



*Arizona Geological Survey*



ANNUAL REPORT 1999

# 1998-1999 ARIZONA GEOLOGICAL SURVEY STAFF

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## MISSION

*The mission of the Arizona Geological Survey (AZGS) is to provide unbiased information that enhances public understanding of geologic processes, materials, and resources and assists citizens, businesses, governmental agencies, and legislators in prudently managing Arizona's land, water, mineral, and energy resources.*

BOOK DESIGN AND LAYOUT: PETER F. CORRAO  
PHOTOGRAPHY: LARRY D. FELLOWS

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19 November 1999

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

Dear Governor Hull:

The Arizona Geological Survey (AZGS) identified four goals to fulfill its statutory mission: 1) provide information, 2) prepare detailed geologic maps, 3) investigate geologic materials, processes, and resources, including potential hazards and restrictions to land management, and 4) provide administrative and staff support for the Arizona Oil and Gas Conservation Commission (AOGCC). This report highlights accomplishments made in meeting those goals during Fiscal Year 1999.

AZGS staff provide information by responding to inquiries, selling maps and reports, maintaining a library, databases, and web site on Arizona geology, publishing a quarterly newsletter (*Arizona Geology*), giving talks, and leading fieldtrips. Information provided is obtained by preparing new geologic maps, conducting field investigations, and compiling information that was prepared and released by other geologists.

Parts of Arizona are subject to earthquakes, land subsidence and earth fissures caused by overdraft of ground water, flooding, and problems associated with cavernous bedrock in limestone terrain. Objective information about these processes that have potential to impact land and resource management is needed more than ever because of increasing population growth.

The AOGCC performs a vital role in regulating the drilling for and production of oil and gas. The missions of the AZGS and AOGCC are complementary relative to maintaining subsurface information and informing the public.

AZGS staff collaborate with Federal and other State agencies on projects of mutual interest, using State funds to match Federal and other funds on cooperative projects. During the fiscal year AZGS staff expended more than \$300,000 in federal and other funds to supplement the General Fund appropriation in studying Arizona's geologic framework.

I'm proud to submit this annual report of the AZGS for FY 1999. I welcome your questions about Arizona's geology and geologic resources and the operation of the AZGS.

Sincerely yours,

A handwritten signature in cursive script that reads "Larry D. Fellows".

Larry D. Fellows  
Director and State Geologist

## EXECUTIVE SUMMARY



LARRY D. FELLOWS  
DIRECTOR AND STATE GEOLOGIST

### INFORMATION

- Answered thousands of requests for geologic information or assistance.
- Sold 11,067 geologic maps and reports.
- Released *Fieldguide to the Geology of Chiricahua National Monument*
- Published four issues of *Arizona Geology*

### MAPPING AND INVESTIGATIONS

- Released 43 geologic reports and maps.
- Spent \$829,508 appropriated from the General Fund and employed 13.25 full-time equivalent employees to do geologic mapping, conduct investigations, and provide information.
- Spent \$306,329 and employed 11 part-time and temporary employees on externally funded projects done under contract. Used the General Fund appropriation as a partial match for these projects.

### OIL AND GAS

- Issued one permit to drill for oil.
- Inspected 28 oil and gas wells to ensure that there were no safety and environmental problems.
- Released five oil and gas reports
- Held three regular meetings of the Arizona Oil and Gas Conservation Commission.

# MISSION, DESCRIPTION AND GOALS

## **MISSION**

The mission of the Arizona Geological Survey (AZGS) is to provide information to enhance public understanding of geologic processes, materials, and resources, and to assist citizens, businesses, governmental agencies, and legislators in prudently managing Arizona's land, water, mineral, and energy resources.

## **DESCRIPTION**

AZGS staff prepare and provide geologic maps, reports, and related information to interested or concerned citizens, governmental agencies, businesses, legislators and committee staff, teachers, and students. Geologists map and describe bedrock and surficial materials; and metallic, nonmetallic, and energy resources. They also identify geologic processes that may be hazardous to the public or limiting to land and resource management (e.g. earthquakes, land subsidence and earth fissures, flooding). Staff conduct investigations, write reports and prepare maps that summarize the results, and make this and related information available to the public. In addition, they compile and maintain data files and computer databases; maintain a library that features the geology of Arizona; and preserve a repository of selected rock cuttings and cores.

The Arizona Oil and Gas Conservation Commission, which regulates the drilling for and production of oil, gas, helium, and geothermal resources, is attached administratively to the AZGS. The AZGS provides staff support. Staff issue permits to drill, monitor drilling, inspect completed wells, compile drilling and production data, and maintain files of well cuttings and related information about subsurface geology. In addition, they prepare maps that show the distribution and thickness of bedrock formations in the subsurface, describe the character of those formations, disseminate information, and encourage the responsible exploration for and development of oil, natural gas, and related resources.

## **GOALS**

### **INFORMATION**

Provide objective information about Arizona's geologic setting to citizens, businesses, governmental agencies, and legislators in a timely, courteous manner.

### **GEOLOGIC MAPPING**

Map and describe the bedrock and surficial geology of Arizona with emphasis on the Phoenix-Tucson urban corridor, which contains 80 percent of the State's population and is experiencing rapid development.

### **INVESTIGATIONS**

Conduct geologic investigations and provide information to local, state, and federal governmental agencies that have responsibility for prudently managing Arizona's land, water, mineral, and energy resources.

### **OIL AND GAS**

Administer the rules, regulations, and policies established by the Arizona Oil and Gas Conservation Commission to protect public health and safety relative to the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources.

# INFORMATION



Provide unbiased information about geologic processes, materials, and resources in a timely, courteous manner.

## ACTIVITIES

### **Inquiries about Arizona Geology**

Staff responded to thousands of requests for information about bedrock and surficial geology, mineral and energy resources, known and potential geologic hazards, and geologic conditions that may impact land and resource management in Arizona. Many purchased maps and reports, used the geology library and databases, and discussed Arizona's geology with staff geologists. In response to requests, Arizona Geological Survey (AZGS) geologists gave talks, led field trips, served on committees, and provided other assistance to the public and profession.

### **AZGS Information Center**

Revenue from the sale of AZGS reports and maps was \$41,754, which was deposited in the Arizona Geological Survey Fund to be used to print and distribute other AZGS publications. The AZGS has released more than 500 different maps and reports that are available for purchase. In addition, the AZGS has a formal agreement to distribute all Arizona Geological Society publications. Selected maps and reports published by other professional societies and groups are also available for purchase.

### **Earth Science Information Center (ESIC)**

The AZGS has a formal cooperative agreement to sell maps and reports published by the U.S. Geological Survey (USGS). All 1,951 of the standard 7.5-minute topographic maps that cover parts of Arizona are available for purchase. AZGS staff provide access to USGS databases and distribute general-interest publications and brochures prepared by the USGS. Sale of USGS topographic maps and other products brought in \$29,365. This revenue is used to purchase other publications for resale and for ESIC operating expenses.

### **Geology Library**

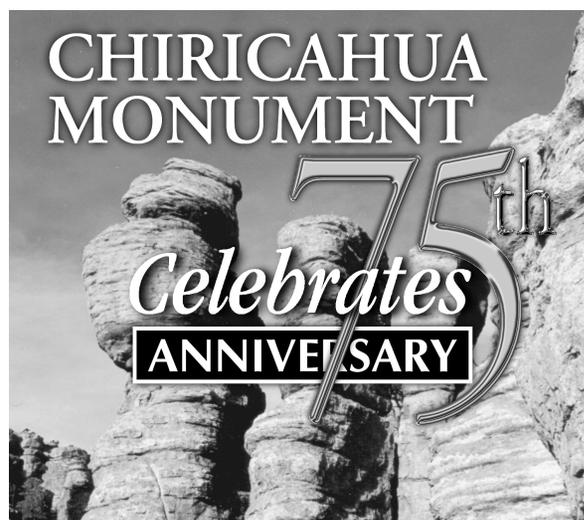
The AZGS Geology Library contains publications of the AZGS, Arizona Oil and Gas Conservation Commission, Arizona Geological Society, U.S. Geological Survey, and selected publications of other governmental agencies. The library also contains theses and dissertations on Arizona geology, selected technical journal and bulletin series, textbooks, environmental impact statements and reviews, and unpublished maps and reports on the geology, water, energy, and mineral resources of Arizona. The library, supervised by T. G. McGarvin, is open to the public. The public may also view AZGS publications at the State Library in Phoenix and at a network of selected depository libraries throughout the State.

### **Information Technology**

R. A. Trapp, database manager, completed a comprehensive review of the stratigraphic-names database, AZSTRAT, which now includes nearly 2,900 stratigraphic terms that have been used in reference to names of rock units in Arizona. AZSTRAT is internally consistent and tightly integrated with AZGEOBIB, the bibliographic database on Arizona geology that now contains nearly 12,400 citations. Plans have been made to release updated versions of these two databases on CD-ROM in FY 2000.

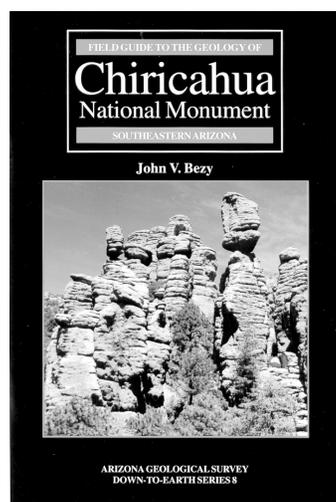
Using these databases C. R. Ferguson and R. A. Trapp have completed a thorough review of the mid-Tertiary stratigraphic nomenclature of the Superstition Mountains, an area recently mapped by AZGS geologists. A revised stratigraphic framework for the area is in preparation.

During the past year the AZGS acquired the capability to publish its databases on CD-ROM. The capacity of the CD-ROM is ideal for distribution of the various databases that AZGS maintains. One CD-ROM should be capable of holding all the publications of AZGS for one year.



*The Chiricahua National Monument celebrated its 75th anniversary in 1999. Pinnacles that formed by weathering along joints in volcanic rock are shown above.*

*"Field Guide to the Geology of Chiricahua National Monument", an AZGS publication, has sold more than 800 copies since it was published in September of 1998.*



### Rock Cuttings and Core Repository

The AZGS is charged by statute to maintain a central repository for rock cuttings and cores and associated supplemental data. Companies that drill for oil, gas, helium, or geothermal resources are required by Arizona Oil and Gas Conservation statutes to submit rock cuttings and cores saved during drilling, together with well logs, results of tests conducted, and other pertinent information, to the AZGS. Because of space limitations, only representative samples of cores are usually saved. Rock cuttings from 23 water wells were added to the repository during the fiscal year. Cuttings from more than 4,000 oil and water wells, and cores from many mineral tests are in the repository, which may be used by the public.

### Web Site

The AZGS web site ([www.azgs.state.az.us](http://www.azgs.state.az.us)) includes information about the history of the agency, staff members, the quarterly newsletter (*Arizona Geology*), and publications for sale by the AZGS. The State geologic map, geologic hazards, and links to other geology-related agencies and groups are also provided. A separate page features the Oil and Gas Conservation Commission, which is attached administratively to the AZGS.

R. C. Harris constructed a radon web page ([www.azgs.state.az.us/radondte.htm](http://www.azgs.state.az.us/radondte.htm)) which contains Down-to-Earth 2, "Radon Gas: A Geologic Hazard in Arizona," written by J. E. Spencer and published by the AZGS. This project was funded by a State Indoor Radon Grant from the U.S. Environmental Protection Agency to the Arizona Radiation Regulatory Agency.

### Arizona Geology

Three 4-page issues and one 6-page issue of *Arizona Geology* were published and distributed. *Arizona Geology* is published quarterly to describe events related to geology, publicize new geologic maps and reports, and highlight other activities or events that pertain to geology in Arizona. Practicing geologists or others who have a special interest in Arizona geology are the intended audience for *Arizona Geology*.

### Down-to-Earth Reports

The AZGS released one non-technical report in the Down-to-Earth (DTE) Series. DTE 8, by John V. Bezy of the National Park Service, tells nongeologists how features in the Chiricahua National Monument were formed. The book includes photographs and descriptions of 18 geologic features that can be observed from the Sugarloaf Mountain and Echo Canyon trails within the monument.

### Nontechnical Talks and Workshops

AZGS staff made numerous nontechnical presentations at workshops, conferences, and meetings of professional societies, service clubs, and other groups. Some of these presentations were made through the AZGS Speakers Bureau.

### REPORTS RELEASED

Bezy, J.V., 1998, **Field Guide to the geology of Chiricahua National Monument, southeastern Arizona**: Arizona Geological Survey Down-to-Earth 8, 32 p.

Fellows, L.D., 1998, **Annual report of the Arizona Geological Survey, 1998**: Arizona Geological Survey Open-File Report 98-28, 20 p.

Trapp, R.A., Reynolds, S.J., and Kneale, S.M., 1998, **Physiographic areas in Arizona used by the Arizona Geological Survey**: Arizona Geological Survey Digital Information Series 10, version 1.0, 3 p., 1 HD disk.



*Governor Jane Dee Hull met with staff of the Arizona Geological Survey (AZGS) and members of the Arizona Geological Society (Society), to accept a copy of the new Geologic Highway Map of Arizona. Left to right: Mark A. Miller (Society), Corolla K. Hoag (Society), Governor Hull, Robert J. Kamilli (Society), Jon E. Spencer (AZGS), Stephen M. Richard (AZGS), and Peter F. Corrao (AZGS).*

## GEOLOGIC MAPPING

# Goal 2

Characterize and prepare detailed geologic maps of the rock units present at the surface and in the subsurface in Arizona. Give special emphasis to areas that are experiencing or will soon be experiencing urban growth and development.

## PROJECTS

**National Geologic Mapping Program.** The AZGS released geologic maps of the New River Mesa and Humboldt Mountain quadrangles north of Phoenix and the Boulder Mountain quadrangle, Tonto Basin quadrangle, and Theodore Roosevelt Dam area. Geologists also completed surficial geologic maps of the Maverick Mountain, Hedgpeth Hills, Biscuit Flat, Union Hills, and New River SE 7.5-minute quadrangles and six quadrangles in the Casa Grande area. All maps were at 1:24,000 scale.

New mapping was begun in the central part of the Phoenix-Tucson urban corridor in the Ninetysix Hills, southern half of the Picacho Mountains, Picacho Peak, Samaniego Hills, and the Sawtooth Mountains. These maps, also at 1:24,000 scale, are within the Casa Grande 30' x 60' Quadrangle and will be ready for release during the next fiscal year.

Geologists also began new surficial geology mapping in six 7.5-minute quadrangles that cover the northern Tucson basin and the Tucson Mountains. These maps will be released during the next fiscal year.

Radiometric age dates are essential for determining sequence of events in map areas. Open-File Report 98-27 contains dates for volcanic rocks in the Superstition volcanic field. Samples were analyzed at the New Mexico Bureau of Mines and Mineral Resources. Open-File Report 99-5 contains radiometric age dates for granitic rocks in the Phoenix-Tucson corridor. These samples were analyzed at the University of Arizona.

**Geology of the Ray-Superior area.** The authors compiled previously published mapping and added new mapping in a number of key areas. On the basis of the new mapping they reinterpreted the nature of many faults and formation contacts. The new geologic map, done at a scale of 1:24,000, includes two east-west cross sections and reconstruction of the pre-extensional geometry of rocks along the cross-section lines. Detailed descriptions of rock units and mineralized sites visited are included. Results of the study were released as Open-File Report 98-13.

**San Bernardino Valley.** T.H. Biggs, R.S. Leighty, S.J. Skotnicki, and P.A. Pearthree continued a mapping project in the San Bernardino Valley in southeastern Arizona. The project is being done cooperatively 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. Preliminary geologic mapping of parts of twelve 7.5' quadrangles was completed and will be ready for release in the fall of 1999. T.H. Biggs summarized the preliminary results of this mapping at a conference in Douglas sponsored by the Malpai Borderlands Group and the U.S. Forest Service.

**River navigability.** AZGS geologists compiled data on the historical geomorphology and hydrology of several rivers for the Arizona State Land Department. This work was done as part of the assessment of river navigability conducted by the Arizona Navigable Stream Adjudication Committee. During the year the AZGS released Open-File Report 99-4 that summarizes the historical geomorphology and hydrology of the Bill Williams River in western Arizona. J.E. Klawon documented the geomorphology and hydrology of Big Sandy Creek, Burro Creek, and the Santa Maria River in western Arizona. A report that summarizes this information was submitted to Arizona State Land Department for review.

**Goldwater Air Force Range.** AZGS geologists completed surficial geologic mapping of portions of the Goldwater Air Force Range in southwestern Arizona. The purpose of these investigations was to develop data to support reauthorization of U.S. Air Force's use of the Goldwater Range. AZGS geologists P.A. Pearthree, J.E. Klawon, K.A. Demsey, and T.H. Biggs completed a number of geologic maps and reports between 1996 and mid-1999 that cover areas southeast and southwest of Gila Bend and east of Yuma. These reports, submitted to the Air Force for review and approval, will subsequently be released by the AZGS as open-file reports.

*Montezuma Castle is an ancient Sinagua cliff dwelling near Camp Verde that was used more than 600 years ago. The cliffs are composed of muddy limestone that was deposited at the bottom of a large lake 2-6 million years ago. Photo © Larry D. Fellows*



**Geology and mineral resources of the Tonto basin.** This study is being done to assess mineral resource potential for a land withdrawal proposed by the U.S. Bureau of Reclamation. The study is based on published literature and recent geologic mapping by AZGS geologists. When completed, it will include a 1:250,000-scale color geologic map of the Tonto basin.

**Digital geologic maps.** Four new digital geologic maps were released. Included are 1:100,000-scale compilations of the Mesa 30' x 60' quadrangle and two-thirds of the Theodore Roosevelt Lake and one-third of the Globe 30' x 60' quadrangles. These datasets are Arc/Info export files, with associated tables that describe the age and general lithology of the rock units. A digital version of the Fountain Hills-Mount McDowell area geologic map (1:24,000 scale) was also released.

## GEOLOGIC MAPS RELEASED

Ferguson, C.A., Gilbert, W.G., and Leighty, R.S., 1998, **Geologic map of the New River Mesa 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-12, 29 p., 3 sheets, scale 1:24,000.

Ferguson, C.A., Skotnicki, S.J., and Gilbert, W.G., **Geologic map of the Tonto Basin 7.5' Quadrangle, Gila and Maricopa Counties, Arizona:** 1998, Arizona Geological Survey Open-File Report 98-16, 15 p., 2 sheets, scale 1:24,000.

Gilbert, W.G., Ferguson, C.A., and Leighty, R.S., 1998, **Geologic map of the Humboldt Mountain 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-11, 17 p., 3 sheets, scale 1:24,000.

Holloway, S.D. and Leighty, R.S., 1998, **Geologic map of the Union Hills 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-20, 22 p., scale 1:24,000.

Kamilli, R.J. and Richard, S.M., 1998, **Geologic highway map of Arizona:** Arizona Geological Society and Arizona Geological Survey, Map 33, 1 sheet containing text and figures, scale 1:1,000,000.

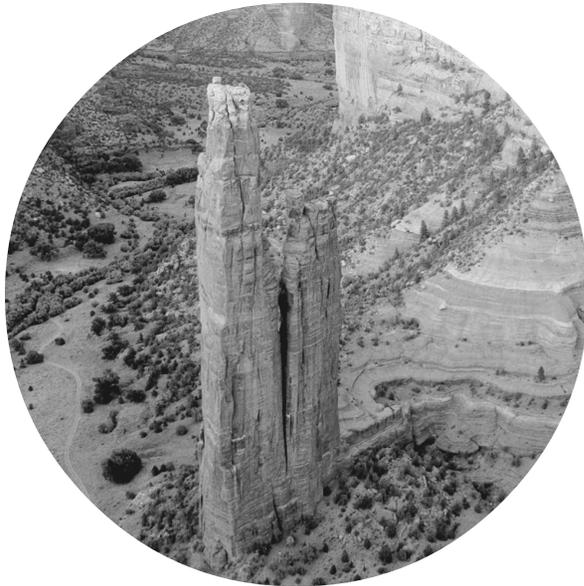
Klawon, J.E., Pearthree, P.A., Skotnicki, S.J., and Ferguson, C.A., 1998, **Geology and geologic hazards of the Casa Grande area, Pinal County, Arizona:** Arizona Geological Survey Open-File Report 98-23, 26 p., 6 sheets, scale 1:24,000.

Leighty, R.S. and Holloway, S.D., 1998, **Geologic map of the New River SE 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-21, 25 p., scale 1:24,000.

Leighty, R.S. and Huckleberry, Gary, 1998a, **Geologic map of the Biscuit Flat 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-19, 21p., scale 1:24,000.

\_\_\_\_\_, 1998b, **Geologic map of the Hedgpeth Hills 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-18, 20 p., scale 1:24,000.

Richard, S.M. and Spencer, J.E., 1998, **Compilation geologic map of the Ray-Superior area, central Arizona:** Arizona Geological Survey Open-File Report 98-13, 47 p., 3 sheets, scale 1:24,000.



*Spider Rock  
in Canyon de Chelly  
National Monument near  
Chinle is an erosional  
remnant of the De Chelly  
Sandstone. The sand was  
blown by the wind and  
deposited throughout this  
area about 260 million  
years ago. Photo ©  
Larry D. Fellows*

Skotnicki, S.J and Leighty, R.S., 1998a, **Geologic map of the Boulder Mountain 7.5' Quadrangle, Maricopa and Gila Counties, Arizona:** Arizona Geological Survey Open-File Report 98-15, 17 p., scale 1:24,000.

\_\_\_\_\_, 1998b, **Geologic map of the Maverick Mountain 7.5' Quadrangle, Maricopa County, Arizona:** Arizona Geological Survey Open-File Report 98-14, 18 p. scale 1:24,000.

Spencer, J.E. and Richard, S.M., 1999, **Geologic map and report for the Theodore Roosevelt Dam area, Gila and Maricopa Counties, Arizona:** Arizona Geological Survey Open-File Report 99-06, 28 p., scale 1:24,000.

## DIGITAL PRODUCTS RELEASED

Richard, S.M., *compiler*, and Kneale, S.M., *digitizer*, 1998, **Geologic map of portions of the Globe 30' x 60' Quadrangle, Arizona:** Arizona Geological Survey Digital Information Series 13, version 1.0, 13 p., 2 HD DOS disks.

Skotnicki, S.J. and Kneale, S.M., *digitizer*, 1998, **Geologic map of the Fountain Hills—Mount McDowell area, Maricopa County, Arizona:** Arizona Geological Survey Digital Information Series 14, version 1.0, 14 p., 1 HD DOS disk.

Spencer, J.E., Pearthree, P.A., and Richard, S.M., *compilers*; Kneale, S.M., *digitizer*, 1998, **Geologic map of portions of the Theodore Roosevelt Lake 30' x 60' Quadrangle, Arizona:** Arizona Geological Survey Digital Information Series 12, version 1.0, 12 p., 2 DOS HD disks.

Spencer, J.E., Richard, S.M., and Pearthree, P.A., *compilers*; Kneale, S.M., *digitizer*, 1998, **Geologic map of the Mesa 30' x 60' Quadrangle, Arizona:** Arizona Geological Survey Digital Information Series 11, version 1.0, 16 p., 3 DOS HD disks.

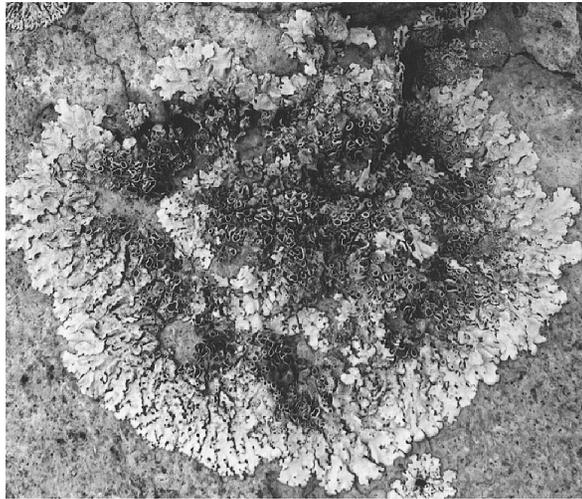
## REPORTS RELEASED

Gleason, J.D., Spencer, J.E., and Richard, S.M., 1999, **Geochemistry of mafic dikes and sills from the lower McCoy Mountains Formation, La Paz County, western Arizona:** Arizona Geological Survey Open-File Report 99-01, 24 p.

Isachsen, C.E., Gehrels, G.E., Riggs, N.R., Spencer, J.E., Ferguson, C.A., Skotnicki, S.J., and Richard, S.M., 1999, **U-Pb geochronologic data from zircons from eleven granitic rocks in central and western Arizona:** Arizona Geological Survey Open-File Report 99-05, 27 p.

McIntosh, W.C. and Ferguson, C.A., 1998, **Sanidine, single crystal, laser-fusion  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology database for the Superstition volcanic field, central Arizona:** Arizona Geological Survey Open-File Report 98-27, 74 p.

Richard, S.M., *compiler*, 1998, **Map showing the orientation of layering and faults in the San Carlos-Safford-Duncan Nonpoint-Source Management Zone, East-Central Arizona:** Arizona Geological Survey Open-File Report 98-08, 4 p., scale 1:250,000.



*Lichens cause rock to be weathered by both chemical and physical processes.*

\_\_\_\_\_, 1999, **Subsurface information from three wells in the Tonto Basin, Gila County, Arizona:** Arizona Geological Survey Open-File Report 99-07, 8 p.

Richard, S.M., McWilliams, M.O., and Gans, P.B., 1998, **<sup>40</sup>Ar/<sup>39</sup>Ar dates from the Harquahala and Little Harquahala Mountains, west-central Arizona. Part I:** Arizona Geological Survey Open-File Report 98-25, 25 p.

## EXTERNAL PUBLICATIONS

Spencer, J.E., 1999a, Discussion of The active southwest margin of the Colorado Plateau: Uplift of mantle origin (by T. Parsons, and J. McCarthy): Geological Society of America Bulletin, v. 111, p. 154-155.

Spencer, J.E., 1999b, Geologic continuous casting below continental and deep-sea detachment faults and at the striated extrusion of Sacsayhuamán, Peru: *Geology*, v. 27, p. 327-330.

Wernicke, Brian, and Spencer, J.E., 1999, Retrospective on “Low-angle (denudation) faults, hinterland of the Sevier orogenic belt, eastern Nevada and western Utah” by Richard Lee Armstrong, *in* Moores, E.M., Sloan, D.L., and Stout, D.L., eds, Classic Cordilleran concepts: A view from California: Boulder, Colorado, Geological Society of America Special Paper 338, p. 357-362.

## CONTRIBUTED MAPS AND REPORTS RELEASED

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

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

Dickinson, W.R., 1998, **Geologic relations of Martinez Ranch fault and Happy Valley Neogene basin, east flank of Rincon Mountains, Pima County, Arizona:** Arizona Geological Survey Contributed Map 98-B, 16 p., scale 1:24,000.

\_\_\_\_\_, 1999, **Geologic framework of the Catalina foothills, outskirts of Tucson (Pima County, Arizona):** Arizona Geological Survey Contributed Map 99-B, 31 p., scale 1:24,000.

Vazquez, J.A., 1999, **Map of the volcanic geology of the Wood Chop Mesa area, Hopi Buttes (Tsézhin Bii), Navajo Nation, Arizona:** Arizona Geological Survey Contributed Map 99-A, scale 1:12,000.

## OUTSIDE PUBLICATION

Biggs, T.H., Leighty, R.S., Skotnicki, S.J., and Pearthree, P.A., 1999, **Geology and geomorphology of the San Bernardino Valley, southeastern Arizona,** *in* Gottfried, G.J. and Curtin, C.G., eds., Toward integrated research, land management, and ecosystem protection in the Malpai Borderlands: Conference summary, p. 11-15.

## HAZARDS AND LIMITATIONS

### Goal 3

Investigate and document the geologic processes and materials that have potential to be hazardous to the public or to cause restrictions to land and resource management.

## PROJECTS

**Quaternary fault compilation.** P.A. Pearthree compiled information about faults in Arizona that are known to have been active in the past two million years. This compilation, released as OFR 98-24, includes a 1:750,000-scale map that shows about 100 Quaternary faults, together with descriptive information about them. The project was done in cooperation with the U.S. Geological Survey as part of their effort to compile information about Quaternary faults throughout the world. Development of this database depended heavily on previous compilations, most of which were done by AZGS geologists. Each fault-data sheet includes data sources, fault location, geologic setting, geomorphic expression, recency of fault movement, fault slip rate(s), and fault-zone length and orientation. These data will be incorporated into a map, in progress, that depicts earthquake hazards in Arizona.

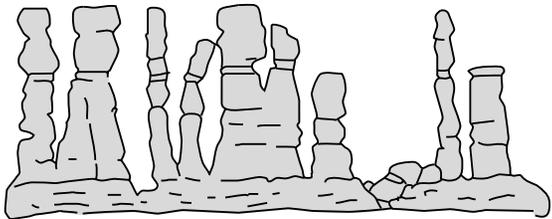
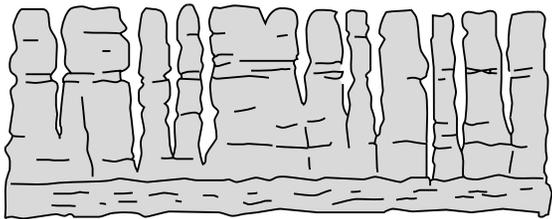
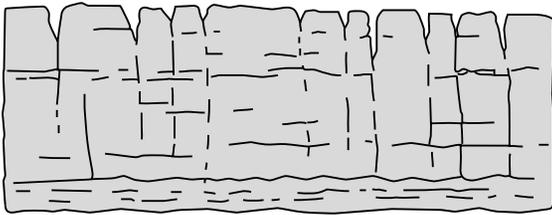
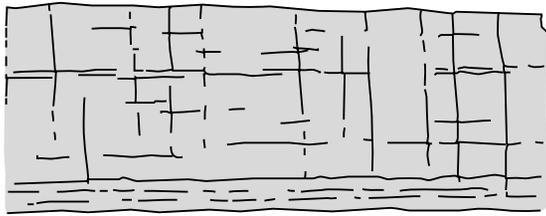
**Hurricane fault.** The AZGS and the Utah Geological Survey (UGS) cooperated in evaluating the seismic hazard associated with the Hurricane fault in southwestern Utah and northwestern Arizona. Results of these investigations were detailed in AZGS Open-File Report 99-8. The research, conducted by AZGS geologists H.D. Stenner and P.A. Pearthree and UGS geologists W.R. Lund and B.L. Everitt, was jointly funded by the two state surveys and the U.S. Geological Survey Earthquake Hazards Reduction Program. These studies show that numerous paleoearthquakes have occurred on the long, active Hurricane fault zone. The investigations are significantly improving our understanding of seismic hazard in this rapidly growing region at a time when this information can be incorporated into design standards and building practices. The Utah and Arizona surveys have received more funding from the Earthquake Hazards Reduction Program to continue investigations.

**Land subsidence and earth-fissure information.** The Center for Land-Subsidence and Earth-Fissure Information at the AZGS functions as a clearinghouse. An annual meeting is held with about a dozen governmental land- and resource-management agencies to discuss new information about subsidence and fissures. R.C. Harris developed pages on the AZGS web site describing geologic hazards in Arizona that include subsidence and earth fissures. The web pages are linked to those of other government agencies and online sources of information. Harris gave a talk about earth fissures at the Arizona Hydrological Society annual symposium in Tucson. New earth-fissure mapping was done in the Queen Creek area in the southeastern part of metropolitan Phoenix.

**Geologic hazards in the Casa Grande area.** J.E. Klawon and P.A. Pearthree mapped the surficial geology and described the potential geologic hazards of six 7.5' quadrangles in the Casa Grande area. Bedrock geologic mapping of the Sacaton Mountains that was done previously by C.A. Ferguson and S.J. Skotnicki was also included in the new maps, which were released as Open-File Report 98-23.

**Verde River floods.** AZGS geologists J.E. Klawon and P.A. Pearthree collaborated with P.K. House of the Nevada Bureau of Mines and Geology to study the historical and prehistoric record of large floods on 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. A summary of the results of these investigations will be released next fiscal year.

**Flood hazards along Cave Creek and Apache Wash.** H.D. Stenner and J.E. Klawon studied the geomorphology and soils of lower Cave Creek and Apache Wash as part of a floodplain-management study funded by the Flood Control District of Maricopa County. They helped document the physical characteristics of the channels and terraces of these washes in order to assess the potential for lateral erosion and downcutting along the washes. This information will be used to develop floodplain-management plans for these washes.



*Diagram that shows how pinnacles developed in the jointed Rhyolite Canyon Tuff.*

**Alluvial fan flooding hazards.** P.A. Pearthree and J.E. Klawon began investigating a recent large flood on the Tiger Wash distributary drainage system in westernmost Maricopa County. Defining the extent and character of alluvial fan flooding is important as urban areas continue to expand onto surrounding piedmonts. The Tiger Wash distributary system experienced a large flood in September 1997 as a result of a regional rainstorm associated with dissipating tropical storm Nora. The abundant, fresh evidence of flood inundation provided an exceptional opportunity to analyze this flood in detail and increase our understanding of the behavior of alluvial-fan floods. In addition, AZGS geologists mapped the surficial geology of the Tiger Wash system as it existed prior to the flood using aerial photographs from 1979. This will allow them to evaluate how well the distribution of young surficial deposits, as mapped from 1979 photos, correlates with areas that were inundated in 1999 and, therefore, whether young surficial deposits can be used to predict areas that might be subjected to flooding in the future. Pearthree and Klawon gave talks at the 1999 Arid Regions Floodplain Management Conference and they submitted papers for inclusion in the proceedings volume for the conference.

**Isotopes as tracers of salinity sources.** This pilot study, partially funded by 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.

**Radon.** This was the ninth and last year that the AZGS received funds under the U.S. Environmental Protection Agency's State Indoor Radon Grant program. Funding for development of an internet web page on radon was awarded to the Arizona Radiation Regulatory Agency and passed through to the AZGS. Web page construction was done by R.C. Harris, who also placed AZGS Down-to-Earth Series 2 (Radon Gas: A Geologic Hazard in Arizona) on the AZGS web site at [www.azgs.state.az.us/radonte.htm](http://www.azgs.state.az.us/radonte.htm).

**Bullhead City area.** This study, done in cooperation with the U.S. Geological Survey, was undertaken to determine the significance of geology, hydrogeology, and mining in controlling the chemistry of ground water in the area. The study area extended westward from the crest of the Black Mountains to the Colorado River and included Bullhead City. Results were released as Open-File Report 98-26.

## REPORTS RELEASED

Harris, R.C., 1998, **A compilation of the geology and hydrology of the Black Mountains-Bullhead City area, Arizona:** Arizona Geological Survey Open-File Report 98-26, 42 p.

\_\_\_\_\_, 1999, **Feasibility of using isotopes as tracers of the sources of dissolved solids in the upper Gila River, Arizona:** Arizona Geological Survey Open-File Report 99-03, 89 p., scale 1:250,000.

House, P.K., Wood, M.L., and Pearthree, P.A., 1999, **Hydrologic and geomorphic characteristics of the Bill Williams River, Arizona:** Arizona Geological Survey Open-File Report 99-04, 46 p., 2 sheets, scale 1:24,000.

Klawon, J.E., Pearthree, P.A., Skotnicki, S.J., and Ferguson, C.A., 1998, **Geology and geologic hazards of the Casa Grande area, Pinal County, Arizona:** Arizona Geological Survey Open-File Report 98-23, 26 p., 6 sheets, scale 1:24,000.

Pearthree, P.A., 1998, **Quaternary fault data and map for Arizona:** Arizona Geological Survey Open-File Report 98-24, 122 p., 1 HD DOS disk, scale 1:750,000.

Stenner, H.D., Lund, W.R., Pearthree, P.A., and Everitt, B.L., 1999, **Paleoseismologic investigations of the Hurricane fault in northwestern Arizona and southwestern Utah:** Arizona Geological Survey Open-File Report 99-08, 130 p.

### **CONTRIBUTED REPORT RELEASED**

Rösner, Ulrike, 1998, **Heavy metals in surface soils and streambed sediments in the Wallapai mining district, northwestern Arizona, a historic mining district in a semiarid region:** Arizona Geological Survey Contributed Report 98-A, 43 p.

*Pinnacles of Echo Canyon*

*Rhyolite in the Chiricabua*

*National Monument.*

*Photo © Larry D. Fellows*



## OIL AND GAS



Administer and enforce the rules, orders, and policies established by the Arizona Oil and Gas Conservation Commission to govern the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources in Arizona.

## ACTIVITIES

### Oil and Gas Conservation Commission (OGCC)

The OGCC was established by the Legislature in 1959 to regulate the drilling for and production of oil, gas, helium, and geothermal resources. It consists of 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, Paradise Valley; Zed Veale, Flagstaff; and Michael E. Anable, *ex-officio* (State Land Commissioner). Mr. Jones replaced Lisa Worthington, who resigned in May. The Arizona Geological Survey (AZGS) provides administrative and staff support. The Commission held three regular meetings.

### Production, refining, and storage

Oil production in calendar year (CY) 1998 totaled 78,109 barrels from 19 producing wells, down from 82,085 barrels from 25 wells in 1997. Gas production in CY1998 totaled 457 million cubic feet from eight producing gas wells, up from 453 million cubic feet from eight wells in 1997.

The two refineries in Arizona remained shut down in 1998. The refinery near Fredonia was shut down in January 1997 and the refinery near Coolidge was shut down in August 1993.

Liquified petroleum gas (LPG) transferred in CY1998 through storage wells near Luke Air Force Base and Adamana included 89 million gallons in receipts and 107 million gallons in deliveries, as compared to 106 million gallons received and 88 million gallons delivered in 1997. About 41 million gallons of LPG were in storage at yearend, down from the 57 million gallons the previous calendar year. Fourteen storage wells are in subsurface salt.

### Oil and gas leasing

Leasing decreased from 417,000 to 324,000 acres during the fiscal year. State Trust land under lease on June 30, 1999 totaled 213,000 acres, down from 305,000 acres in June 1998. Public land under lease on June 30, 1999 totaled 111,000 acres, down from 112,000 acres in June 1998. The State Land Department administers leasing on State Trust Land and the U.S. Bureau of Land Management administers leasing on public lands.

### Drilling

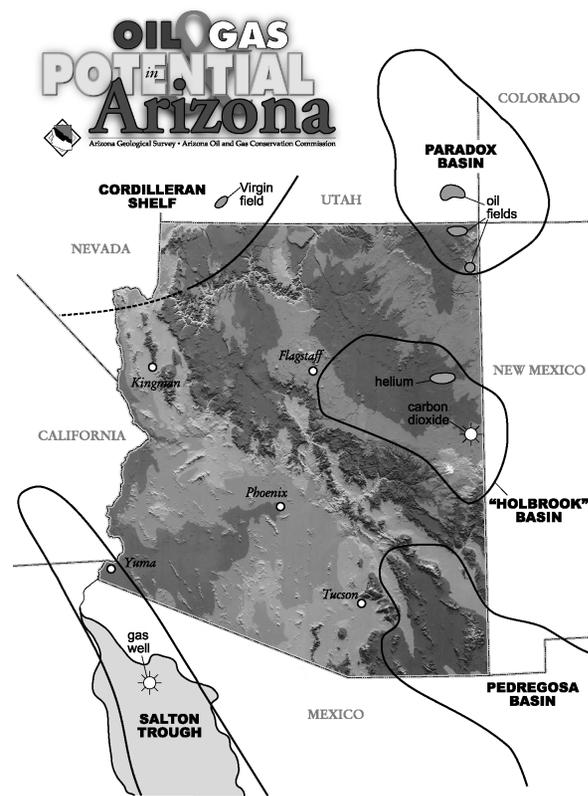
One permit to drill was issued to Thompson Engineering and Production for a development gas well at the Dry Mesa Field in northeastern Apache County. The well was drilled in December 1998 and completed as a gas producer in March 1999. Premco Western was drilling at a depth of about 450 feet on its Dutchman Federal well in northwestern Mohave County at fiscal year end. The Premco well was permitted in FY1998.

### Inspection and enforcement

Twenty-eight wells were inspected. Inspections included semiannual inspections of 14 hydrocarbon-storage wells near Luke Air Base and Adamana. The wells are inspected semiannually to ensure that all valves, safety alarms, and emergency shutdown systems are in good working condition.

### Subsurface data

The OGCC requires subsurface data, including rock samples, logs, and testing results, to be submitted for filing and archiving at the AZGS. These drilling data enhance the understanding of Arizona's geologic framework and subsurface mineral and energy resources. The AZGS maintains a series of maps that show



*Areas with the highest potential for future discoveries of oil and gas in Arizona*

the location of oil, gas, and geothermal wells and the types of subsurface data that are available for examination. Subsurface samples from 23 wells were added to the AZGS sample repository.

**Legislation**

HB 2332, passed in 1999, established a clear, concise definition for completed wells and extended the period of confidentiality for well records to one year. The confidential period is now the same for oil, gas, and geothermal wells. An operator may request that the OGCC extend the confidential period beyond one year. To do so, the operator must explain to the Commission how releasing the well information to the public will cause substantial harm.

**Depositional environment and petroleum potential of the Chuar Group**

The Arizona Geological Survey and Conoco Inc., in cooperation with Grand Canyon National Park, sampled, described, and geochemically analyzed Chuar Group strata (Late Proterozoic age) to determine petroleum and reservoir rock potential and depositional environment. The depositional environment ranged from shallow marine to estuarine. Two shale members have significant hydrocarbon source-rock potential. Sandstone and a few carbonate units have zones with sufficient porosity and permeability to constitute potential reservoir rock. A study collection of representative rock samples was established at the Arizona Geological Survey. Results of the study were released as Open-File Report 98-17.

**Carbon dioxide in the St. Johns and Springerville areas**

Ridgeway Arizona Oil Corporation announced a discovery of carbon dioxide (CO<sub>2</sub>) in the St. Johns and Springerville areas in southern Apache County in August 1994. By May 1997 they had drilled 15 wells. The AZGS released Open-File Report 99-02 in May 1999 to describe the geologic units present in the subsurface in that area and the CO<sub>2</sub> occurrences that are associated with these strata. The report includes a 1:100,000-scale structure contour map and cross sections. No additional drilling was done during FY1999.

**MAPS AND REPORTS RELEASED**

Rauzi, S.L., 1999a, **Annual Oil, Gas, and Helium Production in Arizona 1954 – 1998**: Arizona Geological Survey Oil & Gas Publication OG-2, 17 p.

\_\_\_\_\_, 1999b, **Carbon dioxide in the St. Johns-Springerville area, Apache County, Arizona**: Arizona Geological Survey Open-File Report 99-02, 22 p., 3 sheets. Scale 1:100,000.

\_\_\_\_\_, 1999c, **Dineh-Bi-Keyah Oil Field, Apache County, Arizona**: Arizona Geological Survey Oil & Gas Publication OG-15, scale 1:63,360 (OGCC Pool Series Map P-2).

\_\_\_\_\_, 1999d, **Oil and Natural Gas Occurrence in Arizona**: Arizona Geological Survey Oil & Gas Publication OG-35, chart (OGCC Chart C-1, published annually).

Wiley, B.H., Rauzi, S.L., Cook, D.A., Clifton, E.H., Kuo, Lung-Chuan, and Moser, J.A., 1998, **Geologic description, sampling, petroleum potential, and depositional environment of the Chuar Group, Grand Canyon, Arizona**: Arizona Geological Survey Open-File Report 98-17, 92 p., 2 sheets.

1998-1999  
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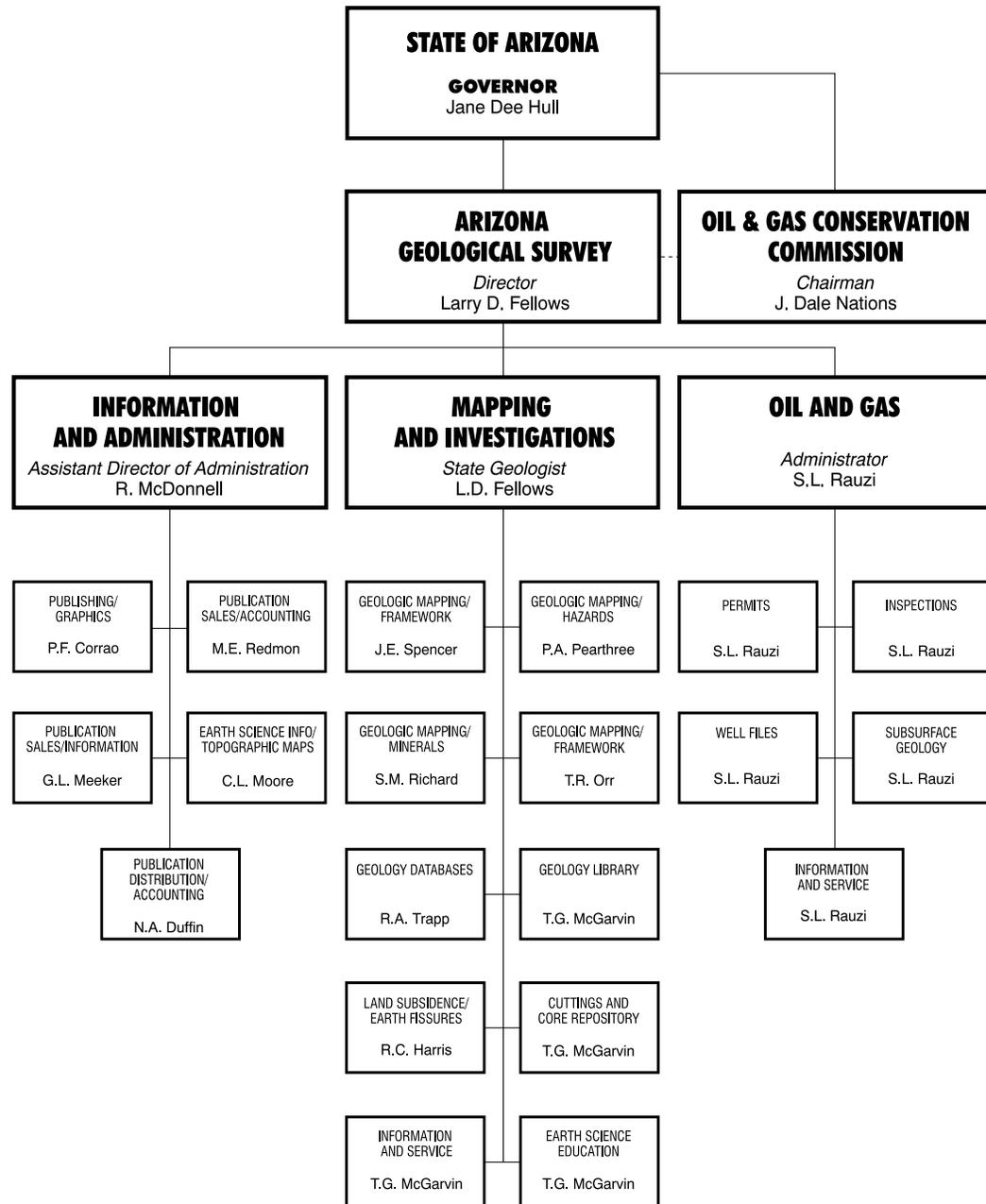
**MARY E. REDMON**  
Administrative Assistant III

**OTHERS EMPLOYED**

MARY E. PASBORG  
CHAD W. ROSEMA

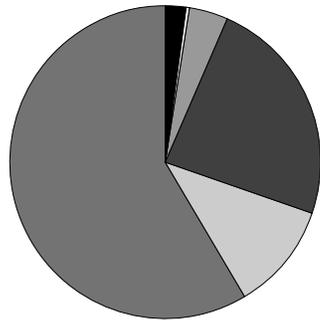
Geologists and support staff listed above were on the payroll June 30, 1999. The Arizona Geological Survey is authorized to employ 13.25 full-time-equivalent staff members with appropriated General Revenue funds. Employees whose names are designated with asterisks were paid partially or entirely from external funds.

# ORGANIZATION AND FUNCTIONS



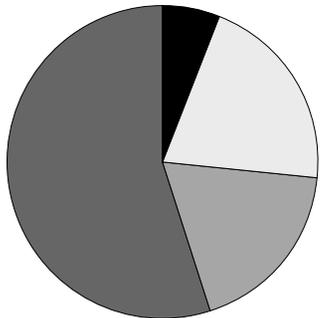
# BUDGET EXPENDITURES

**GENERAL FUND**



- Personal Services
- Benefits
- Operations
- In-State Travel
- Out-of-State Travel
- Capital Equipment

**PRINTING REVOLVING FUND**



- Arizona Geological Survey
- Arizona Geological Society
- U.S. Geological Survey
- Other Publications

## GENERAL FUND

Category	FY 1998 Expended	FY 1999 Expended	FY 2000 Budgeted
Personal Services	445,864	495,774	519,000
Benefits	86,048	93,554	95,600
Operations	186,940	195,179	194,000
In-State Travel	34,191	30,650	37,800
Out-of-State Travel	3,193	2,504	2,000
Capital Equipment	22,698	11,847	13,600
TOTAL	778,934	829,508	862,000

## PRINTING REVOLVING FUND

Publications	Operations
Arizona Geological Survey	22,929
Arizona Geological Society	7,681
U.S. Geological Survey	8,611
Other Publications	2,488
TOTAL	41,709

**CONTRACTED PROJECTS**

<b>Project (Fund Source)</b>	<b>Principal Investigator</b>	<b>Personal Services</b>	<b>Benefits</b>	<b>Operations</b>	<b>In-State Travel</b>	<b>TOTAL</b>
Uranium Levels in Rocks (U.S. Environmental Protection Agency)	Spencer	3,992	798	0	0	4,790
Earth Science Information Center (U.S. Geological Survey)	McDonnell	2,775	505	0	69	3,349
Geologic Mapping Phoenix Quadrangle (U.S. Geological Survey)	Spencer	97,672	19,116	13,290	3,013	133,091
Paleoseismicity and Seismic Hazard (U.S. Geological Survey)	Pearthree	692	69	20,281	0	21,042
San Bernardino (U.S. Forest Service)	Pearthree	29,678	4,759	317	2,259	37,013
Black Mountains (U.S. Geological Survey)	Fellows	6,513	1,215	861	0	8,589
Printing and Distribution (Arizona Geological Society)	McDonnell	143	26	2,729	0	2,898
Ft. Huachuca (U.S. Army)	Pearthree	2,219	300	15	103	2,637
New Verde River (Desert Research Institute)	Pearthree	1,144	149	375	0	1,668
San Pedro Navigability (JEF, Inc.)	Pearthree	1,143	113	0	0	1,256
Safford Isotope (Department of Water Resources)	Richard	4,252	908	13,321	82	18,563
Various Navigable Rivers (Department of Water Resources)	Pearthree	11,567	1,862	270	578	14,277
Cienega Basin (Department of Water Resources)	Richard	3,839	693	0	0	4,532
Cave Creek (JEF, Inc.)	Pearthree	4,754	492	38	360	5,644
Morenci-Clifton (Phelps Dodge, Inc.)	Ferguson	5,731	980	9,197	0	15,908
Earthquake Hazards (U.S. Geological Survey)	Pearthree	3,372	405	189	90	4,056
Tritium (Department of Water Resources)	Spencer	9,860	1,792	1,133	469	13,254
Tiger Wash (JEF, Inc.)	Pearthree	8,625	1,313	10	1,488	11,436
Gila Irrigation District (Department of Water Resources)	Harris	353	69	1,904	0	2,326
<b>TOTAL</b>		<b>198,324</b>	<b>35,564</b>	<b>63,930</b>	<b>8,511</b>	<b>306,329</b>





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