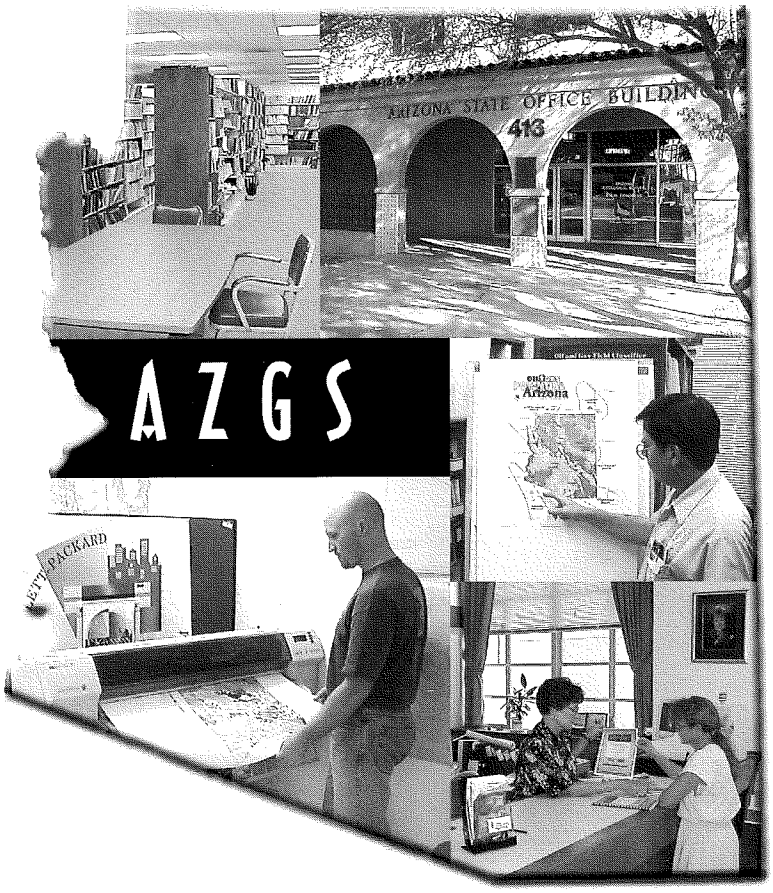

ANNUAL REPORT

FISCAL YEAR 2000

Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701

ANNUAL REPORT

FISCAL YEAR 2000

State of Arizona
Arizona Geological Survey
416 W, Congress, Suite 100
Tucson, Arizona 85701
(520) 770-3500

Jane Dee Hull
Governor

Larry D. Fellows
Director and State Geologist

14 September 2000

The Honorable Jane Dee Hull
Governor of Arizona
1700 West Washington
Phoenix, AZ 85007

Dear Governor Hull:

During Fiscal Year 2000 Arizona Geological Survey (AZGS) staff worked on four intermediate-term goals to provide geologic information to Arizonans. As described below, these goals address several of the major themes on which you have focused your administration.

- **Quality of life.** In areas with potential for population growth it is important to know, at an early stage in the planning process, what geologic materials and processes might impact land and resource development. With this knowledge, land and resource managers can make informed decisions and more prudently manage Arizona's land, water, mineral, and energy resources. Staff completed many geologic mapping and characterization projects in the Phoenix-Tucson corridor during the year.
- **Economic prosperity.** Agency staff compiled data and released several maps and reports that could point to areas, especially rural areas, with potential for discovery and development of energy and other resources.
- **Education.** Many citizens have a strong curiosity about their geologic surroundings, but have had little, if any, education in geology. The AZGS published a non-technical guide to the geology of a national monument and made progress on similar guides in other parks and monuments. Those who understand geologic processes are more capable of making informed decisions about land and resource management than those who don't.
- **Good government.** The AZGS' strategic goals include reaching more customers, making information more readily available, and improving quality of service provided.

I welcome any questions you or your staff might have about the activities of the Arizona Geological Survey or the geologic materials, processes, and hazards in Arizona.

Respectfully yours,

Larry D. Fellows

Larry D. Fellows
Director and State Geologist

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EXECUTIVE SUMMARY

During Fiscal Year 2000, Arizona Geological Survey staff informed and assisted the public as follows:

- Answered thousands of requests for geologic information or assistance.
- Sold 9,988 geologic reports and maps.
- Prepared and released 30 new reports and maps on Arizona geology, including:

  Earthquake Hazards in Arizona (Map 34)

  A Guide to the Geology of Organ Pipe Cactus National Monument and the Pinacate Biosphere Reserve (Down to-Earth 9)

  12 geologic maps in the Phoenix-Tucson corridor,

  three digital map products,

  six reports on geologic hazards and land-management limitations, and

  seven maps and reports on oil, gas, and subsurface geology.
- Released 4 six-page issues of *Arizona Geology*, the quarterly newsletter.
- Presented 30 talks, workshops, and fieldtrips.
- Expended $237,600 that was awarded by Federal and other State agencies for cooperative projects.
- Conducted safety and compliance inspections of 28 gas storage wells.
- Provided all administrative and staff support for the Arizona Oil and Gas Conservation Commission.

Larry D. Fellows
Director and State Geologist

MISSION AND DESCRIPTION

MISSION

To collect and archive information about the geologic character, processes, hazards, and mineral and energy resources of Arizona, and to inform, advise, and assist the public in order to foster understanding and prudent development of the State's land, water, mineral, and energy resources.

DESCRIPTION

Pursuant to A.R.S. Title 27-152, the Arizona Geological Survey (AZGS) was established to be a primary source of information about Arizona geology. To carry out this mandate AZGS geologists map and characterize rock units and their weathering products, describe metallic, non-metallic, and energy resources, and investigate geologic processes such as earthquakes, land subsidence, earth fissures, rock solution, and flooding that have potential to be hazardous to the public or cause limitations to land and resource management. Geologists conduct field investigations and summarize the results of their studies on maps and in reports, which are made available to the public. Staff archive this information in data files, computer databases, and a geology library, all of which are available to the public. The AZGS publishes a quarterly newsletter, maintains a web site, and sells and distributes maps and reports. All staff answer requests for information, advice, and assistance.

The AZGS also provides administrative and staff support for the Arizona Oil and Gas Conservation Commission (OGCC), which regulates the drilling, production, and completion of oil, gas, geothermal, helium, and carbon dioxide wells to ensure sound engineering and environmental practices. AZGS staff assist the OGCC by issuing permits to drill, monitoring drilling, inspecting completed wells, compiling drilling and production data, and maintaining files on each permitted well drilled in the State. Staff also describe the character of underground rock units and encourage exploration for oil, gas, and related resources that may have potential for economic development.

The AZGS is a resource for local, state, and federal land- and resource-management agencies and regularly cooperates with these agencies on projects of mutual interest. Other geologic data users include interested citizens, special interest groups, governmental agencies, elected officials and staff, teachers and students, environmental and engineering geology companies, hydrologists, mineral exploration firms, oil and gas exploration companies, consultants, attorneys, insurance companies, lobbyists, hobbyists, libraries, book dealers, and many other types of businesses.

STRATEGIC ISSUES

Arizona Geological Survey (AZGS) staff analyzed factors that influence the provision of geologic information to the public. Staff also re-examined the performance review of the AZGS that was completed by the Arizona Section of the American Institute of Professional Geologists in late 1997. That review included numerous conclusions and recommendations about future information and investigation needs. On the basis of these reviews, AZGS administration and staff identified the following strategic issues:

1. A growing population requires additional land, water, mineral, and energy resources.

Population growth and related development require more land, water, mineral, and energy resources. Those who site, construct, and maintain housing subdivisions, industrial parks, water wells, waste treatment plants, highways, airports, and other key infrastructure facilities need to be aware of the potential impact that geologic processes (flooding, earthquakes, land subsidence), materials (swelling soils, caliche), and resources (water, metals, sand and gravel) may have on those facilities. An important statutory duty of the AZGS is to provide information about the distribution and character of Arizona's nonrenewable resources and potential hazards and limitations to enable land and resource managers and the public to make informed decisions about these resources.

2. Many citizens want to know about Arizona's geologic heritage, but have had little, if any, education or training in geology.

Informed citizens have the capability to make better decisions about where to live to avoid potential geologic problems, how to vote more intelligently on natural-resource issues, and what courses of action to take to prudently manage Arizona's land, water, mineral, and energy resources. Most people are not capable of understanding technical reports that are written by and for practicing geologists. More information that is understandable by the public needs to be made available.

3. An increasing number of customers want access to large geologic databases in digital format; many prefer to access information and purchase products via the Internet.

Many AZGS customers prefer to receive large databases, including digital maps, on high-capacity electronic media such as CD-ROM. An increasing number expect to access geologic information and purchase AZGS products via the Internet. This is an extremely effective way to serve customers in a large state such as Arizona with widely scattered population centers. If the AZGS had the capability of selling geologic maps and reports over the Internet, it could distribute its products to a much wider audience. Although the AZGS now has a web site and is dispensing information over the Internet, it lacks the computer hardware and software that are needed to provide the level of service our customers expect.

GOALS

The Arizona Geological Survey established the following goals to address the strategic issues described in the preceding paragraphs:

1. Provide more information about Arizona geology and do it more efficiently and effectively.

2. Characterize bedrock and surficial materials and prepare detailed geologic maps in areas that are or will be experiencing population growth and development. Give emphasis to the Phoenix-Tucson corridor, which contains 80 percent of the State's population but only 20 percent of its area.

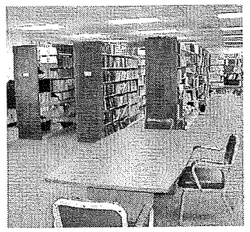
3. Increase understanding of geologic processes and materials that have potential to be hazardous to the public or cause restrictions to land and resource management.

4. Effectively administer the rules, regulations, and policies established by the Arizona Oil and Gas Conservation Commission.

PUBLIC INFORMATION

Goal 1

Provide more information about Arizona geology and do it more efficiently and effectively.



Arizona Geological Survey (AZGS) Information Center. Staff answered thousands of requests for information about Arizona geology and sold reports and maps totaling $42,740. Sales included AZGS and Arizona Geological Society publications. The AZGS has a formal agreement with the Society to be the distributor of Society publications. Revenue from sales was deposited in a revolving fund designated for printing and distributing other AZGS publications. Because of the efforts of G.L. Meeker, M.E. Redmon, and N.A. Duffin, more than 90 percent of the publications ordered were mailed out the same day the order was received.

Earth Science Information Center (ESIC). The AZGS operates the ESIC under terms of a cooperative agreement with the U.S. Geological Survey (USGS) to sell maps, reports, general-interest publications, brochures, and other items the USGS publishes. Revenue from the sale of publications in FY 2000 totaled $21,345. This revenue is used to purchase other USGS products for resale and for ESIC operating expenses. C.L. Moore is responsible for the ESIC.

Geology Library. The AZGS Geology Library, managed by T. G. McGarvin, is open to the public. The library contains published and unpublished items about Arizona and adjacent states. Items in the library do not circulate.

Bibliographic database. More than 12,500 bibliographic citations dealing with Arizona geology have been indexed by key words relative to subjects and geographic areas. The database can be searched to produce lists of citations for each subject or area designated. This is a popular service for those who are starting new projects and need to know what work has already been done within their area of specific interest.

Information Technology. R. A. Trapp was promoted to Information Technology Manager. As such he coordinates the AZGS' computer operations, prepares the Information Technology Plan, and is the director's representative on committees and related assignments. The AZGS increased efforts to distribute products on CD-ROM, an inexpensive, high-capacity medium that can be used on most personal computers. Staff released three products in the Digital Information Series on CD-ROM. The AZGS purchased a large format inkjet printer to assist in producing large map products. The printer was used extensively to produce the new geologic map of Arizona.

Rock Cuttings and Core Repository. The AZGS maintains a repository that contains cuttings from more than 4,000 oil and water wells, and cores from many oil, gas, and mineral tests. The public may examine these samples. Cuttings from 23 water wells were added; cores from Kennecott's Arnett Creek prospect in the Superior basin and Kerr-McGee's Red Mountain porphyry copper prospect were added to the repository.

Web Site. The AZGS web site (www.azgs.state.az.us) includes information about the agency, geology of Arizona, and publications for sale. The state geologic map, geologic hazards, and links to other geology-related agencies and groups are provided. A separate page features the Oil and Gas Conservation Commission. R.C. Harris served as webmaster.

Arizona Geology. The AZGS published four six-page issues of *Arizona Geology* to describe events related to geology, publicize new geologic maps and reports, and to highlight other activities that pertain to geology in Arizona. Land subsidence, global warming, earthquake hazard, and potential geothermal resources were featured in the four issues of *Arizona Geology* during FY 2000.

Down-to-Earth Reports. The AZGS released one non-technical report, *A Guide to the Geology of Organ Pipe Cactus National Monument and the Pinacate Biosphere Reserve*. The book, Down-to-Earth 9, was written in non-technical terms under the direction of J.V. Bezy, National Park Service. It includes photographs and descriptions of geologic features that can be observed from roads within the preserves.

Earth Science Education. T.G. McGarvin, the AZGS' primary contact for earth science education, assists teacher groups in introducing local geology to their classes. McGarvin participated in the annual meetings of the Arizona Science Teachers Association and the Arizona Association for Learning in and about the Environment.

SERVICE TO COMMUNITY AND PROFESSIONAL GROUPS

American Geophysical Union: Possible giant metamorphic core complex at the center of Artemis Corona, Venus, and some tectonic implications; talk given at Fall 1999 Meeting in San Francisco; J.E. Spencer

American Institute of Professional Geologists, Arizona Section: Field trip to San Bernardino volcanic area; S. J. Skotnicki, leader

_____: Field trip to Chiricahua National Monument; L. D. Fellows, leader

American Institute of Professional Geologists (Arizona Section) and Arizona Hydrological Society: Field trip to Picacho basin; R.C. Harris, leader

Arizona Association for Learning in and About the Environment: oral presentation at annual conference, T.G. McGarvin

Arizona Council for Earthquake Safety: L.D. Fellows, vice chair; P.A. Pearthree, member

Arizona Floodplain Managers Association: Geomorphology for Floodplain Managers — An Introductory Course; talk presented in Phoenix by P.A. Pearthree

_____: Field trip to Skunk Creek, Maricopa County, as part of "Geomorphology for floodplain managers, an introductory short course;" P.A. Pearthree, leader

_____: Field trip to Tiger Wash alluvial fan, Maricopa County; P.A. Pearthree, leader

Arizona Geographic Information Council: R.A. Trapp

Arizona Geological Society: Vice-president for programs, S.M. Richard; Secretary, J.E. Spencer; J. Harold Courtright Scholarship Committee, J.E. Spencer, member

_____: Field trip to Mogul fault, northern Santa Catalina Mountains, J.E. Spencer, S.M. Richard, and C.A. Ferguson, leaders

_____: Geologic perspective on flooding and flood hazards in Arizona; talk presented by P.A. Pearthree

_____: Field trip to Madera Canyon alluvial fan and the Santa Rita fault zone, southern Arizona; P.A. Pearthree, leader

Arizona Mining Association: Display at education conference; T.G. McGarvin

Arizona-Nevada Academy of Science: P.A. Pearthree, chair of Geology Section at Annual Meeting in Tucson

_____: Surficial geology and geoarchaeology of Growler Valley, Goldwater Air Force Range, southwestern Arizona; talk presented at 2000 Annual Meeting in Tucson by P.A. Pearthree and A.K. Freeman (see Abstracts Published)

Arizona Science Teachers' Association: Talk given at 1999 annual conference; T.G. McGarvin

Arizona State Land Department: Workshop for the assessment of alluvial aggregates on selected State lands, Maricopa, Pinal, and Pima Counties; P.A. Pearthree, panel member

_____: Workshop for the assessment of porphyry copper deposits in Maricopa, Pinal, and Pima Counties; S.M. Richard, panel member

Arizona State University, Department of Geology: Uplift of the Colorado Plateau - Some constraints on magnitude, timing, and a driving mechanism; talk by J.E. Spencer

Association of American State Geologists: Statemap Peer Review Panel, John C. Frye Award Committee, NSF Field Mentoring Awards Committee, and Honorary Members Committee, L.D. Fellows, member

Flood Control District of Maricopa County: Piedmont Flood Hazards Workshop - Geology and geomorphology of Arizona piedmonts; presented in Phoenix by P.A. Pearthree

_____: Field trip to South Mountain Park alluvial fan, Maricopa County, as part of Piedmont Flood Hazards Workshop; P.A. Pearthree, leader

Geological Society of America: Development of an earthquake hazards map for Arizona; talk presented at 1999 Annual Meeting in Denver, CO by D.B. Bausch, R. Hughes, D.S. Brumbaugh, P.A. Pearthree, T.R. Orr, and S.M. Richard (abstract published)

_____: Evaluation of alluvial fan flood hazards based on surficial geologic mapping and geomorphologic analyses: An example from west-central Arizona; talk presented at 1999 Annual Meeting in Denver, CO, by P.A. Pearthree, J.E. Klawon, and T.W. Lehman (abstract published)

_____: Geology and geomorphology of the San Bernardino Valley, southeastern Arizona; talk presented at 1999 Annual Meeting in Denver, CO, by T.H. Biggs, T.R. Orr, R.S. Leighty, S.J. Skotnicki, P.A. Pearthree, S.M. Richard, and C.E. McGuire (abstract published)

Old Pueblo Lapidary Club: What's beneath Tucson?; talk by T.G. McGarvin

Pima County Flood Control District Advisory Committee: P.A. Pearthree, vice-chair

Second International Paleoflood Conference, Prescott: Field trip to Tiger Wash alluvial fan, Maricopa County; J.E. Klawon and P.A. Pearthree, leaders

Tohono Chul Park: Talk on geology of Tucson area to Docent training class; T.G. McGarvin

Tucson Gem and Mineral Society: Show Committee — Retail Minerals Chairman, R.A. Trapp

Verde River Days: Two field trips to observe geologic features of Verde Valley; L.D. Fellows, leader

Western States Seismic Policy Council: Member of Board of Directors: L.D. Fellows, member

University of Arizona, Department of Geosciences: Field trip to Waterman Mountains as part of annual Geodaze, Spencer, J.E., Richard, S.M., and Ferguson, C.A., leaders

_____: **Department of Mining and Geological Engineering:** A Performance-review panel, L.D. Fellows member

_____: **Department of Planetary Sciences:** Metamorphic core complexes on Earth and Venus; talk by J.E. Spencer

REPORTS RELEASED

A guide to the geology of Organ Pipe Cactus National Monument and the Pinacate Biosphere Reserve: Bezy, J.V., Gutmann, J.T., and Haxel, G.M., 2000, Arizona Geological Survey Down-to-Earth 9, 64 p.

Goal 2

Characterize the bedrock and surficial geology and prepare detailed geologic maps in areas that are or will be experiencing urban growth and development. Give emphasis to the Phoenix-Tucson corridor, which contains 80 percent of the State's population but only 20 percent of its area.

Phoenix-Tucson Corridor. Arizona Geological Survey (AZGS) geologists mapped twelve 7.5' Quadrangles in the Phoenix-Tucson corridor as follows: one 7.5' Quadrangle in the Phoenix North 30' x 60' Quadrangle, five in the Theodore Roosevelt Lake 30' x 60' Quadrangle, three in the Casa Grande 30' x 60' Quadrangle, two in the Silver Bell 30' x 60' Quadrangle, and one in the Tucson 30' x 60' Quadrangle. One digital map was released.

This work was done as part of the Statemap component of the National Cooperative Geologic Mapping Program, administered by the U.S. Geological Survey. The AZGS was awarded $126,401 for mapping during the year. Federal funding was matched equally by activities funded by the AZGS General Fund appropriation. Mapping was concentrated in the Phoenix-Tucson corridor in southern Arizona, which constitutes 20 percent of the State's area but has 80 percent of its population. The Phoenix area has already been mapped; current emphasis is on the Tucson area. Maps in the Phoenix area are being digitized. Mapping priorities were determined by the State Geologic Mapping Advisory Committee.

Geologic mapping is coordinated by J.E. Spencer, who was promoted to Senior Geologist during the year. He is assisted by Research Geologists P.A. Pearthree and S.M. Richard. Other geologists are hired under contract for specific projects.

Davis Dam. Mapping was done cooperatively with the Nevada Bureau of Mines and Geology (NBMG) in the Davis Dam 7.5' Quadrangle in western Arizona. The project is funded by the National Cooperative Geologic Mapping Program through an award to the NBMG.

San Bernardino Valley. Geologists completed mapping in the San Bernardino Valley in Cochise County in cooperation with the U.S. Forest Service. Geologic and geomorphic data obtained will be incorporated with soils and vegetation information to help develop sustainable range-management practices in the Malpai Borderlands of Arizona and New Mexico. One traditional paper map and two digital maps were released.

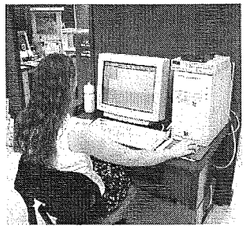
Geologic Map of Arizona. AZGS geologists completed revision of the *Geologic Map of Arizona*, which will be printed and released during the first quarter of FY 2001. The previous edition of this 1:1,000,000-scale map has been out of print since 1999.

Digital geologic maps. The AZGS is working on a GIS database of geologic maps for Arizona. Geologists are producing digital geologic map data statewide at 1:1,000,000 scale and for 30 x 60-minute Quadrangles at 1:100,000 scale. The U.S. Geological Survey, Geological Survey of Canada, and Association of American State Geologists are developing a standard North American data model that will allow construction of a distributed, seamless database containing many geologic maps, along with supporting data on the age and character of rock units. S.M. Richard served as the AZGS representative on this effort.

GEOLOGIC MAPS RELEASED

OFR 98-22. Compilation geologic map of the Daisy Mountain 7.5' Quadrangle, Maricopa County, Arizona: Leighty, R.S., 1998, Arizona Geological Survey Open-File Report 98-22, 30 p., scale 1:24,000.

OFR 99-10. Geologic map of the northwestern part of the Greenback Creek 7.5' Quadrangle, Gila County, Arizona: Spencer, J.E., Richard, S.M., Ferguson, C.A., and Gilbert, W.G., 1999, Arizona Geological Survey Open-File Report 99-10, scale 1:24,000.



OFR 99-12. Preliminary bedrock geologic map and cross sections of the Windy Hill 7.5' Quadrangle, Gila County, Arizona: Spencer, J.E., Richard, S.M., Ferguson, C.A., and Gilbert, W.G., 1999, Arizona Geological Survey Open-File Report 99-12, scale 1:24,000.

OFR 99-15. Geologic map of the Horseshoe Dam 7.5' Quadrangle, Maricopa County, Arizona: Ferguson, C.A., Gilbert, W.A., Skotnicki, S.J., Wrucke, C.T., and Conway, C.M., 1999, Arizona Geological Survey Open-File Report 99-15, 11 p., scale 1:24,000.

OFR 99-16. Geologic map of the Sawtooth Mountains and the north end of the West Silver Bell Mountains, Pinal and Pima Counties, southern Arizona: Ferguson, C.A., Gilbert, W.A., Klawon, J.E., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-16, 25 p., scale 1:24,000.

OFR 99-17. Geologic map of the Samaniego Hills, Pinal and Pima Counties, southern Arizona: Ferguson, C.A., Gilbert, W.A., Orr, T.R., Spencer, J.E., Richard, S.M., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-17, 15 p., scale 1:24,000.

OFR 99-18. Geologic map of the Picacho Mountains and Picacho Peak, Pinal County, southern Arizona: Richard, S.M., Spencer, J.E., Ferguson, C.A., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-18, 43 p., 2 sheets, scale 1:24,000.

OFR 99-19. Geology and geomorphology of the San Bernardino Valley, southeastern Arizona: Biggs, T.H., Leighty, R.S., Skotnicki, S.J., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-19, 20 p., 3 sheets, scale 1:32,000.

OFR 99-20. Geologic map of the Ninetysix Hills, Pinal County, Arizona: Skotnicki, S.J., 1999, Arizona Geological Survey Open-File Report 99-20, 14 p., 4 sheets, scale 1:24,000.

OFR 99-21. Surficial geology and geologic hazards of the northern Tucson basin, Pima County, Arizona, Tucson North and Sabino Canyon Quadrangles: Klawon, J.E., Dickinson, W.R., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-21, 28 p., scale 1:24,000.

OFR 99-22. Surficial geology and geologic hazards of the Tucson Mountains, Pima County, Arizona, Avra, Brown Mountain, Cat Mountain, and Jaynes Quadrangles: Pearthree, P.A., and Biggs, T.H., 1999, Arizona Geological Survey Open-File Report 99-22, 19 p., 2 sheets, scale 1:24,000.

OFR 99-23. Geologic map of the Picture Mountain Quadrangle, Gila County, Arizona: Skotnicki, S.J., 1999, Arizona Geological Survey Open-File Report 99-23, 12 p., scale 1:24,000.

OFR 99-24. Geologic map of the Copper Mountain Quadrangle, Gila County, Arizona: Skotnicki, S.J., 1999, Arizona Geological Survey Open-File Report 99-24, 10 p., scale 1:24,000.

DIGITAL PRODUCTS RELEASED

DI 15. Digital maps and geographic database of the geology, geomorphology, and soils of the San Bernardino Valley, southeastern Arizona: Biggs, T.H., Leighty, R.S., Skotnicki, S.J., Pearthree, P.A., and Orr, T.R., 1999, Arizona Geological Survey Digital Information Series 15.

DI 16. Digital geomorphic surface map and geographic database of the southern Animas Creek Valley, Hidalgo County, New Mexico: Orr, T.R., and Richard, S.M., 1999, Arizona Geological Survey Digital Information Series 16, 1 CD-ROM.

DI 17. Digital surficial geologic map and geographic database of the northern Tucson basin and Tucson Mountains, Pima County, Arizona: Pearthree, P.A., Klawon, J.E., Dickinson, W.R., Biggs, T.H., and Orr, T.R., 1999, Arizona Geological Survey Digital Information Series 17.

CONTRIBUTED MAPS AND REPORTS RELEASED

CM 99-C. Geologic map of the New River Quadrangle and part of the Daisy Mountain Quadrangle, Maricopa and Yavapai Counties, Arizona: Bryant, Bruce, 1999, Arizona Geological Survey Contributed Map 99-C, 32 p., scale 1:24,000.

CM 00-B. Summary of Tertiary stratigraphic and structural relationships, Camp Grant Wash — Antelope Peak area, Pinal County, Arizona: Dickinson, W.R., 2000, Arizona Geological Survey Contributed Map 00-B, 10 p., scale 1:24,000.

PROCESSES, MATERIALS, AND HAZARDS

Goal 3

Increase understanding of geologic processes and materials that have potential to be hazardous to the public or to cause restrictions to land and resource management.

PROJECTS

Alluvial fan flooding. Arizona Geological Survey (AZGS) geologists investigated the extent and character of alluvial-fan flooding along Tiger Wash west of Phoenix with support from the Flood Control District of Maricopa County. Because urban areas are expanding onto adjacent piedmonts, research such as this helps predict areas that might be subjected to future flooding.

Earthquake hazard. AZGS geologists completed a 1:1,000,000-scale map that shows Quaternary faults, epicenters of historic earthquakes, tabular information about selected Quaternary faults and notable historic earthquakes, and text discussing earthquake hazards. This map was done cooperatively with the Earthquake Program in the Arizona Division of Emergency Management (ADEM), Federal Emergency Management Agency (FEMA), Arizona Earthquake Information Center at Northern Arizona University, Arizona Council for Earthquake Safety, National Earthquake Hazard Reduction Program of the U.S. Geological Survey (USGS), and the AZGS. Funding was provided by the AZGS and FEMA in cooperation with the ADEM.

Hurricane fault. The Utah Geological Survey and the AZGS are cooperating on a study of the Hurricane fault, which extends from northwestern Arizona into southwestern Utah. Trenching is being done to determine the age of paleo-earthquakes and amount of displacement that occurred during those events. The research is being funded by the two state geological surveys and the USGS National Earthquake Hazards Reduction Program.

Isotopes as tracers of salinity sources. This pilot study, partially funded from the Arizona Department of Water Resources' Water Protection Fund, was undertaken to demonstrate that isotopes can be used to "fingerprint" sources of salinity. The study area included the Duncan and Safford basins along the Gila River in southeastern Arizona. Isotopes of sulfur, chlorine, boron, nitrogen, oxygen, hydrogen, and strontium were used to compare compositions of evaporite deposits and water from springs, deep artesian wells, water wells, and the Gila River. Evidence suggests that much of the salinity in the Gila River is from natural sources and that deep artesian wells are not connected with agriculture.

Land subsidence and earth fissures. The AZGS maintains a Center for Land Subsidence and Earth-Fissure Information. Geologists inform the public about areas in which land subsidence is known or suspected to have occurred and areas where earth fissures are present. Meetings are held periodically with other agencies to discuss subsidence and fissures.

Mineral resource potential. This study was done to assess mineral resource potential for a land withdrawal proposed by the U.S. Bureau of Reclamation in the Tonto basin-Roosevelt Lake area. The study is based on published literature and recent geologic mapping by AZGS geologists. A report was submitted to the U.S. Forest Service for review.

River navigability. In FY 1999 the AZGS completed reports on the historical geomorphology and hydrology of several rivers for the Arizona State Land Department (ASLD). This work was done as part of an assessment of river navigability conducted by the ASLD for the Arizona Navigable Stream Adjudication Committee. During FY 2000 the AZGS released final reports on the upper Santa Cruz River and the Santa Maria River, Big Sandy Creek, and Burro Creek.

Surficial geology. Geologists completed a number of geologic maps and reports between 1996 and mid-1999 that cover parts of the Goldwater Air Force Range southeast and southwest of Gila Bend, and east of Yuma. A report on the northern Growler Valley was submitted to the Air Force for review and approval will subsequently be released by the AZGS as an open-file report.

Verde River floods. AZGS geologists, in cooperation with the Desert Research Institute at the University of Nevada-Reno, completed a study of the historical and prehistoric record of large floods along the Verde River in central Arizona. They documented large floods that range back several thousand years. The largest have been somewhat larger than any floods of the past century. The USGS provided partial funding for these investigations.

REPORTS RELEASED

MAP 34. Earthquake hazards in Arizona: Pearthree, P.A., and Bausch, D.B., 1999, Arizona Geological Survey Map 34, scale 1:1,000,000.

OFR 99-09. Geology of the Socorro mine-White Marble mine area, western Harquahala Mountains, west-central Arizona: Richard, S.M., 1999, Arizona Geological Survey Open-File Report 99-09, 35 p., 2 sheets, scale 1:12,000.

OFR 99-11. Brief overview of the geology and mineral resources of the Tonto Basin, Gila County, Arizona: Richard, S.M., 1999, Arizona Geological Survey Open-File Report 99-11, 16 p., scale 1:100,000.

OFR 99-13. Historical geomorphology and hydrology of the Santa Cruz River: Wood, M.L., House, P.K., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-13, 98 p., scale 1:100,000.

OFR 99-21. Surficial geology and geologic hazards of the northern Tucson Basin, Pima County, Arizona, Tucson North and Sabino Canyon Quadrangles: Klawon, J.E., Dickinson, W.R., and Pearthree, P.A., 1999, Arizona Geological Survey Open-File Report 99-21, 28 p., scale 1:24,000.

OFR 99-22. Surficial geology and geologic hazards of the Tucson Mountains, Pima County, Arizona, Avra, Brown Mountain, Cat Mountain, and Jaynes Quadrangles: Pearthree, P.A., and Biggs, T.H., 1999, Arizona Geological Survey Open-File Report 99-22, 19 p., 2 sheets, scale 1:24,000.

OFR 99-25. A bibliography and review of water quality studies in the upper Gila River watershed, Arizona: Harris, R.C., 1999, Arizona Geological Survey Open-File Report 99-25, 67 p.

OFR 99-26. Field guide to earth fissures and other land subsidence features in Picacho Basin, Arizona Geological Society and Arizona Hydrological Society Fall 1999 Field Trip: Harris, R.C., leader, 1999, Arizona Geological Survey Open-File Report 99-26, 55 p.

OFR 00-01. Field guide to a dynamic distributary drainage system-Tiger Wash, western Arizona: Klawon, J.E., and Pearthree, P.A., 2000, Arizona Geological Survey Open-File Report 00-01, 34 p., scale 1:70,000.

OFR 00-02. Hydrology and geomorphology of the Santa Maria and Big Sandy Rivers and Burro Creek, western Arizona: Klawon, J.E., 2000, Arizona Geological Survey Open-File Report 00-02, 46p.

ABSTRACTS PUBLISHED

Development of an earthquake hazards map for Arizona: Bausch, D.B., Hughes, R., Brumbaugh, D.S., Pearthree, P.A., Orr, T.R., and Richard, S.M., 1999, Geological Society of America Abstracts with Programs, v. 31, n. 7, p. A46.

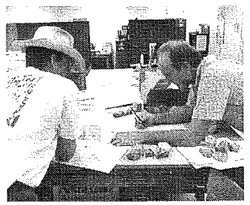
Evaluation of alluvial fan flood hazards based on surficial geologic mapping and geomorphologic analyses: An example from west-central Arizona: Pearthree, P.A., Klawon, J.E., and Lehman, T.W., 1999, Geological Society of America Abstracts with Programs, vol. 31, n. 7, p. A194.

Geology and geomorphology of the San Bernardino Valley, southeastern Arizona: Biggs, T.H., Orr, T.R., Leighty, R.S., Skotnicki, S.J., Pearthree, P.A., Richard, S.M., and McGuire, C.E., 1999, Geological Society of America Abstracts with Programs, v. 31, n. 7, p. A79-80.

Surficial geology and geoarchaeology of Growler Valley, Goldwater Air Force Range, southwestern Arizona: Pearthree, P.A., and Freeman, A.K., 2000, Arizona-Nevada Academy of Science 2000 Proceedings Supplement, v. 35, p. 36.

UNPUBLISHED REPORTS AND ABSTRACTS

Field guide to a dynamic distributary drainage system: Tiger Wash, western Arizona: Klawon, J.E., and Pearthree, P.A., 1999, Field trip guidebook for Second International Paleoflood Conference, Prescott, Arizona, September 29 - October 1, 1999.



Geology and geomorphology of the San Bernardino Valley, southeastern Arizona, *in* Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands: Conference summary: Biggs, T.H., Leighty, R.S., Skotnicki, S.J., and Pearthree, P.A., 1999, U.S.D.A., Forest Service, Rocky Mountain Research Station, Proceedings RMRS-P-10, p. 11-15.

Geomorphologic assessment of flood hazards in southern and central Arizona: Pearthree, P.A., House, P.K., and Vincent, K.R., 2000, Floodplain Management in the Desert Arid Regions Floodplain Management Eighth Biennial Conference, Las Vegas, Nevada, p. 82-91.

Geomorphology of lower Oak Creek archaeological project, with reference to Verde River and Sinagua agricultural dynamics: Huckleberry, Gary, and Pearthree, P.A., 2000, report submitted to the Arizona Department of Transportation, in cooperation with Statistical Research, Incorporated.

Mapping of flood related landscape change in southwestern Arizona associated with Hurricane Nora using satellite remote sensing: Mayer, Larry, and Pearthree, P.A., 1999, abstract of poster presentation at Second International Paleoflood Conference, Prescott, Arizona, September 26-29, 1999.

Mineral potential report, Bureau of Reclamation withdrawal for Theodore Roosevelt Lake area, Tonto National Forest, AZ-950-5700-77: Richard, S.M., 1999, submitted to U.S. Forest Service.

Surficial geology and geoarchaeology of the south TAC area in northern Growler Valley, Goldwater Air Force Range, southwestern Arizona: Pearthree, P.A., and Demsey, K.A., 1999, submitted to the U.S. Air Force for review and comment.

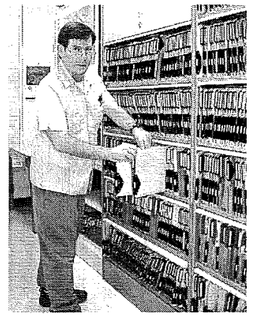
Twentieth century channel change and related flood hazards near Casa Grande, Arizona: Klawon, J.E., House, P.K., and Pearthree, P.A., 2000, Floodplain Management in the Desert Arid Regions Floodplain Management Eighth Biennial Conference, Las Vegas, NV, p. 92-102.

ACTIVITIES

OIL AND GAS

Goal 4

Effectively administer and enforce the rules, orders, and policies established by the Arizona Oil and Gas Conservation Commission.



Oil and Gas Conservation Commission (OGCC). The OGCC, attached to the Arizona Geological Survey (AZGS), regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources. The Commission has five members appointed by the Governor and one ex-officio member, the State Land Commissioner. Commissioners are J. Dale Nations, Flagstaff, Chairman; Donald C. Clay, Yuma; Robert L. Jones, Sun City West; James C. Lanshe, Scottsdale; Zed Veale, Flagstaff; and Michael E. Anable, State Land Commissioner. The AZGS provides all administrative and staff support. S.L. Rauzi is the Oil and Gas Administrator.

Production, refining, and storage. Oil production in calendar year (CY) 1999 totaled 66,483 barrels from 24 producing wells, down from 78,109 barrels from 19 wells in 1998. Gas production in CY 1999 totaled 474 million cubic feet from eight producing gas wells, up from 457 million cubic feet in 1998.

Both of Arizona's refineries remained shut down. The refineries, near Fredonia and Coolidge, have been shut down since January 1997 and August 1993, respectively.

Liquefied petroleum gas (LPG) transferred in CY 1999 through storage wells near Luke Air Force Base and Adamana included 90 million gallons in receipts and 104 million gallons in deliveries. In 1998 89 million gallons were received and 106 million gallons delivered. About 26 million gallons of LPG were in storage at yearend, down from the 41 million gallons the previous year. Fourteen storage wells constructed in subsurface salt are currently in use.

Leasing. In 2000 303,000 acres were under lease for oil and gas exploration. This was down from 324,000 acres in 1999 and 417,000 in 1998. State Trust land under lease on June 30, 2000, totaled 191,000 acres, down from 213,000 acres in 1999 and 305,000 in 1998. Public land under lease on June 30, 2000 totaled 111,500 acres compared with 111,000 in 1999 and 112,000 in 1998. The State Land Department administers leasing on State Trust Land. The U.S. Bureau of Land Management administers leasing on public lands.

Drilling. One permit was issued to reenter and deepen the previously abandoned Townsend 26-1 State hole near Meteor Crater in Coconino County. The operator deepened the well to 3900 feet, ran casing, and is planning to test Devonian strata. Premco Western was drilling at a depth of about 1500 feet on the Dutchman Federal well in Mojave County in northwestern Arizona.

Inspection and enforcement. Staff made semiannual inspections of 14 hydrocarbon-storage wells near Luke Air Base and Adamana. The inspections are conducted to ensure that all valves, safety alarms, and emergency shutdown systems are in good working condition.

Subsurface data. The OGCC requires drilling operators to submit subsurface data, including rock samples, logs, and all test results, to the AZGS to be filed and archived. These data add to the general understanding of Arizona's geologic framework and subsurface mineral and energy resources. The AZGS maintains a series of maps that show the location of oil, gas, and geothermal wells and the types of subsurface data that are available for examination. Subsurface samples from one oil and gas well were added to the AZGS sample repository.

Legislation and rules. HB 2492 was passed by the Legislature and signed by Governor Jane Dee Hull. The bill amended the confidentiality period for well records and the procedure for publishing information about active oil and gas projects. The OGCC initiated the rulemaking process to incorporate the changes made in HB 2492.

Carbon dioxide update. Ridgeway Arizona Oil Corporation announced a discovery of carbon dioxide (CO_2) in the St. Johns and Springerville areas in southern Apache County in August 1994. By the end of May 1997 the company had drilled 15 wells. At the end of Fiscal Year (FY) 2000 two wells have been completed as gas wells; seven have been temporarily abandoned; and six have been plugged and abandoned. No drilling was done during FY 2000 and no requests for permits to drill were received by the OGCC.

At a meeting of the House of Representatives Natural Resources Committee in Springerville in August 1999, Ridgeway representatives stated that initial development to supply CO_2 for enhanced oil recovery would require two to three years and about 200 wells. The company informed meeting attendees that as many as 1,195 wells would eventually be drilled over the 25-40 year life of the project. At the May 2000 meeting of the OGCC a Ridgeway representative announced that the company plans to begin producing carbon dioxide for a liquid CO_2 plant from three wells, two in Arizona and one in New Mexico, in about five months.

MAPS UPDATED

OPG 2. Annual oil, gas, and helium production in Arizona 1954-1999: Rauzi, S.L., 2000, Arizona Geological Survey Oil and Gas Publication 2, 18 p.

OPG 11. Well location map, Colorado Plateau province, Arizona; Apache, Coconino, Navajo, and portions of adjacent counties: Conley, J.N. and Rauzi, S.L., 1999, Arizona Geological Survey Oil and Gas Publication 11, 48 p.(1975), 4 p. addendum, scale 1:500,000. (OGCC County Series Map 9)

OPG 12. Arizona well location map and report: Rauzi, S.L., 1999, Arizona Geological Survey Oil and Gas Publication 12, 27 p., scale 1:675,000. (2 blueline sheets; OGCC State Series Map)

OPG 15. Dineh-Bi-Keyah oil field, Apache County, Arizona: Rauzi, S.L., 2000, Arizona Geological Survey Oil and Gas Publication 15, scale 1:63,360. (OGCC Pool Series Map P-2)

OPG 35. Oil and natural gas occurrence in Arizona: Rauzi, S.L., 2000, Arizona Geological Survey Oil and Gas Publication 35, chart (OGCC Chart C-1) [published annually]

REPORTS RELEASED

OFR 99-14. Index of samples of wells drilled for oil and gas in Arizona: Rauzi, S.L., 1999, Arizona Geological Survey Open-File Report 99-14, 14 p.

OFR 00-3. Permian salt in the Holbrook Basin, Arizona: Rauzi, S.L., 2000, Arizona Geological Survey Open-File Report 00-03, 20 p., 6 sheets, scale 1:250,000

Grand Canyon Conference. Many geologists have a deep professional interest in the Grand Canyon and its origin. Two years ago several of them recognized the need to meet to discuss research that has been done on the origin of the Canyon since the last organized conference in 1964. A conference was held June 7-9, 2000 at Grand Canyon Village. Richard A. Young, Department of Geological Sciences, State University of New York, Geneseo, organized the meeting and is preparing an abstract volume for publication. The meeting title was "A working conference on the Cenozoic geologic evolution of the Colorado River system and the erosional chronology of the Grand Canyon Region." The Arizona Geological Survey (AZGS) was one of the co-sponsors. J.E. Spencer and P.A. Pearthree, AZGS geologists, made oral presentations and gave a poster session, abstracts of which will be included in the abstract volume:

A K-Ar geochronologic survey of the Hopi Buttes volcanic field. Damon, P.E., and Spencer, J.E.

Ar40/Ar39 geochronology of the Hualapai Limestone and Bouse Formation and implications for the age of the lower Colorado River. Spencer, J.E., Peters, L., McIntosh, W.C., and Patchett, P.J.

Cosmogenic dating of late Pleistocene lava flows in western Grand Canyon: Implications for offset rates on the Toroweap and Hurricane faults: Fenton, C.R. Cerling, T.E., Webb, R.H., Pearthree, P.A., and Poreda, R.J.

The Colorado River system and Neogene sedimentary formations along its course: Apparent Sr isotopic connections: Patchett, P.J., Gross, E.L., Dallegge, T.A., and Spencer, J.E.

Headward erosion vs. closed-basin spillover as alternative causes for the integration of the lower Colorado River: Spencer, J.E., and Pearthree, P.A. (poster session)

Morenci project. This project is a cooperative effort between Phelps Dodge Morenci, Inc. (PDM) and the Arizona Geological Survey (AZGS). The project, funded by PDM, was initiated in 1998 as part of M. Stephen Enders' Ph.D. dissertation at the University of Arizona that focused on supergene copper enrichment in the Clifton-Morenci district. Enders (PDM) and C.A. Ferguson (AZGS) studied the Mid-Tertiary volcanic and sedimentary stratigraphy, which constrained many aspects of the supergene enrichment process. Detailed provenance studies of the conglomeratic rocks of the Gila Group, together with $^{40}Ar/^{39}Ar$ dates of important volcanic units, were used to construct a regional time-space diagram that integrates the new work with previously published maps and reports, principally from the U.S. Geological Survey.

This project will be completed early in Fiscal Year 2001. A digital map with multiple structural cross sections, an exhaustive digital database, and a report on the Mid-Tertiary geochronology and stratigraphy of the region are being prepared for release.

REPORTS RELEASED

OFR 99-27. Annual Report of the Arizona Geological Survey, Fiscal Year 1999: Fellows, L.D., 2000, Arizona Geological Survey Open-File Report 99-27, 19 p.

EXTERNAL PUBLICATIONS

Possible origin and significance of extension-parallel drainages in Arizona's metamorphic core complexes: Spencer, J.E., 2000, Geological society of America Bulletin, v. 112, p. 727-735.

ABSTRACTS PUBLISHED

Possible giant metamorphic core complex at the center of Artemis Corona, Venus, and some tectonic implications: Spencer, J.E. 1999, EOS, American Geophysical Union, Fall meeting abstracts, p. F629 (poster session).

CONTRIBUTED MAPS AND REPORTS RELEASED

CR 99-B. The geology, leasing, and production history of the Martin uranium-vanadium mine, Apache County, Arizona: Chenoweth, W.L., 1999, Az. Geological Survey Contributed Report 99-B, 34 p.

CR 99-A. The geology, leasing, and production history of the uranium-vanadium mines on North Star Mesa, Apache County, Arizona and San Juan County, New Mexico: Chenoweth, W.L., 1999, Arizona Geological Survey Contributed Report 99-A. 24 p.

CM 00-A. Map of the volcanic geology of the Castle Butte Trading Post vicinity, Hopi Buttes (Tsézhin Bií), Navajo Nation, Arizona: Hooten, J.A., 1999, Arizona Geological Survey Contributed Map CM-00-A, scale 1:12,000.

THE ARIZONA GEOLOGICAL SURVEY AND ITS PREDECESSORS

OFFICE OF THE TERRITORIAL GEOLOGIST

The eleventh Legislative Assembly of Arizona Territory established the office of the Territorial Geologist in Prescott in 1881. Its primary function was to collect and periodically publish information about the geology, mineralogy, and mining in the Territory. After the University of Arizona (UA) opened in Tucson in 1891, Territorial Geologists held joint appointments as faculty members.

ARIZONA BUREAU OF MINES

In 1915, three years after Statehood, the Arizona Legislature established the Arizona Bureau of Mines. It continued, essentially unchanged, functions of the Territorial Geologist and the UA metallurgical testing laboratory. The Bureau's mission was to collect, compile, and publish information about Arizona mining. The enabling act specified that the Bureau be administered as a department of the UA.

ARIZONA BUREAU OF GEOLOGY AND MINERAL TECHNOLOGY

After World War II ended in 1945, the population of Arizona began to increase rapidly. In 1977 the Legislature recognized the need for geologic information relative to population growth and urban development and passed a bill that updated, modernized, and renamed the Bureau of Mines. The new Bureau, composed of a Geological Survey Branch and a Mineral Technology Branch, was administered as a division of the UA.

ARIZONA GEOLOGICAL SURVEY

In 1988 the Legislature transformed the Geological Survey Branch of the Bureau of Geology and Mineral Technology into the Arizona Geological Survey, a stand-alone state agency. This change was made to give the Geological Survey increased visibility and accountability. The Legislature added responsibility for administering the Arizona Oil and Gas Conservation Commission in 1991.

PERSONNEL AND BUDGET

PERSONNEL[1]

OFFICE OF THE DIRECTOR

LARRY D. FELLOWS, Director and State Geologist
B.S., Iowa State University; M.A., University of Michigan; Ph.D., University of Wisconsin

ROSE ELLEN McDONNELL, Assistant Director of Administration
B.S., University of Arizona

GEOLOGISTS

RAYMOND C. HARRIS,[2] Geologist II
B.S., Oregon State University; M.S., University of Arizona

THOMAS G. McGARVIN, Geologist I
B.A., California Lutheran College

TIM R. ORR,[2] Geologist I
B.S., University of Montana; M.S., Northern Arizona University

PHILIP A. PEARTHREE, Research Geologist
B.A., Oberlin College; M.S., University of Arizona; Ph.D., University of Arizona

STEVEN L. RAUZI, Oil and Gas Administrator
B.S. and M.S., Utah State University

STEPHEN M. RICHARD, Research Geologist
B.S. and M.S., University of Arizona; Ph.D., University of California, Santa Barbara

JON E. SPENCER, Senior Geologist[3]
B.S., University of California, Santa Cruz; Ph.D., Massachusetts Institute of Technology

RICHARD A. TRAPP, Information Technology Manager[4]
B.S., University of Nebraska, Omaha; M.S., University of Arizona

PROJECT GEOLOGISTS

Lee Amoroso,[2] M.S.
Douglas B. Bausch,[2] M.S.
Thomas H. Biggs,[2] Ph.D.
Charles A. Ferguson[2], Ph.D.
Wyatt G. Gilbert,[2] Ph.D.
Jeanne E. Klawon,[2] B.S.
Steven J. Skotnicki,[2] M.S.
Ann M. Youberg,[2] M.S.

SUPPORT STAFF

PETER F. CORRAO, Program and Project Specialist II
B.A., Arizona State University

GEORGEANNA L. MEEKER, Administrative Assistant I

CATHY L. MOORE,[2] Geologist I
B.S., University of Wisconsin; M.S., University of Arizona

NANCY A. DUFFIN,[2] Accounting Technician II

MARY E. REDMON, Administrative Assistant III

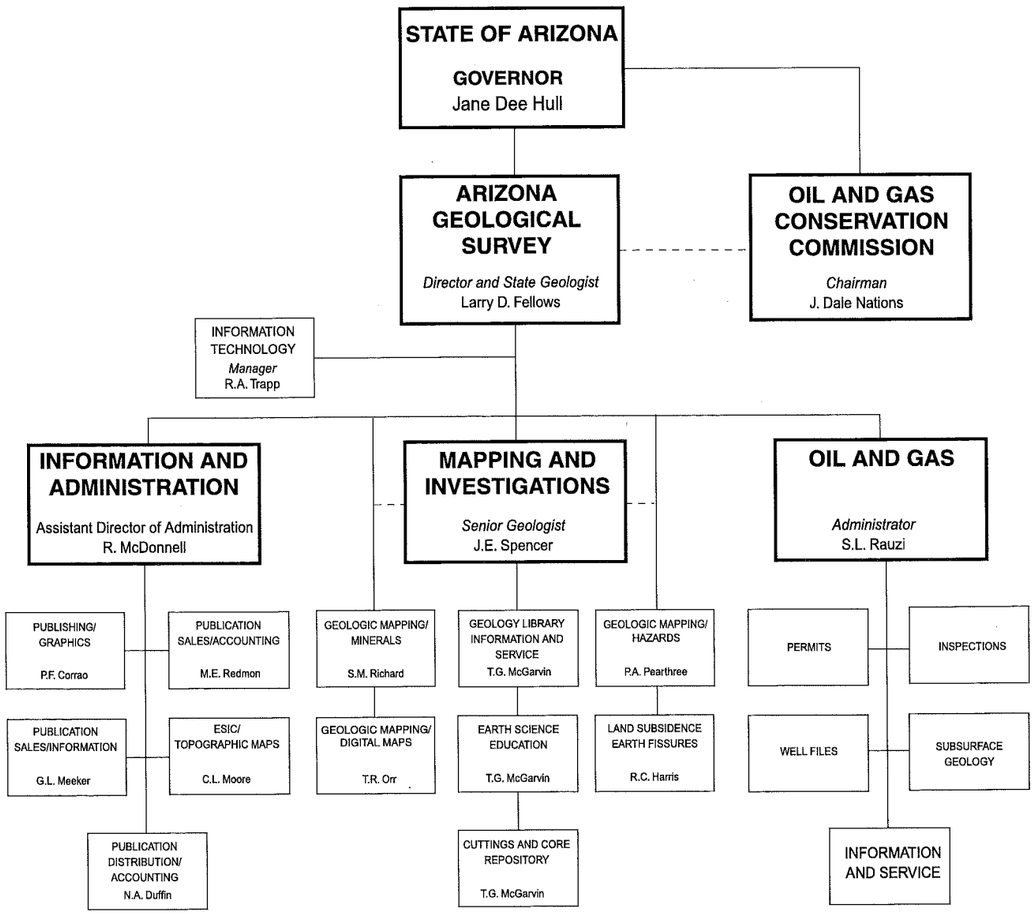
(1) Geologists and support staff listed were on the payroll June 30, 2000. The Arizona Geological Survey is authorized to employ 13.25 full-time-equivalent staff members from the General Fund appropriation.

(2) Paid partially or entirely from external funds

(3) Promoted to Senior Geologist July 1, 1999

(4) Promoted to Information Technology Manager July 1, 1999

ORGANIZATION AND FUNCTIONS



GENERAL FUND EXPENDITURES

Category	FY 1999 Expended	Fy 2000 Expended	Fy 2001 Budgeted
Personal Services	495,774	518,825	530,600
Benefits	93,554	93,713	99,800
Professional Services	0	300	0
Operations	195,179	192,226	194,000
In-State Travel	30,650	31,103	46,400
Out-of-State Travel	2,504	2,194	2,000
Capital Equipment	11,847	23,848	12,400
TOTAL	**829,508**	**862,209**	**885,200**

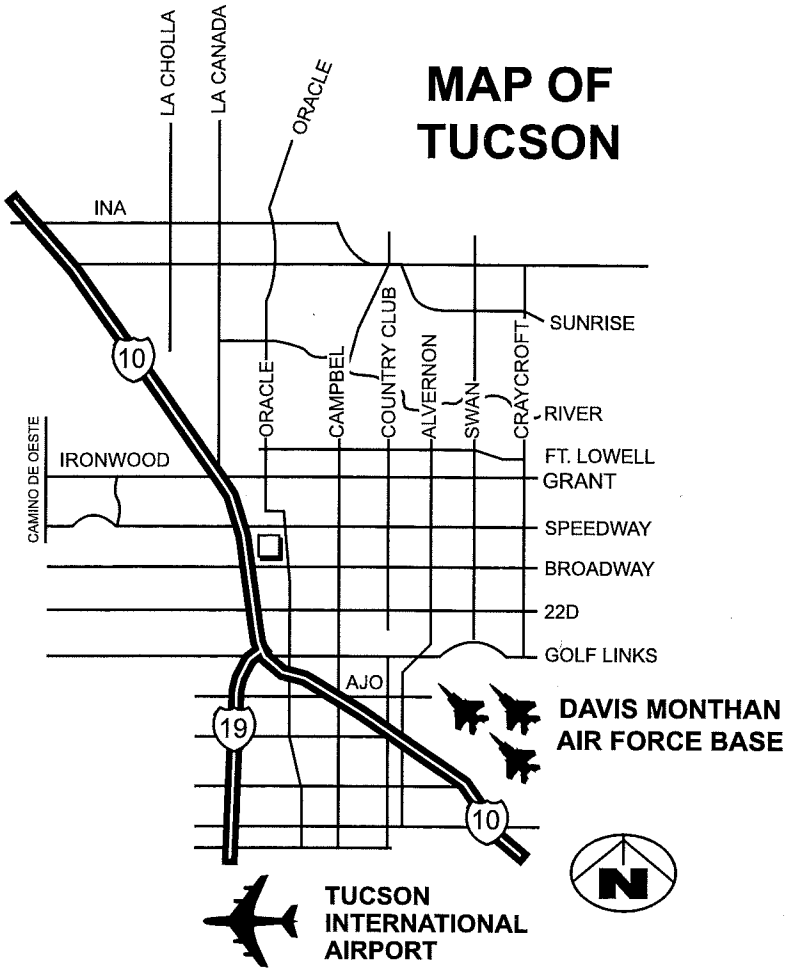
PRINTING REVOLVING FUND

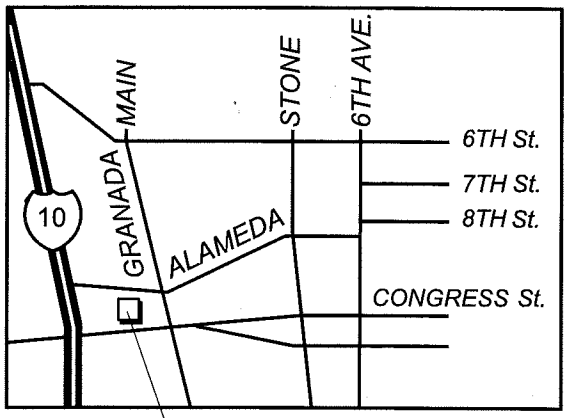
Publicatons	FY 2000 Expended
Arizona Geological Survey	38,317
Arizona Geological Society	3,153
U.S. Geological Survey	27,884
Other Publications	1,342
TOTAL	**70,696**

CONTRACTED PROJECTS

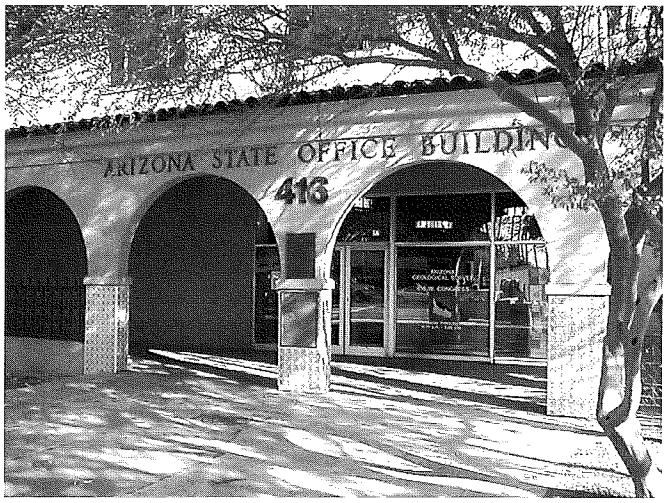
PROJECT (FUND SOURCE)	PRICIPAL INVESTIGATOR	PERSONAL SERVICES	BENEFITS	OPERATIONS	IN-STATE TRAVEL	TOTAL
URANIUM LEVELS (U.S. Environmental Protection Agency)	SPENCER	778	132	-	-	910
GEOLOGIC MAPPING (U.S. Geological Survey)	SPENCER	80,160	17,325	37,928	2,521	137,934
COAL RESOURCE (U.S. Geological Survey)	SPENCER	24,864				24,864
SAN BERNARDINO (U.S. Geological Survey)	PEARTHREE	5,969	962	91	199	7,221
PRINTING & DISTRIBUTION (Arizona Geological Society)	McDONNELL	144	26	1,851	-	2,021
FT HUACHUCA (U.S. ARMY)	PEARTHREE	460	79	-	-	539
SAFFORD ISOTOPE (DWR)	RICHARD	379	96	-	-	779
GROWLER WASH (Geraghty & Miller, Inc.)	PEARTHREE	602	120	57	-	475
MORENCI-CLIFTON (PHELPS DODGE)	SPENCER	11,444	2,106	1,352	-	14,902
EARTHQUAKE HAZARD (AZ Div of Emergency Management)	PEARTHREE	5,954	788	3,696	70	10,508
TRITIUM (Arizona Department of Water Resources)	SPENCER	7,662	1,392	13,614	970	23,638
TIGER WASH (JEF, Inc.)	PEARTHREE	2,988	510	1,381	773	5,652
HURRICANE FAULT (Utah Geological Survey)	PEARTHREE	5,610	654	471	1,283	8,018
DAVIS DAM (University of Nevada)	PEARTHREE	-	-	-	156	156
TOTAL		147,014	24,190	60,441	5,972	237,617

MAP OF TUCSON





ARIZONA GEOLOGICAL SURVEY
416 W. CONGRESS St.



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