moved very close to the reality. Energy Extraction Hole No. 1 (total depth 3064m, bottomhole temperature 205.5°C) was successfully connected to GT-2 (total depth 2929m, bottomhole temperature 197°C) by hydraulic fracturing and directional drilling in both holes. This connection was the first attempt to directionally drill hot granitic rock.

Quoting from the LASL Mini-Review 77-8, July 1977, "During a 20-h (hour) pumping experiment, cold water pumped down EE-1 at 6.89MPa (1000psi) was heated to 130°C (266°F), and the rate of water recovery was 85% of the injection rate. The temperature and the recovery rate are expected to increase as the system is operated."

This program has developed many new downhole instruments capable of operating at temperatures of 200°C and pressures of 400bar. Future plans call for heat extraction experiments which will hopefully lead to a 100 megawatt electrical generating plant. Considering that the program has only been in existence five years, the progress has been outstanding.

Continued on page 5

Geothermal Pipeline *continued from page 4*

Geothermal Library

Compilation of the geothermal energy library at the Geological Survey Branch in Tucson is progressing well. Some of the more recent additions or books on order are:

Geothermal Energy; Resources, Production, Stimulation: Proceedings of Special Symposium, American Nuclear Society, June 1972, Paul Kruger and Carl Otte, editors.

Proceedings: Second United Nations Symposium on the Development and Use of Geothermal Resources, Volumes 1, 2 and 3, 1976.

Geology, Geophysics and Hydrogeology of the Monte Amiata Geothermal Fields, Special Issue #1.

Proceedings of the U.N. Geothermal Symposium, Vol. 2, parts 1 and 2.

Geothermal State of the Art: Transactions of the 1977 Annual Meeting of the Geothermal Resources Council.

Cenozoic Volcanism in S.W. New Mexico, by Wolfgang E. Elston and Stuart A. Northrop, editors, 1976.

A Bibliography: Geothermal Resources, Exploration and Exploitation, Technical Information Center, ERDA, 1976.

Two monthly publications have also been ordered: *Geothermal Hotline* (California Division of Oil and Gas), and *Geothermal Energy.* Also on hand are various reports from many agencies concerning experiments and research in geothermal energy.

Landsat Lineament Map

Work was commenced on the Landsat lineament map of Arizona, scale 1:1,000,000, and the map and text with optical Fourier analysis should be available to interested persons sometime in September. The proposed infrared imagery study for rock alteration in the Safford area will not be conducted at this time.

Field Exploration

Initially, three areas have been designated for more detailed investigation. These areas are the Springerville-St. Johns area, the Clifton-Morenci-Safford area and the San Bernadino valley area, all three located on the eastern side of the state.

The more detailed investigation will involve geological mapping, geochemical water and possibly soil sampling and analysis and geophysical measurements of the thermal conductivity of the rocks. In an attempt to curtail exploration costs, every effort will be made to utilize existing drill holes. The majority of these drill holes will probably be in the form of water wells, hopefully in excess of 400 feet, which greatly increases the reliability of the information.

Et cetera

I would very much like to have some input from you readers. While I can't guarantee that information concerning your projects, progress reports and areas of interest will always be printed, my staff and I will endeavor to act as a clearinghouse for parties of similar interest.

While we are on the subject of staff, I will mention that Trace Calhoun is our very competent secretary, and geologist Claudia Stone is our new research assistant. Claudia has prior geothermal experience in Hawaii and is a most welcome addition to our staff.

BIBLIOGRAPHY

Regional Operations Research for the Development of Geothermal Energy, Southwest United States, Technical, New Mexico Energy Institute, Las Cruces, New Mexico, 67p.

Mortense, Jeannette J., 1977. The LASL Hot Dry Rock Geothermal Energy Development Project, LASL Mini-Review 77-8, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, 4p.

International Carboniferous Congress to meet in U.S.

The Bureau's Geological Survey Branch will participate in the Ninth International Carboniferous Congress in 1979 – the first meeting of this group ever to be held in the United States.

The Congress will be an official event in the centennial celebration of the U.S. Geological Survey, which will publish a Professional Paper on the Carboniferous rocks (combined Mississippian-Pennsylvanian Periods) of the United States. Each of the states in which these rocks are significantly involved has been assigned a chapter in this publication. Much of the compilation work is being done by individual state geological agencies; our Geological Survey Branch is responsible for the chapter on Arizona. Not only is the geology of this time interval to be covered, but the associated utilitarian aspects are to be discussed as well.

Arizona's share of Carboniferous rocks include: (1) most of the important lime and limestone resources of the State (chemical lime and cement), (2) most of the oil and gas production and much of the remaining potential, (3) some uranium potential, and (4) most of the recreational-tourism aspects associated with caves. The early mining efforts in many areas were directed at high-grade deposits found in limestones of the Carboniferous Period. Such deposits probably still remain – but they are buried beyond easy recognition.

The Congress will include fifteen field trips; in Arizona, a seven-day trip will feature the Grand Canyon. The technical sessions will be held at Urbana, Illinois from May 21 to 25, 1979. If you have any interest in the Ninth International Carboniferous Congress, please contact us for additional information.

Right; geothermal project research assistant Claudia Stone.

Oak Creek Canyon Discussed

"Cenozoic Geology of Oak Creek Canyon Area – an Enigma" is the title of a talk given in early September by Bureau Geologist Dr. H. Wesley Peirce. This paper, co-authored by Drs. M. Shafiqullah and Paul Damon of the Department of Geosciences, University of Arizona, was given as a part of the 30th Annual Symposium on Southwestern Geology sponsored by and held at the Museum of Northern Arizona in Flagstaff.

Peirce emphasized that the "enigma" mentioned in the title succumbed to field and laboratory work done subsequent to the submission of the title in early summer.

The Cenozoic geology of Oak Creek Canyon and adjacent regions involves the timing and interrelationships among faulting, erosion, gravel deposition, and volcanism.

The results of this recent work differ with previously recorded observations and conclusions. Whereas others have considered the gravels in question (on the east side of Oak Creek Canyon beneath basaltic lavas) to have been deposited by northerly-directed currents prior to the formation of the Mogollon Rim, recent work suggests that the gravels were deposited by headwaters of a southerly to easterly directed drainage associated with an already existent ancestral "Rim." This is made possible by observing, in contrast to earlier concepts, that the faulting in question likely is pre-gravel and basalt, and that both gravels and basalts are occupying relatively low, structurally influenced, eroded topography.

In the past, much has been made of the presence in the gravels of a few clasts derived from Precambrian source rocks. While it is agreed that such rocks are the ultimate sources, the immediate sources seem to be older, higher-level gravels – the true "Rim" gravels.

New publication from Dept. of Mineral Resources

The Arizona Department of Mineral Resources has published "Arizona Land Status and Ownership Determination" by John Lacy, an Arizona mining attorney.

This publication will be sold by Department offices in Tucson and Phoenix at a cost of 55¢. Please include postage and handling costs for mail orders: 10% of the total order, or 25¢ minimum. Mail requests (with a check or money order) to: Arizona Department of Mineral Resources, Minerals Building, Fairgrounds, Phoenix AZ 85007.

View of cinder cones in White Mountains Volcanic Field, looking north across State Highway 260. Photograph no. 3934 by Troy L. Péwé, March 19, 1977.

White Mountains report starts Special Paper series

The Special Paper series of the Bureau of Geology and Mineral Technology was introduced in December 1977 with the appearance of the pioneer number, an extensive report on the geology of the White Mountains in eastern Arizona. Special Paper No. 1, *The late Cenozoic geology of the White Mountains, Apache County, Arizona,* was written by Robert K. Merrill and Troy L. Péwé. Dr. Merrill is now with the Cities Service Oil Company in Tulsa and Dr. Péwé is professor and former chairman of the Department of Geology at Arizona State University.

The report describes the large White Mountain massif, 230 square miles of high volcanic mountains including Mount Ord and Mount Baldy between Greer and White River. Never before mapped in detail, the area is high, rugged, forested country above 7000 feet elevation culminating in 11,404-foot-high Mount Baldy. It is the headwater for the Salt River and the Little Colorado River drainages on the Mogollon Rim and lies entirely within the White Mountain Apache Indian Reservation and the Apache National Forest. The complex geology was mapped on a scale of 1:24,000 and is published in the report on a multicolored geologic map on a scale of 1:48,000.

The White Mountains are volcanic and were built by lava flows, explosive deposits, and mud flows from 10 to

Continued on page 7

Three appointments announced

Bureau of Geology and Mineral Technology becomes a reality

With the passage into law of Arizona House Bill 2060, Arizona has an official state geological survey organization for the first time in its history.

The Arizona Bureau of Mines, which was established in 1915 for the purpose of enhancing mineral resource development in Arizona, has given way to the Bureau of Geology and Mineral Technology – an organization serving the State in the broader role of both a "mines bureau" and a "geological survey."

Dr. Edgar J. McCullough, head of the Department of Geosciences of the University of Arizona, has been appointed Acting State Geologist and Acting Assistant Director in charge of the Bureau's Geological Survey Branch. Dr. McCullough will coordinate the work of this branch with agencies of local, state, and federal governments and with the State's three academic departments of geology. The machinery for permanently filling this position has been set into

Continued on page 8

Dr. E.J. McCullough, left; Dr. W.H. Dresher, right.

Dr. G.H. Geiger

White Mountains *continued from page 6*

about 2 million years ago. While the present Mt. Baldy rises 3,000 feet above the canyon floors, the ancestral volcano reached approximately 13,000 feet prior to erosion. During the Ice Ages, alpine glaciation occurred on the remnants of Mount Baldy Volcano; although no glaciers are present on the mountain today, they existed as recently as 3,000 years ago.

The earliest activity of the Mount Baldy Volcano was the eruption of latite from a central vent onto a surface of moderate relief cut into faulted volcanic and volcaniclastic rocks of middle Tertiary age. The latite volcanism was followed by a brief period of explosive activity during which a local lahar was deposited. Subsequently, light latite, alkali trachyte, and quartz latite lavas were extruded to a thickness of 600 to 700 m. An age of 8.6 $\pm$ 0.4 m.y. has been determined for one of the late quartz latite flows. A basalt flow having an age of 8.9 $\pm$ 0.9 m.y. overlies the unfaulted Mount Baldy lavas at the base of the lava cone.

Although extensive field work covered the entire area, no metalliferous ore deposits were encountered. However, distribution and types of nonmetallic resources of sand, gravel, peat, building stone, rock fill, and cinders can be interpreted from the report.

In keeping with the pioneer nature of Special Paper No. 1, it includes the first extensive presentation of a glacial record in Arizona. A thorough study of the land forms and deposits indicates that mountain glaciers existed at least four different times during approximately the last 200,000 years. During the oldest glacial advance, ice streams extended five miles down Ord Creek and four miles down the West Fork of the Little Colorado River.

One of the report's major contributions is a reconstruction of past climatic fluctuations in the area from studies of glacial advances, past vegetation distribution from pollen records in bogs, and periglacial forms; also, it includes the reconstruction of past snowlines' altitudes as determined by the Equilibrium Line Altitude Method. Study of past climates is instrumental to the study of future climatic changes – changes which will control our environment and our ability to efficiently utilize it. In the White Mountains during the late Pleistocene time (approximately 13,000 years ago) the mean annual air temperature was 5°C to 6°C colder than today and precipitation was 20 to 25% higher.

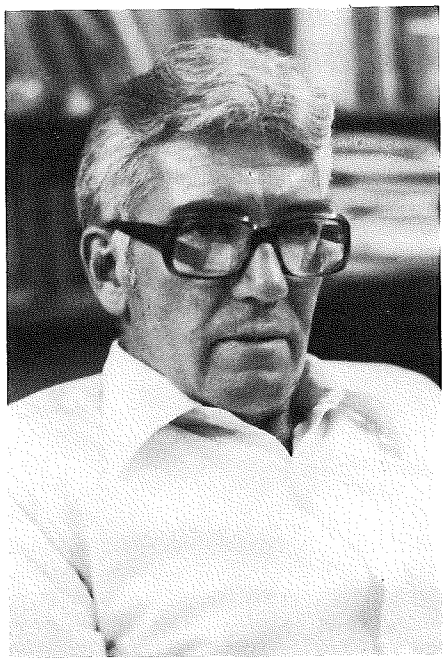
This report is based largely on field work by Merrill and Péwé from 1968-71, earlier reconnaissance by Péwé in 1965-67, and subsequent field checking since 1971. The work served as a basis for a M.S. thesis and Ph.D. dissertation in Geology by R. K. Merrill at Arizona State University, Tempe. His dissertation was the first awarded by the Geology Department at Arizona State University.

Financial support for this study was furnished by the National Science Foundation and a grant from the Museum of Northern Arizona. The office of the Vice President for Research and Advanced study of Arizona State University, under the direction of W. S. Burke and C. M. Woolf, shared publication costs with the Bureau. The U.S. Forest Service, Springerville District, provided the writers with some logistical support, and the White Mountain Apache Tribe kindly allowed the writers to work freely on their lands.

Special Paper No. 1 is 65 pages long and contains 50 figures. Two plates (a colored geologic map with 19 map units, and cross sections through the Mt. Baldy volcano) are in a separate map pocket.

The report may be purchased for $4.50 over the counter or $4.95 by mail order from the Bureau of Geology and Mineral Technology, Publication Office, 845 North Park Ave., Tucson, AZ 85719.

Bureau appointments *continued*



Dr. H.W. Peirce

motion.

Dr. Gordon H. Geiger, head of the Department of Metallurgical Engineering of the University of Arizona, has been appointed Acting Assistant Director of the Bureau with responsibility for the Mineral Technology Branch. This branch of the Bureau will retain the original mission of the Arizona Bureau of Mines in assisting in the development of the State's mineral resources by ore testing process development and information services. Dr. Geiger will coordinate the work of this branch with agencies of local, state and federal governments and local industry.

Dr. H. Wesley Peirce has been appointed Principal Geologist of the Geological Survey Branch. Dr. Peirce has been with the Bureau for 22 years and maintains a wide-ranging diversity of geological interests.

Dr. R.T. Moore

Tertiary History of the Grand Canyon reprinted

A limited edition of Clarence E. Dutton's classic *Tertiary History of the Grand Cañon District* is being printed this fall by Peregrine Smith, Inc. This publication was originally issued 95 years ago as the first of the Special Monographs of the U.S. Geological Survey under John Wesley Powell's direction.

Tertiary History covers much of Arizona, Nevada and Utah as well as the immediate Grand Canyon region. Illustrations are by photographer J.K. Hillers (who accompanied Powell on his expeditions) and artists Thomas Moran and W.H. Holmes.

This two-volume set includes a 360-page text and an atlas of 23 double-spread removable color plates. Only 1,500 copies will be printed, and orders are accepted by the publisher on a first-come, first-serve basis.

The cost is $175 per set plus sales tax and $3 for shipping and insurance. Contract Peregrine Smith, Inc., Box 667, Layton UT 84041.

Dick Moore weighs anchor

After 26 years with the Bureau, Principal Geologist Richard T. Moore is trading a geologist's life in the desert for a seafarer's life on a 42-foot sailboat.

Dr. Moore and his wife Elizabeth are on their way to Taiwan, where they will have a ketch built to their specifications, and they plan to spend the rest of their able-bodied days cruising the high seas.

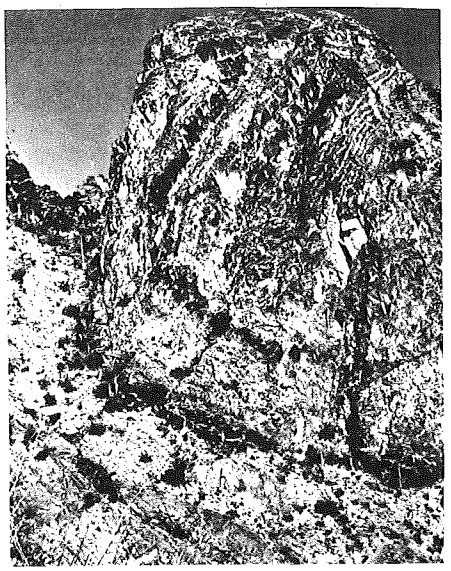
As head of the Geological Survey Branch, Dick played a major role in the development of that branch of the Bureau into a modern state geological survey. He was a guiding light in the drafting of legislation to authorize the function of a state geological survey and worked with members of the State Legislature to bring this legislation into law. In addition, he represented the Bureau at many state and national meetings in the role normally served by a state geologist during the years that the state had no official geological survey.

Dick received his B.S. and M.S. degrees from the College of Mines, University of Arizona, and his Ph.D. from Stanford University. He is registered as a geologist in Arizona and California.

We all wish the Moores many bon voyages.

Socorro Peak study printed

"Geology of the Socorro Peak area, western Harquahala Mountains, Arizona," by Robert J. Varga, has been published by the Bureau of Geology and Mineral Technology as Circular 20.



Socorro Peak

The research for this 20-page publication was completed by Mr. Varga while he was a Research Assistant with the Bureau in 1975-76 (see June, 1976 FIELDNOTES).

Circular 20 costs $1.00; for mail order instructions, see page 11.

WANTED-- TWO GEOLOGISTS

The Bureau of Geology and Mineral Technology is accepting applications for two positions: State Geologist and Economic/Structural Geologist. The deadline for applications will be April 1, 1978.

The State Geologist will be also responsible for administering the programs of the Bureau's Geological Survey Branch as Assistant Director.

Applicants for the position of Economic/Structural Geologist should be interested in acquiring, disseminating, and applying basic geologic data to a variety of problems in this State.

For more complete job descriptions, educational and work experience requirements, and instructions for application, please contact the Director's Office, Bureau of Geology and Mineral Technology, 134 Geology Building, University of Arizona, Tucson AZ 85721. Phone (602) 884-1401.

The University of Arizona is an equal opportunity/affirmative action Title IX/Section 504 employer.

Arizona Bureau of Mines, 1976-1977

Following is a brief summary of the Bureau's activities during fiscal 1976-77, the last year this organization was known as the Arizona Bureau of Mines.

Geological Survey Branch

The U.S. Geological Survey funded a two-year project, ending June 30, 1977, to define and delineate geologic hazards in the rapidly developing area of approximately 1,240 square miles north and northwest of Tucson. During the project's first year, a map of slope stability was drafted; during the second year, a map of erosional hazards was completed and data on the engineering properties of the soils in the area were collected. Principal Geologist Dr. Richard Moore headed the project and was assisted by Bruce Murphy.

The U.S. Energy Research and Development Administration (now the U.S. Department of Energy) funded a geothermal resources study of the State of Arizona. The project began in May 1977 and was initially funded for one year. Geologist W. Richard Hahman was hired to serve as principal investigator.

State-funded research for the *Index of Mining Properties in Yuma County,* the fourth in the Bureau's continuing series of county indices, was written by Geologist Stanton B. Keith. Covering historic and present mining properties, and with maps of mineralized areas within the county, this book will be published by March 1, 1978 as Bureau Bulletin 192.

The Bureau sponsored graduate research assistant Gene Suemnicht in his study of an area of the Santa Catalina Mountains previously unmapped in detail. His thesis, "The geology of the Canada del Oro headwaters, Santa Catalina Mountains, Arizona," filled a gap that existed in the geological knowledge of the northern rugged slopes of this mountain range.

"An evaluation of the olivine resources of the San Carlos Apache Indian Reservation and recommendations for potential development" was the title of a project funded by the Economic Development Administration through the University's Office of Arid Lands Studies for the benefit of the San Carlos Apache Tribe. Geologists John Vuich and Richard Moore headed this study.

Bureau Circular 18, *Chemical analyses of coal samples from the Black Mesa Field, Arizona,* was published during fiscal 1976-77. The result of an 18-month coal-sampling project funded by the U.S. Geological Survey, the 14-page circular lists analyses of approximately 40 samples taken by Principal Investigator Richard Moore and assistant field geologist Charles Kiven.

The results of a uranium study which had been funded by the U.S. Geological Survey were published as Bureau Circular 19. Dr. H. Wesley Peirce (Principal Investigator) and assistants Nile Jones and Ralph Rogers authored this 72-page publication, *A survey of uranium favorability of Paleozoic rocks in the Mogollon Rim and Slope region – east-central Arizona.*

In addition to research, staff geologists provided services to state and federal agencies, industry, and the public. They assisted other researchers and answered questions about the geology, geological hazards and mineral resources of Arizona.

Geologist H.W. Peirce spoke to school and college classes, professional meetings, various organizations, and on geology field trips for the Youth Conservation Corps. Dr. Peirce also contributed to publications issued by the Geological Society of America, the University of Arizona Press, and the Arizona Geological Society.

Dr. R.T. Moore served as Arizona Collaborator in Seismology for the National Oceanic and Atmospheric Administration and represented the Bureau at the annual meeting of the American Association of State Geologists for the purpose of coordinating the activities of the Bureau with those of similar organizations in other states.

Mineral Technology Branch

"Scale-up of hydrometallurgical leach processes," a project funded by the U.S. Bureau of Mines, was headed by Metallurgist Dr. Walter Fisher. The research involves scaling-up of leaching processes through the development of mathematical models which are amenable to computer simulation.

A state-funded project which involved the study of acid leaching of chalcocite was headed by Dr. Fisher. A publication will be issued in the future on the results of this research.

The Office of Water Research and Technology funded research to isolate and identify components of sewage effluent which are detrimental to flotation and recovery of copper and molybdenum sulfides. Dr. Fisher is also heading this project.

"A New Metal Recycling System" is the title of an article which was published by the *Journal of Metals* and written by Metallurgist Sam Rudy. His research resulted in the development of a new physical beneficiation method for recycling metals and alloys from municipal wastes and manufacturing scrap.

The development of standard tests for the amenability of gold, copper, molybdenum, lead, zinc, and silver recovery was begun by Mr. Rudy. This research will continue throughout the present fiscal year.

A project was undertaken by Mineralogist Robert O'Haire in cooperation with several Arizona copper companies to do mineralogical studies of polished sections. He defined the mineral associations in the specimens, determining the character of the minerals and verifying proposed beneficiation processes for the samples.

The Arizona Corporation Commission requested Mining Engineer David Rabb to evaluate several out-of-state stock promotions for Arizona mining properties. Mr. Rabb also worked with an Arizona-based bank on mine property evaluations, with a federally funded project in Mohave County to accumulate data and provide expertise on a custom mill, and with an Arizona salt mining company on the development of a new method for mining salt.

Mineral Technology Branch staff members worked with the Bureau's Geological Survey Branch on the study of olivine resources on the San Carlos Indian Reservation – designing the beneficiation and recommending mining methods.

In addition, MTB staff designed a method for the separation of scheelite and galena; worked with the Arizona Department of Health's Water Quality Control Section on leaching of ore in the Tombstone area; analyzed costs and evaluated the economics of approximately 40 mining properties in Arizona; and gave technical advice for the start-up and successful operation of heap leaching of gold-silver ores.

Staff members taught hydrometallurgy and solution mining courses in the College of Mines, and they participated in professional meetings and conferences. Dr. Fisher presented a paper on the "Use and re-use of water by the mining industry in Arizona" at a conference cosponsored by the United Nations and the State of California.

Publications Office

Almost five thousand bulletins and six thousand maps were sold over the counter or by mail order by the Publications Office staff. In addition, almost 27,000 copies of FIELDNOTES were distributed.

The office personnel also distributed free rock and mineral kits to Arizona schools, free copies of Arizona Highways road maps, helped researchers in the Bureau library, and made referrals to other agencies when necessary.

Arizona's Oil and Gas Conservation Commission

by W.E. Allen and J.N. Conley

When former Arizona governor Howard Pyle signed the "Oil and Gas Conservation Act" into law in 1951, he laid the groundwork for the later creation of the Arizona Oil and Gas Conservation Commission (OGCC).

Between 1951 and the OGCC's establishment in 1959, the State Land Commissioner enforced the regulations on oil and gas exploration and production which were created by this Act. In 1959, the State Land Commissioner became an ex-officio member of the OGCC; the five other members of the Commission are appointed to five-year terms by the governor.

The Commission's staff is headed by Executive Secretary John Bannister and is divided into two sections, Geology and Enforcement. Support personnel consist of the Section directors, two secretaries, and a staff geologist.

Enforcement Section

Originally, the Commission's organization included only the Enforcement Section, which has the responsibility of enforcing all rules and regulations and monitoring drilling and producing operations. Due to amendments of the Act of 1951, these responsibilities now include helium and geothermal resources as well as oil and natural gas.

The personnel in this section consult with operators on various problems which may be encountered. This section also gathers and maintains well data, publishes production information, and assists operators and prospective operators with problems that may be encountered with other government agencies or departments. This section cooperates, and coordinates its activities, with the United States Geological Survey, Bureau of Indian Affairs, and the Bureau of Land Management.

The Enforcement Section publishes a monthly production report for oil, gas, and helium, and updates and publishes a summary of yearly production.

Exploration hit its peak in 1967 with the discovery of the Dineh-Bi-Keyah field in northeastern Apache County. Subsequently, oil production reached record highs in 1968 (Fig. 1) with a total annual production of 3,359,605 barrels. Since the late 1960s, both exploration and production have continued to decline. There are presently 28 producing wells in the State, 2 wells presently being drilled, and 2 drilling permits outstanding.

Geology Section

The Geology Section, which was established in 1970, acquires, disseminates, and applies basic geologic data that are designed to encourage and expedite exploration for Arizona's oil, natural gas, helium, and geothermal energy resources.

This Section has produced and published a series of maps covering the State, showing the location of wells drilled for oil, natural gas, helium, potash, halite, structural and stratigraphic information, and geologically significant water wells. These maps were prepared in formats and at scales suitable for subsurface mapping purposes. Supplementary tabulated well information is presented on each map, separate sheet or in a companion text.

W.E. Allen is Director of the OGCC's Enforcement Section; J.N. Conley is Director of the Geology Section.

Currently the Geology Section is producing a series of subsurface geologic structure and thickness maps, and companion structure and correlation sections, in east-central and northeast Arizona. Several of these maps and sections have been published. A list of currently available maps and other publications will be sent upon request. Write to the Arizona Oil and Gas Conservation Commission, 1645 West Jefferson, Suite 420, Phoenix AZ 85007.

In addition to producing various maps needed by exploration geologists, this Section has published miscellaneous petroleum-oriented materials produced by the staff or in cooperation with the University of Arizona's Department of Geosciences, Office of Arid Lands Studies, and Bureau of Geology and Mineral Technology. It has also furnished lithologic and geophysical logs, drill-bit cuttings, geologic and well data, and advice to graduate students investigating some geologic aspect of the subsurface formations of the State.

Only two publications pertaining to geothermal resource investigations have been published. However, temperature data have been assembled and processed for more than 1,500 water wells in the Basin and Range province of the State. A preliminary analysis of the data tentatively identifies several potential geothermal resource areas warranting additional investigations. Futher processing of the data and publishing as an open-file item will constitute the Commission's participation in the ongoing assessment of Arizona's geothermal energy potential by the Bureau of Geology and Mineral Technology.

The Section maintains a map and geologic information library which may be consulted by the public. Map coverage of the State includes a complete set of currently available U.S. Geological Survey topographic maps and extensive general highway and orthophotoquad maps published by the State. The geological library contains U.S.G.S. bulletins, professional papers, and geological and geophysical quadrangle maps, plus American Association of Petroleum Geologists bulletins (1935 through 1976), Geological Society of America bulletins (1948 through June 1976), and miscellaneous publications pertaining to the geology of Arizona.

Although primarily concerned with petroleum and geothermal energy resources, much of the information compiled by the Geology Section is applicable to exploration for other natural resources such as uranium, potash, halite, and water. Currently a large proportion of requests for maps, reports, geologic and well data pertain to uranium, potash, and halite.

Joint efforts

The Enforcement and Geology Sections jointly maintain a library of drill-bit cuttings and core chips of wells drilled for oil, natural gas, helium, potash, halite, structural and stratigraphic information, and numerous wells drilled for water.

Commission staff members serve on various governmental committees, primarily those concerned with some phase of natural resources or the environment.

They are also requested to contribute articles to the various trade journals and to discuss energy and environmental matters with clubs, schools, and other groups.

Available Bureau Publications

ORDERING INSTRUCTIONS

The Bureau of Geology and Mineral Technology has the following publications available at the prices indicated. These publications may be purchased over the counter at the distribution center located in Room 101, 845 N. Park Avenue, Tucson, on the edge of the University of Arizona campus.

MAIL ORDERS will be accepted and should be sent to the following address:

Publications
Bureau of Geology and Mineral Technology
845 N. Park Avenue
Tucson, Arizona 85719

PAYMENT by check or money order, including a handling charge of ten percent of the total amount of the order ($.25 minimum) MUST ACCOMPANY ALL PUBLICATION ORDERS.

Payment in U.S. currency is required on all foreign orders and additional charges will be made to cover foreign postage (approximately 20% of order for surface mail).

Special Papers

NOS. **PRICE**

1. Late Cenozoic geology of the White Mountains, Arizona
R.K. Merrill and T.L. Péwé (1977) $4.50

2. Guidebook to the geology of central Arizona *(will be available March 1, 1978* 6.00

Bulletins

137. Arizona lode gold mines and gold mining
E.D. Wilson, J.B. Cunningham and G.M. Butler 1.00

162. Pegmatite deposits of the White Picacho district, Maricopa and Yavapai counties, Arizona
R.H. Jans 1.25

164. Exploration and development of small mines
H.E. Krumlauf ..... .25

165. One hundred Arizona minerals
R.T. Moore ..... .75

167. Some rare-earth mineral deposits in Mohave county, Arizona
E.W. Heinrich ..... .50

168. Gold placers and placering in Arizona
E.D. Wilson and others 1.00

171. A resumé of the geology of Arizona
E.D. Wilson 1.50

172. The use of compressed air in small mines
H.E. Krumlauf ..... .50

173. Bibliography of the geology and mineral resources of Arizona 1848-1964
R.T. Moore and E.D. Wilson 3.00

174. Guidebook 1 – highways of Arizona, U.S. highway 666
E.D. Wilson ..... .50

175. Field tests for the common mineral elements
G.H. Roseveare ..... .75

176. Geologic guidebook 2 – highways of Arizona, Arizona highways 77 and 177
H.W. Peirce 1.25

177. Mineral deposits of the Fort Apache Indian Reservation, Arizona
R.T. Moore 1.25

178. A brief history of the United Verde open pit, Jerome, Arizona
M.J. Alehius ..... .50

179. Mineral deposits of the Gila River Indian Reservation, Arizona
E.D. Wilson 1.00

180. Mineral and water resources of Arizona 4.50

182. Coal, oil, natural gas, helium and uranium in Arizona
H.W. Peirce, S.B. Keith and J.C. Wilt 4.50

183. Geologic guidebook 3 – highways of Arizona, Arizona highways 85, 86 and 396
S.B. Keith 1.00

184. Geologic guidebook 4 – highways of Arizona, Arizona highways 87, 88 and 188
C.F. Royse, M.F. Sheridan and H.W. Peirce ..... .75

185. Arizona well information
H.W. Peirce and J.R. Scurlock 2.00

186. Geology of the Virgin and Beaverdam Mountains, Arizona
R.T. Moore 2.00

187. Index of mining properties in Cochise county, Arizona
S.B. Keith 1.00

188. The mineral industry of Arizona in 1971 ..... .15

189. Index of mining properties in Pima county, Arizona
S.B. Keith 2.00

190. Bibliography of the geology and mineral resources of Arizona 1965-1970 *(a supplement to 173)*
J.S. Vuich and J.C. Wilt 2.00

191. Index of mining properties in Santa Cruz county, Arizona
S.B. Keith 1.50

192. Index of mining properties in Yuma county, Arizona *(will be available by March 1, 1978)*
S.B. Keith 3.00

Circulars

16. Strata-bound sulfide deposits and suggestions for exploration in Arizona
J.S. Vuich ..... $ .50

Continued on page 12

Bureau publications *continued from page 11*

17. Utilization of municipal waste water for froth flotation of copper and molybdenum sulfides
W.W. Fisher and Samuel Rudy ..... .75

18. Chemical analyses of coal samples from the Black Mesa field, Arizona ..... .50

19. A survey of uranium favorability of Paleozoic rocks in the Mogollon rim and slope region, east-central Arizona
H.W. Peirce et al. 1.75

20. Geology of the Socorro Peak area, western Harquahala Mountains
R.J. Varga 1.00

Maps

All maps are printed in color at a scale of approximately 16 miles/inch (1:1,000,000) unless otherwise specified. Mail orders will be accepted for folded maps only.

1. Base map of Arizona *(not in color)* ..... $.25

3. County geologic map series. *Printed in color, scale approximately 6 miles/inch (1:375,000).*
   - 3-1 Cochise County (1959) ..... .75
   - 3-2 Coconino County (1960) 1.00
   - 3-3 Gila County (1959) ..... .75
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   - 3-5 Maricopa County (1957) ..... .75
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   - 3-9 Pinal County (1959) ..... .75
   - 3-10 Yavapai County (1958) ..... .75
   - 3-11 Yuma County (1960) ..... .75

4. Metallic mineral occurrence maps
   - 4-1 Map of known nonferrous base and precious metal mineral occurrences in Arizona (1969) ... .75
   - 4-2 Map of known metallic mineral occurrences in Arizona (excluding base and precious metals) (1969) ..... .75

5. Map of known nonmetallic mineral occurrences in Arizona (1965) ..... .75

6. Map and index of Arizona mining districts (1961) ... .75

7. Geologic cross sections of Arizona (1962). *Printed in color, at a scale of approximately 3 miles/inch. A free index of the cross sections, printed in color on the base map of Arizona, will be included with the purchase of any of these maps.*
   - 7-1 Sheet one, sections 1, 2, and 3 ..... 1.00
   - 7-2 Sheet two, sections 4, 5, and 6 ..... 1.00
   - 7-3 Sheet three, sections 7 and 8 ..... 1.00

8. Map of outcrops of Precambrian rocks in Arizona (1962) ..... .50

9. Map of outcrops of Paleozoic and Mesozoic rocks in Arizona (1962) ..... .50

10. Map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona (1962) ..... .50

11. Map of outcrops of Tertiary and Quaternary igneous rocks in Arizona (1962) ..... .50

12. Map of Arizona showing principal power and transportation facilities ..... .50

13. Geologic map of Arizona (1969). *Printed in color, scale approximately 8 miles/inch (1:500,000)* 3.00

14. Geologic map and cross sections of Arizona. *Printed in color, scale approximately 40 miles/inch (1:2,500,000)* ..... .25

FIELDNOTES

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