

ANNUAL REPORT

OF THE

ARIZONA GEOLOGICAL SURVEY

FY 2002



Earth fissures such as this one near Queen Creek develop in areas where groundwater was pumped much faster than natural recharge could take place. Fissures are commonly used as illegal dump sites. Earth fissures and other geologic hazards are described in *A Home Buyer's Guide to Geologic Hazards in Arizona*, which was published during Fiscal Year 2002.

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Jane Dee Hull
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Larry D. Fellows
Director and State Geologist

August 22, 2002

The Honorable Jane Dee Hull
Governor
1700 W. Washington
Phoenix, AZ 85007

Dear Governor Hull:

I'm pleased to submit the Annual Report of the Arizona Geological Survey for FY 2002. Activities and accomplishments of the Arizona Geological Survey (AZGS) parallel the major themes on which you have focused your administration, as summarized below.

Quality of life. The Phoenix-Tucson "corridor," as well as many other parts of Arizona, are experiencing rapid population growth and development. It is important to know, at an early stage in the planning process, what geologic materials, hazards, and limitations are present and how they may impact prudent development.

During the year AZGS geologists prepared detailed geologic maps of seven quadrangles within the Phoenix-Tucson corridor. In addition, the AZGS released a report, *A Home Buyer's Guide to Geologic Hazards in Arizona*, in which the authors summarized geologic factors that potential buyers should consider. The book was written specifically for persons who have had no formal education in geology.

Economic prosperity. The AZGS published a report, *Arizona Has Salt!*, in which seven known and 18 potential salt deposits are described. Caverns dissolved in salt provide excellent storage space for natural gas. The purpose of the book is to inform the public about the location and character of known and potential salt deposits and encourage drilling to develop this resource.

Education. Many Arizonans have a strong curiosity about their geologic surroundings, but have had no formal education in geology. To better inform these people, AZGS staff prepare reports and maps in the "Down-to-Earth" publication series. During the fiscal year the agency released a report on the geology of the western Santa Catalina Mountains and Catalina State Park. This report was done in cooperation with Arizona State Parks and the National Park Service. Citizens who understand how geologic processes have shaped our state and national parks will also understand that similar processes were active in shaping their own communities.

Good government. The AZGS is attempting to inform more Arizonans about the services and products available from the agency, while maintaining the quality of service provided. In FY 2002 publication sales increased by two percent, even though the economy was in decline. Staff filled 94 percent of all mail orders for geologic publications and returned them the same day they were received in the mail.

The AZGS shared resources with other governmental agencies on nine geologic projects of mutual interest.

If you or your staff have any questions about the geologic materials or processes in Arizona, please contact the AZGS. It has been a pleasure to serve Arizonans as part of your administration.

Respectfully submitted,

Larry D. Fellows
Director and State Geologist

EXECUTIVE SUMMARY

Arizona Geological Survey (AZGS) employees informed and assisted the public in the following ways during Fiscal Year 2002:

- Answered thousands of routine requests for geologic information or assistance
- Provided special assistance requested by 38 governmental agencies, professional societies, university departments, and other groups by giving talks, presenting workshops, leading fieldtrips, reviewing manuscripts, advising students, serving on committees, and doing related activities
- Participated in cooperative projects, some under contract, with State and Federal agencies and other groups, including the Arizona Department of Water Resources, Arizona State Parks, Flood Control District of Maricopa County, National Park Service, U.S. Army, U.S. Army Corps of Engineers, U.S. Bureau of Land Management, U.S. Forest Service, and U.S. Geological Survey. These projects were done at the request of the other agencies or groups. An in-kind matching contribution of 25-50 percent was required from the AZGS for most of the projects.
- Sold more than 9,500 geologic reports and maps (Ninety-four percent of mail orders were filled and returned the same day they were received).
- Released 27 new reports and maps on Arizona geology, including

Arizona Has Salt! (Circular 30),

Guide to the Geology of Catalina State Park and the Western Santa Catalina Mountains
(Down-to-Earth 12),

A Home Buyer's Guide to Geologic Hazards in Arizona
(Down-to-Earth 13),

Eight geologic-quadrangle maps, including seven in the Phoenix-Tucson corridor, all available in digital format or as hard copies,

Eight applied geology studies, released as open-file reports, on topics such as earth fissures, flooding, gas storage, mineral potential, solution features, and young faults and earthquakes, and

Five reports and maps contributed by other geologists.

- Released eight articles on Arizona geology in professional journals or other external publications
- Published four 6-page issues of *Arizona Geology*, the quarterly newsletter

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MISSION AND DESCRIPTION

MISSION

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To inform and advise the public about the geologic character of Arizona in order to improve understanding and support prudent development of the State's land, water, mineral, and energy resources.

DESCRIPTION

Informing the public about Arizona's geologic character involves geologic mapping, field investigations, and office activities. In addition, the AZGS provides administrative and staff support for the Arizona Oil and Gas Conservation Commission (OGCC), which is attached to the AZGS. The OGCC regulates the drilling for and production of oil, gas, geothermal, helium, and carbon dioxide to ensure sound engineering, environmental, and conservation practices are followed. To carry out the AZGS mission, staff members conduct the following activities:

- Public Information.** Inform the public by answering inquiries, preparing and selling maps and reports, maintaining a library and databases, maintaining a website, giving talks, and leading fieldtrips.
- Hazards and Limitations.** Investigate geologic hazards and limitations such as earthquakes, land subsidence, flooding, and rock solution that may affect the health and welfare of the public or impact land and resource management.
- Energy and Mineral Resources.** Describe the origin, distribution, and character of metallic, non-metallic, and energy resources and identify areas that have potential for future discoveries.
- Geologic Mapping.** Map and describe the origin and character of rock units and their weathering products.
- Oil and Gas Conservation Commission.** Assist in carrying out the rules, orders, and policies established by the Arizona Oil and Gas Conservation Commission.

Geologic data users include interested citizens and citizen groups, elected officials and staff, governmental land-and resource-management agencies, environmental and engineering geology companies, hydrologists, energy-and mineral-exploration companies, consultants, attorneys, realtors, insurance companies, teachers, students, libraries, book dealers, and others.

GOALS AND OBJECTIVES

6 Each year state agencies identify goals and prepare a strategic plan to attain the goals. The strategic plan also includes identification of specific objectives and performance measures. For FY 2002, the AZGS identified the four goals listed below. More detailed information about these and other related activities is provided in this report.

GOAL 1. OIL AND GAS CONSERVATION COMMISSION

To improve effectiveness in administering the rules, orders, and policies established by the Arizona Oil and Gas Conservation Commission.

- Objective 1. Respond to requests for drilling permits within 5 working days.
Result: Issued 5 permits to drill with an average 5-day turn-around time.
- Objective 2. Inspect gas-storage wells twice during year.
Result: Conducted safety inspections of 14 wells in November and April.
- Objective 3. Microfilm oil and gas records.
Result: Microfilming was completed May 31, 2002.

GOAL 2. GEOLOGIC INVESTIGATIONS AND MAPPING

To increase knowledge of geologic materials, processes, and resources in areas with potential for population growth and resource development.

- Objective 1. Submit geologic map deliverables on time and within budget.
Result: Deliverables were submitted on time and within budget.
- Objective 2. Finish three applied studies (hazards; mineral/energy resources).
Result: Completed eight applied geology studies.
- Objective 3. Improve quality of geologic maps and reports released.
Result: Customers rated quality of products 4.7 (scale of 1-5, 5 best).
Same rating as in FY 2001.

GOAL 3. PUBLIC INFORMATION

To increase publication sales and maintain high quality of service.

- Objective 1. Increase sale of geologic maps and reports by five percent.
Result: Sold 150 more maps and reports (two percent increase).
- Objective 2. Maintain or improve quality of service provided.
Result: Customers rated satisfaction with service 4.9 (scale 1-5, 5 best), the same as for FY 2001.
- Objective 3. Release two nontechnical reports.
Result: Released two reports—one on Catalina State Park and one Home Buyer's Guide to Geologic Hazards in Arizona.

GOAL 4. DIGITAL INFORMATION

To improve access to digital geologic information.

- Objective 1. Update computer hardware and software according to IT Plan.
Result: Met objective.
- Objective 2. Produce and release spatial database products.
Result: Released two spatial data products.
- Objective 3. Produce digital geologic maps on CD-ROM.
Result: Released eight digital geologic maps.

SUMMARY OF ACTIVITIES

OIL AND GAS CONSERVATION COMMISSION

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The Arizona Oil and Gas Conservation Commission (OGCC) regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources. The Governor appoints five members of the commission. The sixth member, the State Land Commissioner, is ex officio. Commissioners are J. Dale Nations, Tucson, chairman; Robert L. Jones, Sun City West, vice chairman; Joseph J. Lane, Phoenix; Michele P. Negley, Phoenix; Robert L. Wagner, Yuma; and Michael E. Anable, State Land Commissioner. The OGCC met three times during fiscal year (FY) 2002.

The AZGS provides administrative and staff support for the OGCC, including issuing permits to drill, monitoring drilling, inspecting completed wells, compiling drilling and production data, and maintaining well files. Steven L. Rauzi is the Oil and Gas Administrator.

Production and storage. Oil production in 2001 totaled 60,297 barrels from 23 producing wells, up from 57,483 barrels from 21 wells in 2000. Gas production in 2001 totaled 307 million cubic feet from eight producing gas wells, down from 368 million cubic feet from nine wells in 2000.

Liquefied petroleum gas (LPG) transferred in 2001 through storage wells near Luke Air Force Base and Adamana included 127 million gallons in receipts and 107 million gallons in deliveries. In 2000, 108 million gallons were received and 97 million gallons were delivered. About 60 million gallons of LPG were in storage at year end, up from the 38 million gallons the previous year. Fourteen storage wells constructed in subsurface salt are currently in use.

Both of Arizona's refineries remained closed. The refineries, near Fredonia and Coolidge, have been shut down since January 1997 and August 1993, respectively. The refinery near Fredonia is now used for storage of asphalt products.

Leasing. In 2001, 381,000 acres were under lease for oil and gas exploration, up from 344,000 acres in 2000. State Trust land under lease in December 2001 totaled 274,500 acres, up from 250,000 acres in December 2000. Public land (federal) under lease in December 2001 totaled 106,500 acres, up from 94,000 acres in December 2000.

The State Land Department administers leasing on State Trust Land. The U.S. Bureau of Land Management administers leasing on federal lands.

Drilling. Five permits were issued to drill or re-enter in FY 2002. The average length of time to issue a permit was five working days. One hole was drilled.

Recent interest in building new gas-fired power plants has led three companies to investigate the feasibility of storing natural gas in large underground salt deposits. Copper Eagle Gas Storage, LLC is evaluating the suitability of storing natural gas in the Luke salt deposit. The company drilled the second of two stratigraphic holes to evaluate characteristics of the salt for storage and the underlying sedimentary units for brine disposal. Analysis of core samples of the salt indicated that the character of the salt is similar to that of other salt formations in the country where natural gas is stored safely. Copper Eagle plans to drill two additional stratigraphic holes in FY 2003.

Desert Crossing Gas Storage and Transportation System, LLC and Aquila Inc. have initiated studies of the feasibility of storing natural gas in the Red Lake salt deposit in the Hualapai Valley north of Kingman. Aquila was issued a permit for a stratigraphic test in FY 2002 but had not started drilling before the end of the fiscal year.

Inspection and enforcement. Staff made semiannual inspections of the 14 hydrocarbon-storage wells near Luke Air Base and Adamana, and witnessed the cementing of surface casing in the stratigraphic hole near Luke Air Force Base. Inspections are conducted to ensure that all wellhead valves, safety alarms, and emergency shutdown systems are in good working condition and that cement is circulated back to the surface when surface casing is set in a newly drilled well.

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. The files include information from more than 1,100 oil tests dating back to 1905. These drilling data add to the understanding of the geologic framework and subsurface mineral and energy resources. The AZGS maintains 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 the stratigraphic hole near Luke Air Force Base were added to the sample repository.

Summary of Activities—*continued*

8 **Legislation and rules.** The OGCC completed a five-year review of its rules and identified two rules that need to be amended. Revision of the two rules will be completed during FY 2003.

Carbon dioxide update. Ridgeway Arizona Oil Corporation announced the discovery of carbon dioxide in the St. Johns and Springerville areas in southern Apache County in August 1994. The company subsequently drilled 15 wells before the end of May 1997. Two of the wells were completed as gas wells; seven were temporarily abandoned; and six were plugged and abandoned. No additional drilling has been done since May 1997. No requests for permits to drill were received during the year.

In August 1999, Ridgeway representatives announced that initial development to supply carbon dioxide for enhanced oil recovery would require two to three years, during which time about 200 wells would be drilled. The company estimated that as many as 1,195 wells would eventually be drilled over the 25-40 year life of the project. In May 2000, Ridgeway announced plans to produce liquid carbon dioxide from three wells, two in Arizona and one in New Mexico during that year. By the end of June 2002, 14 miles of pipe connected the three wells to the carbon dioxide processing plant, which was constructed at the Tucson Electric Power facility between Springerville and St. Johns. Carbon dioxide production did not begin during FY 2002.

Oil and gas records microfilmed. A contract was awarded to LASON, in Tucson, to microfilm the oil and gas well files for disaster recovery. Microfilming was completed May 31. The original microfilm is stored at the State Records Center in Phoenix. A copy is also on file at the Arizona Geological Survey.

HAZARDS AND LIMITATIONS

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A Home Buyer's Guide to Geologic Hazards. This full-color book, Down-to-Earth 13, summarizes geologic hazards encountered in Arizona, including flooding, earthquakes, unstable shrinking and swelling soils, debris flows, landslides, rockfalls, subsidence and fissures, radon gas, karst (sinkholes), and abandoned mines. Raymond C. Harris and Philip A. Pearthree wrote the book.

Colorado Plateau karst study. Raymond C. Harris studied sinkholes and related features on the southern Colorado Plateau between Snowflake and Winslow. These features are the result of thick layers of salt having dissolved at depth. Voids that form as the salt dissolves propagate to the surface, forming large sinkholes and deep fissures. These fissures and sinkholes may provide conduits for contaminants to the underlying aquifers. Harris' report was released as OFR 02-07.

Piedmont flood hazards. For the past decade the Arizona Geological Survey (AZGS) has cooperated with local floodplain management agencies to provide geologic mapping to help define flood-prone areas on desert piedmonts. Piedmonts are the gently sloping areas adjacent to mountains. Active alluvial fans, where floodwater spreads widely and new channels may form during floods, are the areas of primary concern. JE Fuller Hydrology & Geomorphology used surficial geologic mapping and inundation mapping from a 1997 flood on the Tiger Wash alluvial fan in westernmost Maricopa County to delineate flood hazard zones for the Flood Control District of Maricopa County (FCDMC). The flood hazard maps prepared are in review by the Federal Emergency Management Agency as prototype for procedures to delineate alluvial-fan flooding hazard in Maricopa County. The AZGS worked under contract with the FCDMC to help revise a manual for assessing piedmont flood hazards in Maricopa County. The project will be completed during FY 2003.

AZGS geologist Philip A. Pearthree, in cooperation with a University of Arizona geologist Larry Mayer, used repeat satellite images to detect the extent of flood inundation on piedmonts.

Center for Land Subsidence and Earth Fissure Information (CLASEFI). The AZGS maps, describes, and compiles information about subsiding areas and earth fissures caused by overpumping groundwater and provides information about them to the public. Meetings are held periodically with other agencies to discuss recent events related to subsidence and fissures. Raymond C. Harris oversees CLASEFI activities. A new earth fissure was reported to AZGS in the summer of 2001. Harris investigated and mapped the fissure in detail and prepared a report that described it (Open-File Report 01-10).

Giant desiccation cracks. Following years of drought, desiccation of the top tens of feet of clay-rich soil and sediments is causing giant cracks to form. The cracks are up to three feet wide and eight feet or more deep, and can form polygons 50-200 yards across. AZGS geologist Raymond C. Harris has been mapping the distribution of the giant cracks throughout Arizona. An open-file report detailing giant desiccation cracks near Wintersburg (OFR 01-10) was released as part of this continuing study.

Relationships among fires, soil geochemistry, and geomorphology in southeastern Arizona. The AZGS has cooperated with the U.S. Forest Service on several projects to provide geologic mapping and other data to support sustainable range management practices in southeastern Arizona. Thomas H. Biggs is currently engaged in a project to assess the effects of different burn frequencies and geomorphic settings on soil nutrients on Ft. Huachuca. This project, funded by the U.S. Forest Service, will be completed in FY 2003.

Oil well plugging. AZGS continued an irrigation-well monitoring program as part of a project that plugged an abandoned oil-exploration well in the Safford basin. Sampling of water wells near the oil well, plugged in December 2000, is intended to determine the effect on groundwater quality of saline artesian water formerly discharged from the oil well. Isotope geochemistry studies by AZGS suggest that this and other artesian wells in the Safford basin are an important source of salinity in the Gila River. Raymond C. Harris sampled the well water. Funding for this project was provided by the Water Protection Fund, administered by the Arizona Department of Water Resources.

10 ENERGY AND MINERAL RESOURCES

Arizona has salt. Recent interest in building gas-fired power plants in Arizona has focused attention on storing natural gas in subsurface salt deposits. Nine salt deposits are known and 18 areas, not yet explored, may have subsurface salt deposits. Circular 30, *Arizona Has Salt!*, includes information about these deposits such as the literature, drilling, and geophysical data that define the deposits. S.L. Rauzi, who wrote the book, documents the relationship between geophysical data and salt deposits, characterizes areas where additional deposits may be present, and shows the proximity of highways, railroads, and pipelines to known and potential salt deposits.

Metallic mineral districts map. S.M. Richard revised the boundaries of the metallic mineral districts, initially defined in 1983, to make them more consistent with the bedrock geology and locations of prospects. The new map was released as Digital Information 23. The database includes production data from Bulletin 194 (1983). The project was completed with partial funding from the U.S. Bureau of Land Management.

GEOLOGIC MAPPING

Phoenix-Tucson corridor. The National Cooperative Geologic Mapping Act, passed in 1992 and administered by the U.S. Geological Survey (USGS), includes a provision for funding state geological surveys to prepare original, detailed geologic maps to meet societal needs. Federal funding awarded to a state geological survey must be matched equally by State funds. State mapping advisory committees determine mapping priorities.

Geologic mapping in Arizona continues to be focused in the Phoenix-Tucson corridor, which includes 20 percent of the area of the State and 80 percent of the population. Mapping in the metropolitan Phoenix area has been completed. Maps in the Phoenix area are being digitized for release on CDs. In FY 2001 the AZGS mapping team worked south and southeast of the Tucson metropolitan area and completed the following 7.5' quadrangles: Mount Fagan, Narrows, Mescal, Galleta Flat, Amado, Tubac, and the southern parts of the Rincon Peak and Vail quadrangles. Deliverables were submitted to the USGS in September 2001 and were subsequently released as Digital Geologic Maps 08, 09, 10, 11, 12, and 13.

Mapping for the FY 2002 project began in October 2001 in the northern and northwestern fringes of Tucson and on the southwestern fringe of the Phoenix metropolitan area.

Since 1992 the AZGS has been awarded more than \$1,100,000 to do geologic mapping. The federal dollars plus the state matching funds bring the total value of the Arizona mapping program to more than \$2,200,000.

The AZGS mapping team included Jon E. Spencer, Philip A. Pearthree, Stephen M. Richard, Tim R. Orr, Stephen B. DeLong, Charles A. Ferguson, Wyatt G. Gilbert, Bradford J. Johnson, David J. Maher, Todd C. Shipman, Steven J. Skotnicki, and Ann M. Youberg.

Arizona Geological Survey (AZGS) Information Center. Staff, primarily Thomas G. McGarvin and Richard A. Trapp, answered thousands of requests for information about Arizona geology. Other staff, primarily Mary N. Andrade and Rachel A. Aragon, sold reports and maps published by the AZGS and the Arizona Geological Society and answered customer inquiries. They filled and mailed ninety-four percent of mail orders the same day the orders were received. The AZGS has a formal agreement to distribute Society publications. Revenue from publication sales is used to print and distribute AZGS publications.

Earth Science Information Center (ESIC). The ESIC is a joint venture between the AZGS and the U.S. Geological Survey (USGS) that is collocated at the AZGS. The ESIC was established to enhance customer service by providing information from the state and federal geological surveys from a single location. USGS topographic and geologic maps, reports, general-interest publications, brochures, and other items are available for purchase. Revenue from the sale of publications is used to purchase other USGS products for resale and for ESIC operating expenses. Mary N. Andrade and Thomas G. McGarvin are the ESIC representatives.

Geology Library and Databases. The AZGS maintains a non-circulating library that contains the following published and unpublished items: U.S. Geological Survey publications, maps, and open-file reports; theses and dissertations on Arizona geology; reports by Arizona state agencies; and publications of the geological surveys in adjacent states. The library, managed by Thomas G. McGarvin, is open to the public.

AZGEOBIB is a database that contains more than 12,500 bibliographic citations dealing with Arizona geology. The database is key-worded by subject and geographic area. AZGS staff provide lists of citations for specific requests. This is a popular service for those who are starting new projects and need to know what geologic maps and reports are available within the project area. Richard A. Trapp, IT Manager, maintains the databases.

Web Site. The AZGS web site (www.azgs.az.gov) 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. John A. Birmingham is the 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. Feature articles described crude oil supply and demand, salt deposits in Arizona, mineral potential in eastern Pima County, the Arizona Oil and Gas Conservation Commission, and Chiricahua National Monument and Fort Bowie National Historic Site.

Down-to-Earth Reports. The AZGS released two non-technical reports: *A Guide to the Geology of Catalina State Park and the Western Santa Catalina Mountains* (Down-to-Earth 12) and *A Home Buyer's Guide to Geologic Hazards in Arizona* (Down-to-Earth 13). Both are in full color and are illustrated with descriptions and photographs. The National Park Service, Arizona State Parks, and AZGS cooperated to produce Down-to-Earth 12.

Earth Science Education. Thomas G. McGarvin, the AZGS' primary contact with science and earth science teachers, assisted teacher groups in incorporating local geology in their courses. McGarvin conducted geology workshops for the Arizona Association for Environmental Education and at the annual meeting of the Arizona Science Teachers Association. He also led a field trip for the Tucson Unified School District, D.T. Smith Science Center.

Rock Cuttings and Core Repository. The AZGS maintains a repository containing cuttings from more than 4,000 oil and water wells, and core from a number of energy and mineral exploration drill holes. The cuttings, core samples, and well logs are available for examination and research by the public.

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Service to Community and Professional Groups. AZGS geologists participated in a variety of activities requested by community and professional groups, including serving as an officers or committee members, giving talks, leading fieldtrips, conducting workshops, serving on panels, reviewing applications or proposals for funding or awards, and reviewing manuscripts submitted for publication. Staff assisted the following groups:

American Association of Petroleum Geologists: led field trip
American Geophysical Union: reviewed manuscript
American Institute of Professional Geologists, hosted meeting
Amerind Foundation: led field trip
Arizona Association for Environmental Education: conducted workshop
Arizona Geological Society: served as an officer (4)
_____, Courtright Scholarship Committee: member (2)
Arizona Hydrological Society: led field trip, gave talks (3)
Arizona Science Teachers Association: conducted workshop
Arizona Society for Scientific Advancement: gave talk
Arizona State University, Department of Geology: served on dissertation committee
Association of American State Geologists: served on committees (3)
Computers in Geosciences: reviewed manuscript
Downtown Kiwanis Club, Tucson: gave talk
Economic Geology (Journal): reviewed manuscript
Geological Society of America: reviewed manuscripts (8)
Journal of Structural Geology: reviewed manuscript
National Science Foundation: reviewed funding proposals (2)
New Mexico State University Department of Geology, Las Cruces: gave talk
Pima County Flood Control District Advisory Committee: member and officer
Sabino Canyon docents: led field trip
Sabino Canyon Visitor Center: gave talk
Society of Economic Paleontologists and Mineralogists: reviewed manuscript
South American Journal of Earth Sciences: reviewed manuscript
Southwest Minerals Exploration Association: formatted publication for release
Stanford University: reviewed manuscript
Sunsites Gem and Mineral Society: gave talk
Tohono O'Odham Nation: led field trips (2)
Tucson Unified School District, D.T. Smith Science Center: led field trip
University of Arizona, Office of Arid Lands Studies: gave talk
_____, Center for Mineral Resources: reviewed manuscript
_____, Department of Geosciences: served on masters thesis (1) and dissertation committees (1)
_____, School of Renewable Natural Resources: gave talk
Utah Geological Association: contributed manuscript for a book
U.S. Army Corps of Engineers: served on technical advisory panel
U.S. Geological Survey: served on committees (3)
Verde River Day, Cottonwood: led field trips (2)
Wings Over Willcox, crane festival: gave talk, led field trips (2)

DIGITAL MAPS.

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AZGS geologists released the digital geologic maps of the Amado, Tubac, Galleta Flat West, Mescal, Mount Fagan, Narrows and southern Rincon Peak, and the southern Vail 7.5 minute quadrangles (Digital Geologic Maps 08-13). In addition, digital geologic maps of the Grasshopper Junction SE 7.5 minute quadrangle (Mohave County) and the White Tank Mountains were released as Digital Geologic Map 07 and 14, respectively.

NORTH AMERICAN GEOLOGIC MAP DATA MODEL.

The Association of American State Geologists (AASG), U.S. Geological Survey (USGS), and Geological Survey of Canada established a North American Data Model Steering Committee. Stephen M. Richard, Arizona Geological Survey geologist (AZGS), serves on the Data Model Design Team. The group compiled results of a community survey as the basis for a requirements document to guide development of the standard, and is in the process of developing a proposed standard. In addition, Richard serves on a work-group that is developing a standard list of science language terms for metamorphic rocks that will be considered by the Science Language Technical Team.

Richard is also a member of the National Geologic Map Database Technical Advisory Committee, which prepared a report that was submitted to the USGS and the AASG. Results of this effort are being used in AZGS geologic map databases.

GEOSCIENCE DATABASES.

Digital Information 23, a database of metallic mineral districts in Arizona, was released. This is a digital version of Map 18 (1983). Boundaries of districts were revised to be consistent with the bedrock geology and locations of prospects. The database includes production data from Bulletin 194. The project was done cooperatively with the U.S. Bureau of Land Management.

Richard and Orr are progressively building more capability into AZGS geologic map databases to provide access to more in-depth information.

PERSONNEL ⁽¹⁾

14 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

Jon E. Spencer, Senior Geologist
B.S., University of California, Santa Cruz;
Ph.D., Massachusetts Institute of Technology

Raymond C. Harris, Geologist II
B.S., Oregon State University; M.S., University of Arizona

Thomas G. McGarvin, Geologist II
B.A., California Lutheran College

Tim R. Orr, Geologist II
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., Massachusetts Institute of Technology;
M.S., University of Arizona;
Ph.D., University of California, Santa Barbara

Richard A. Trapp, Information Technology Manager
B.S., University of Nebraska, Omaha; M.S., University of Arizona

Support Staff

Mary E. Redmon, Administrative Assistant III

Mary N. Andrade, Administrative Assistant I

Rachel A. Aragon, Secretary

John A. Birmingham, Program and Project Specialist II
B.A., University of Arizona

Nancy A. Duffin,⁽²⁾ Accounting Technician II

Cathy L. Moore,⁽³⁾ Geologist I
B.S. University of Wisconsin; M.S., University of Arizona

Contracted Geologists and Student Assistants ⁽⁴⁾

Thomas H. Biggs, Ph.D.
Stephen B. DeLong, Ph.D. candidate
Charles A. Ferguson, Ph.D.
Noah E. Egge
Lisa N. Florkowski
Wyatt G. Gilbert, Ph.D.
Bradford J. Johnson, Ph.D.
David J. Maher, Ph.D. candidate
Christopher C. Morrison
Todd C. Shipman, Ph.D. candidate
Steven J. Skotnicki, Ph.D.
Ann M. Youberg, M.S.

(1) Geologists and support staff listed were employed June 30, 2002, except as otherwise noted below. The Arizona Geological Survey is authorized to employ 13.25 full-time-equivalent staff members from the General Fund appropriation.

(2) Deceased, October 3, 2001.

(3) Resigned, July 27, 2001.

(4) Employed on contracted projects funded by other agencies or groups during Fiscal Year 2002 to complete a specific product or service within an agreed-upon period of time.

GENERAL FUND EXPENDITURES

Category	FY 2001 Expended	FY 2002 Expended	FY 2003 Budgeted
Personal Services	532,040	510,104	500,800
Benefits	97,243	95,630	95,200
Operations	193,349	214,232	219,500
In-State Travel	43,193	40,221	46,400
Out-of-State Travel	2,081	913	1,000
Capital Equipment	18,732	19,910	7,900
TOTAL	886,638	881,010	870,800

PRINTING REVOLVING FUND

PUBLICATIONS	FY 2002 Expended
Arizona Geological Survey	39,375
Arizona Geological Society	2,140
U.S. Geological Survey	16,287
Other Publications	2,856
TOTAL	60,658

CONTRACTED PROJECTS

Project Fund Source	Principal Investigator	Personal Services	Benefits	Operations	In State Travel	Other Costs	TOTAL
Geologic Mapping USGS	Spencer	118,195	25,282	6,506	2,127	26,018	178,128
Fort Huachuca Fire on Soil USFS	Pearthree	9,612	948	4,978			15,538
Jackrabbit Wash Flood Control District of Maricopa County	Pearthree	6,001	1,185	203	302		7,691
Metallic Mineral District BLM	Richard	4,055	1,160	206		1,084	6,505
AGS Publications Arizona Geological Society	McDonnell			2,140			2,140
U.S. Army Corps of Engineers	Pearthree	1,573	198				1,771
Piedmont Flood Hazard Flood Control District of Maricopa County	Pearthree	1,155	145				1,300
Gila Oil Well Gila Valley NRCD	Harris	412	76				488
TOTAL		141,003	28,994	14,033	2,429	27,102	213,561

PUBLICATIONS RELEASED

18 PUBLICATIONS RELEASED ARIZONA GEOLOGICAL SURVEY FY 2002

Arizona Geology

Chiricahua Monument and Fort Bowie: Fellows, L.D., 2001, *Arizona Geology*, v. 31, n. 3, p. 1-2.
Mineral potential in eastern Pima County: Fellows, L.D., 2001, *Arizona Geology*, v. 31, n. 3, p. 2-3.
Crude oil supply and demand: long-term trends: Spencer, J.E., and Rauzi, S.L., 2001, *Arizona Geology*, v. 31, n. 4, p. 1-5.

Arizona has salt: Rauzi, S. L., 2002, *Arizona Geology*, v. 32, n. 1, p. 1-4.
Exploring Arizona: J.D. Nations, 2002, *Arizona Geology*, v. 32, n. 2, p. 1-4.

Circulars

C 30. *Arizona has salt*: Rauzi, S.L., 2002, Arizona Geological Survey Circular 30, 36 p.

Contributed Maps

CM 01-A. Geologic map of Tertiary volcanic rocks in the southern King Canyon and east central Chino Valley North 7.5' quadrangles, Yavapai County, Arizona: Cunningham, Heather, 2001, Arizona Geological Survey Contributed Map 01-A, 2 sheets, scale 1:12,000.

CM 02-A. Structural reconnaissance of lower-plate rocks along the Catalina-Rincon range front, Pima County, Arizona: Force, E.R., 2002, Arizona Geological Survey Contributed Map 02-A, 11 p., 2 sheets, scale 1:24,000 and 1:48,000.

Contributed Reports

CR 01-B. Mineral potential of eastern Pima County, Arizona: Southwest Minerals Exploration Association, 2001, Arizona Geological Survey Contributed Report 01-B, 24 p., 9 color sheets.

CR 01-C. Geologic field guide to the Copper Butte area, eastern Pima County, Arizona: Dickinson, W.R., 2001, Arizona Geological Survey Contributed Report 01-C, 16 p.

Digital Geologic Maps

DGM 07. Geologic map of the Grasshopper Junction SE 7.5' Quadrangle, Mohave County, Arizona: Varga, R.J., 2001, Arizona Geological Survey Digital Geologic Map 07, 1 CD-ROM, scale 1:24,000.

DGM 08. Compilation geologic map of the Galleta Flat West 7.5' Quadrangle, Pima and Cochise Counties, Arizona: Skotnicki, S.J., and Siddoway, C.H., 2001, Arizona Geological Survey Digital Geologic Map 08, 1 CD-ROM, 18 p., scale 1:24,000.

DGM 09. Geologic map of the Mescal 7.5' Quadrangle, Pima and Cochise Counties, Arizona: Skotnicki, S.J., 2001, Arizona Geological Survey Digital Geologic Map 09, 1 CD-ROM, 25 p., scale 1:24,000.

DGM 10. Spencer, J.E., Ferguson, C.A., Richard, S.M., Orr, T.R., Pearthree, P.A., Gilbert, W.G., and Krantz, R.W., 2001, Geologic map of The Narrows 7.5' Quadrangle and the southern part of the Rincon Peak 7.5' Quadrangle, eastern Pima County, Arizona: Arizona Geological Survey Digital Geologic Map 10, 1 CD-ROM, 33 p., scale 1:24,000.

DGM 11. Geologic map of the Mount Fagan 7.5' Quadrangle, eastern Pima County, Arizona: Ferguson, C.A., Youberg, A., Gilbert, W.G., Orr, T.R., Richard, S.M., and Spencer, J.E., 2001, Arizona Geological Survey Digital Geologic Map 11, 33 p., 1 sheet, scale 1:24,000, 1 CD-ROM.

DGM 12. Geologic map of the southern part of the Vail 7.5' Quadrangle, eastern Pima County, Arizona: Richard, S.M., Spencer, J.E., Ferguson, C.A., and Youberg, Ann, 2002, Arizona Geological Survey Digital Geologic Map 12, 29 p., 1 sheet, scale 1:24,000, 1 CD ROM

DGM 13. Youberg, A., and Helmick, W.R., 2001, Surficial geology and geologic hazards of the Amado-Tubac area, Santa Cruz and Pima Counties, Arizona: Arizona Geological Survey Digital Geologic Map 13, 1 CD-ROM, 17 p., 2 sheets, scale 1:24,000.

DGM 14. Geologic map of the White Tank Mountains, central Arizona: Reynolds, S.J., Wood, S.E., Pearthree, P.A., and Field, J.J., 2002, Arizona Geological Survey Digital Geologic Map 14, 1 CD-ROM, 2 sheets, scale 1:24,000.

Digital Information

DI 23. Database for mineral districts in the State of Arizona: Richard, S.M., ed., 2002, Arizona Geological Survey Digital Information 23, 1 CD-ROM.

Down-To-Earth

DTE 12. *A guide to the geology of Catalina State Park and the western Santa Catalina Mountains:* Bezy, J.V., 2002, Arizona Geological Survey Down-to-Earth 12, 56 p.

DTE 13. A home buyer's guide to geologic hazards in Arizona: Harris, R.C., and Pearthree, P.A., 2002, Arizona Geological Survey Down-to-Earth 13, 38 p.

Open-File Reports

OFR 01-07. Field guide to "A" Mountain and description of surrounding region, Pima County, Arizona: McGarvin, T.G., 2001, Arizona Geological Survey Open-File Report 01-07, 9 p.

OFR 01-09. Data structure for the Arizona Geological Survey Geologic Information System - basic geologic map data, v. 1.0: Richard, S.M. and Orr, T.R., 2001, Arizona Geological Survey Open-File Report 01-09, 50 p.

OFR 01-10. A new earth fissure near Wintersburg, Maricopa County, Arizona: Harris, R.C., 2001, Arizona Geological Survey Open-File Report 01-10, 22 p.

OFR 01-11. Annual Report, fiscal Year 2001: Fellows, L.D., 2001, Arizona Geological Survey Open-File report 01-11, 22 p.

OFR 02-01. Geologic description, sampling, and petroleum source rock potential of the Awatubi and Walcott Members, Kwagunt Formation, Chuar Group of the Sixtymile Canyon section, Grand Canyon, Arizona: Wiley, B.H., Dehler, C.M., Ghazi, S.A., Kuo, Lung-Chuan, and Rauzi, S.L., 2002, Arizona Geological Survey Open-File Report 02-01, 84 p.

OFR 02-02. Surficial geology and geomorphology of the Tinajas Altas area, Barry M. Goldwater Air Force Range, Yuma County, southwestern Arizona: Biggs, T.H., Demsey, K.A., and Pearthree, P.A., 2002, Arizona Geological Survey Open-File Report 02-02, 22 p.

OFR 02-03. Surficial geology and geomorphology of the central Saucedo Valley, Barry M. Goldwater Air Force Range, Maricopa County, Arizona: Demsey, K.A., Meglioli, Andres, Biggs, T.H., and Pearthree, P.A., 2002, Arizona Geological Survey Open-File Report 02-03, 13 p.

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OFR 02-04. Giant desiccation cracks in the southwestern part of the Tohono O'Odham Nation, Pima County, Arizona: Harris, R. C., 2002, Arizona Geological Survey Open-File Report 02-04, 46 p. (Due to the Tohono O'Odham Nation's confidentiality rules, copies of this report are not distributed to the public,)

OFR 02-05. Paleoseismology and neotectonics of the Shivwitz section of the Hurricane Fault, Mohave County, northwestern Arizona: Amoroso, Lee, Pearthree, P.A., and Arrowsmith, J.R., 2002, Arizona Geological Survey Open-File Report 02-05, 93 p., scale 1:24,000.

OFR 02-06. A compilation of geomorphologic and hydrologic reports on the Jackrabbit Wash flood, October 2000, Maricopa County, Arizona, by Ann Youberg, P.A. Pearthree, Larry Mayer, Ted Lehman, and Mike Kellogg, 2002, Arizona Geological Survey Open-File Report 02-06, 98 p., scale 1:24,000, 1 CD-ROM.

OFR 02-07. A review and bibliography of karst features of the Colorado Plateau, Arizona: Harris, R.C., 2002, Arizona Geological Survey Open-File Report 02-07, 43 p.

Oil And Gas Maps And Reports Updated

OG-02. Annual oil, gas, and helium production in Arizona 1954 - 2001: Rauzi, S.L., 2002, Arizona Geological Survey Oil and Gas Publication 2, 18 p.

OG-12. Arizona well location map and report: Rauzi, S.L., 2001, Arizona Geological Survey Oil and Gas Publication 12, 27 p., scale 1:675,000. (2 blue-line sheets; OGCC State Series Map)

OG-15. Dineh-Bi-Keyah oil field, Apache County, Arizona: Rauzi, S.L., 2002, Arizona Geological Survey Oil and Gas Publication 15, scale 1:63,360. (OGCC Pool Series Map P-2)

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External publications

Fenton, C.R., Webb, R.H., Pearthree, P.A., Cerling, T.E., and Poreda, R.J., 2001, Displacement rates on the Toroweap and Hurricane faults: Implications for Quaternary downcutting in Grand Canyon: *Geology*, v. 29, p. 1035-1038

Lund, W.R., Taylor, W.J., Pearthree, P.A., Stenner, H.D., Amoroso, Lee, and Hurlow, H.A., 2002, Structural development and paleoseismology of the Hurricane fault, southwestern Utah and northwestern Arizona, in Lund, W.R., ed., *Field guide to geologic excursions in southwestern Utah and adjacent areas of Arizona and Nevada*: U.S. Geological Survey Open-File Report 02-172, pp. 1-84.

House, P.K., Pearthree, P.A., and Klawon, J. E., 2002, Paleoflood history of the lower Verde River, Arizona, in House, P.K., et. al., eds., *Ancient Floods, Modern Hazards: Principles and Applications of Paleoflood Hydrology*: American Geophysical Union, p. 267-293.

Mayer, L., and Pearthree, P.A., 2002, Mapping hurricane-induced flooding in southwestern Arizona using Landsat TM data: A method for rapid regional flood assessment following large storms, in House, P.K., et. al., eds., *Ancient Floods, Modern Hazards: Principles and Applications of Paleoflood Hydrology*: American Geophysical Union, p. 61-76.

Rauzi, S.L., 2002, Salt deposits in Arizona promise gas-storage opportunities: *Oil & Gas Journal*, v. 100, no. 17 (April 29), pp. 68-70.

Richard, S.M., 2001, Rock classification for Geologic Map Database applications, in Soller, D.R., ed., Digital mapping techniques '01 Workshop Proceedings: U.S. Geological Survey Open-File Report 01-223, pp. 135-138.

Richard, S.M., and Orr, T.R., 2001, Data structure for the Arizona Geological Survey Geologic Information System-Basic Geologic Map Data, in Soller, D.R., ed., Digital mapping techniques '01 Workshop Proceedings: U.S. Geological Survey Open-File Report 01-223, pp. 167-188.

Spencer, J.E., Richard, S.M., and Ferguson, C.A., 2001, Cenozoic structure and evolution of the boundary between the Basin and Range and Transition Zone provinces in Arizona, in Erskine, M.C., Faulds, J.E., Bartley, J.M., and Rowley, P.D., eds., The geologic transition, High Plateaus to Great Basin - A symposium and field guide: Salt Lake City, Utah Geological Association Publication 30, p. 273-289.

Manuscripts Submitted For External Publication

Allis, R.G., Moore, J.N., Chidsey, T., Morgan, C. Gwynn, W., Doelling, H., Adams, M., and Rauzi, S.L., CO₂ geysers, springs, and massive travertine deposits in central Utah and eastern Arizona: indications of a long history of outflow of deep basin fluids saturated in CO₂, 2002, manuscript for inclusion in GRC Transactions volume.

Damon, P.E., and Spencer, J.E., A K-Ar geochronologic survey of the Hopi Buttes volcanic field, in Young, R.A., ed., The Colorado River: Origin and Evolution: Grand Canyon Association Monograph.

Faulds, J.E., House, P.K., Bell, J.W., Pearthree, P.A., and Ramelli, Alan, Geologic map of the Davis Dam 7.5' Quadrangle, Nevada and Arizona: Nevada Bureau of Mines and Geology

Fenton, C.R., Webb, R.H., Pearthree, P.A., Cerling, T.E., Poreda, R.J., and Nash, B.P., Cosmogenic ³He dating of western Grand Canyon basalts: implications for Quaternary incision of the Colorado River, in Young, R.A., ed., The Colorado River: Origin and Evolution: Grand Canyon Association Monograph.

Patchett, P.J., Gross, E.L., Dallegge, T.A., and Spencer, J.E., The Colorado River system and Neogene sedimentary formations along its course: Apparent Sr isotopic connections, in Young, R.A., ed., The Colorado River: Origin and Evolution: Grand Canyon Association Monograph.

Spencer, J.E., and Pearthree, P.A., Headward erosion vs. closed-basin spillover as alternative causes for integration of the lower Colorado River, in Young, R.A., ed., The Colorado River: Origin and Evolution: Grand Canyon Association Monograph.

Spencer, J.E., Peters, L., McIntosh, W.C., and Patchett, P.J., in press, Ar⁴⁰/Ar³⁹ geochronology of the Hualapai Limestone and Bouse Formation and implications for the age of the lower Colorado River, in Young, R.A., ed., The Colorado River: Origin and Evolution: Grand Canyon Association Monograph.

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Amoroso, Lee, Pearthree, P.A. and Stenner, Heidi, 2002, Evidence for a M7 earthquake on the Shivwitz section of the Hurricane fault zone, northwestern Arizona: Geological Society of America Abstracts with Programs v. 34, n. 3.

Faulds, J.E., Gonzalez, L.A., Perkins, M.E., House, P.K., Pearthree, P.A., Castor, S.B., and Patchett, P.J., 2002, Late Miocene-early Pliocene transition from lacustrine to fluvial deposition: inception of the lower Colorado River in southern Nevada and northwest Arizona: Geological Society of America Abstracts with Programs v. 34, n. 3.

Publications Released—*continued*

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House, P.K., Pearthree, P.A., Bell, J.W., Ramelli, A.R., and Faulds, J.E., 2002, New stratigraphic evidence for the late Cenozoic inception and subsequent alluvial history of the Colorado River from near Laughlin, Nevada: Geological Society of America Abstracts with Programs v. 34, n. 3.

Pearthree, P.A., Amoroso, Lee, Fenton, C.R., and Stenner, H.D., 2002, Paleoseismology of the Hurricane fault zone in northwestern Arizona: Geological Society of America Abstracts with Programs, v. 34, n. 3.

Skotnicki, S.J., and Spencer, J.E., 2001, Stream incision in central and southeastern Arizona as a possible consequence of climate change: Arizona Hydrological Society 14th Annual Conference, p. 28-29.

Spencer, J.E., and Duncan, J.T., 2001, Mineral deposits produced by Miocene basin brines in western Arizona: Arizona Hydrological Society, Proceedings of the 14th Annual Symposium, p. 59.

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