ANNUAL REPORT

OF THE

ARIZONA GEOLOGICAL SURVEY

FY 2004

Pegmatite dikes intruded into the Leatherwood granodiorite,
Arizona Geological Survey, Down-to-Earth 17.

Larry D. Fellows
Director and State Geologist

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

(520) 770-3500 www.azgs.az.gov

402 (274) F322

Janet Napolitano
Governor

State of Arizona
Arizona Geological Survey
416 W. Congress, Suite 100
Tucson, Arizona 85701
(520) 770-3500
www.azgs.az.gov

Larry D. Fellows
Director and State Geologist

27 August 2004

The Honorable Janet Napolitano
Governor
1700 W. Washington
Phoenix, AZ 85007

Dear Governor Napolitano:

The Annual Report of the Arizona Geological Survey (AZGS) for FY 2004 describes how staff carried out the AZGS mission by informing and assisting the public about the character of rock formations, geologic hazards, and mineral and energy resources.The report also summarizes geologic maps and studies that AZGS staff completed, including those that focused on the following topics:

- Distribution and character of rocks and sediment between Benson and Sierra Vista in Cochise County and near Green Valley in Pima County
- Alluvial-fan flooding on desert piedmonts in western Maricopa County
- Potential helium resources in the Holbrook basin in Navajo and Apache Counties
- Polygonal ground cracks in southern Arizona caused by prolonged drought

The report also describes special projects that were done under contract to provide information other agencies needed to carry out their missions. Funding for these projects supplemented the AZGS General Fund appropriation and expanded agency productivity.

The purpose of AZGS projects and activities is to produce and disseminate information that is used to make informed decisions and prudently manage Arizona's land, water, energy, and mineral resources.

I'll gladly answer any questions you or your staff might have about the report, the Arizona Geological Survey, or the geology of Arizona.

Respectfully submitted,

Larry D. Fellows
Director and State Geologist

EXECUTIVE SUMMARY

Arizona Geological Survey (AZGS) employees informed and assisted the public during Fiscal Year 2004 as follows:

- Responded to thousands of requests for information and assistance.

- Sold 9,076 reports and maps, an increase of 8.9 percent from last year. Revenue from sale of publications totaled $70,567, an increase of 11.8 percent from last year. Almost 97 percent of mail orders were filled and mailed not more than one day after they were received.

- Released 24 new reports and maps on Arizona geology, including:

  - Four digital geologic quadrangle maps in the Santa Cruz River Valley south of Tucson in Pima County, and three in Cochise County along the San Pedro River Valley between Benson and Sierra Vista., including Kartchner Caverns State Park. (These maps are available in both paper and digital form.)

  - Three down-to-earth (non-technical) books (Wupatki and Sunset Crater Volcano National Monuments, White Mountains and the Springerville Volcanic Field, and Sabino Canyon and the Catalina Highway) done in cooperation with the National Park Service and the U.S. Forest Service

  - Two open-file reports that characterized rock units

  - Five open-file reports on applied geology subjects such as helium, asbestos, desiccation cracks, and alluvial-fan flooding

  - Seven articles published outside of the AZGS

- Participated in eleven cooperative projects under contract with governmental agencies including Arizona State Land Department, Flood Control District of Maricopa County, National Park Service, U.S. Department of Energy, U.S. Forest Service, and U.S. Geological Survey. Project expenditures totaled $437,265. AZGS staff supervised the work of 15 temporary and part-time employees who were paid with contract funds to work on the projects.

- Gave 12 talks and led 18 field trips as requested by representatives of governmental agencies, professional societies, universities, and citizen groups.

- Updated five Digital Geologic Maps and three oil and gas maps.

- Submitted three manuscripts for publication outside of the AZGS.

- Published four 6-page issues of *Arizona Geology,* the AZGS newsletter.

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MISSION

To inform and advise the public about the geologic character of Arizona to help meet societal needs for water, energy, and mineral resources and assist in prudently managing the State's land and natural resources.

DESCRIPTION

AZGS staff, who prepare geologic maps, complete field studies, compile data, and disseminate information, perform the following functions:

- **Geology for Societal Needs.** Map and characterize rock formations and their weathering products; investigate geologic hazards and land-use 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; describe the origin, distribution, and character of metallic, non-metallic, and energy resources; and identify areas that may have potential for discovery of mineral and energy discoveries.

- **Information and Service.** Inform and assist the public by answering inquiries, preparing and selling maps and reports, giving talks, leading field trips, and maintaining a library, databases, and a website.

- **Oil and Gas.** Provide administrative and staff support to the Arizona Oil and Gas Conservation Commission. The Commission regulates the drilling for and production of oil, natural gas, geothermal, helium, and carbon dioxide, to ensure that sound engineering, environmental, and conservation practices are followed.

- **Geologic Data Users**
  Citizens and citizen groups; elected officials and their staff, land- and resource-management agencies (e.g. State Land Department, Department of Water Resources, Department of Environmental Quality, Department of Transportation, State Parks, Office of Tourism, Attorney General), environmental and engineering geology companies, hydrologists, energy- and mineral-exploration companies, consultants, planners, attorneys, realtors, insurance companies, teachers, students, libraries, book dealers, and others.

GEOLOGY FOR SOCIETAL NEEDS

GOAL 1. To characterize rocks, surficial materials, mineral and energy resources, and geologic hazards, with emphasis on areas that have potential for urban and resource development, and provide this information to the public.

Objective 1. Increase the distribution of technical maps/reports by 2 percent.Result: Did not meet objective – sale of technical maps/reports increased 0.5 percent.

INFORMATION AND SERVICE

GOAL 2. To inform those not trained in geology about geologic processes and resources in Arizona.

Objective 1. Increase the distribution of non-technical reports by 15 percent.Result: Exceeded objective – sale of non-technical reports increased 39 percent.

Objective 2. Inform the public by giving 20 talks or field trips Result: Exceeded objective – gave 30 talks and field trips

GOAL 3. To disseminate more information while maintaining efficient service and high customer satisfaction.

OIL AND GAS CONSERVATION COMMISSION

GOAL 4. To effectively assist the Arizona Oil and Gas Conservation Commission

Objective 1. Respond to requests for drilling permits within 5 working days.
Result: Exceeded objective – issued 6 permits to drill with an average turn-around time of 4 business days from when the completed application was received

Objective 2. Inspect gas-storage wells twice and other wells as drilling takes place.
Result: Met objective - conducted safety inspections of 14 wells in November and April and two wells during drilling.

4 GEOLOGY FOR SOCIETAL NEEDS

National Cooperative Geologic Mapping Program. Arizona Geological Survey (AZGS) geologists have participated in this cooperative program since its inception in 1993. They have completed mapping in most of the Phoenix-Tucson corridor and are expanding into other population-growth areas. During FY 2004 the AZGS released maps of four 7.5-minute quadrangles along and west of the upper Santa Cruz River valley south of Tucson in Pima County (Digital Geologic Maps 30-33). Citations for these and other publications released in FY 2004 are listed on pages 15-18. The agency also released maps of three 7.5-minute quadrangles along the upper San Pedro River between Benson and Sierra Vista in Cochise County (Digital Geologic Maps 34-36). Mapping is in progress on the southeast margin of Tucson, west of the White Tank Mountains in western Maricopa County, and in the Bullhead City area along the Colorado River.

The following AZGS geologists served on the mapping team: Jon E. Spencer, Stephen M. Richard, Charles A. Ferguson, and Bradford J. Johnson, bedrock geology; Philip A. Pearthree, Ann M. Youberg, and Todd C. Shipman, surficial geology; and Erin M. Moore and Stephen M. Richard, digital map preparation.

In addition to mapping the distribution of rock and surficial material units, AZGS geologists characterize the map units. In one project, released as Open-File Report 03-08, ages of 23 igneous rock samples from central and southeastern Arizona were determined. Geologists also described the mineralogy of granitic rocks that underlie much of northeasern Maricopa and northern Gila counties and released the results as Open-File Report 03-09.

The Statemap component of the National Cooperative Geologic Mapping Program, administered by the U.S. Geological Survey, provided half of the funding for geologic mapping in FY 2004. In accordance with the mapping act, the AZGS matched the federal funds received with an equal amount of state support. AZGS geologists provided in-kind service by doing geologic mapping and related activities. Requests for funding were judged competitively with proposals from the other state geological surveys. The AZGS was awarded $217,439 for FY 2004; the total value of the mapping project, including the AZGS match, was $434,878.

Priority of areas to be mapped was determined by the Arizona Geologic Mapping Advisory Committee, which is composed of representatives of state land- and resource-management agencies and the private sector. Committee members are:

Al Burch (U.S. Bureau of Land Management)
Charles D. Graf (Arizona Department of Environmental Quality)
William M. Greenslade (Southwest Ground-water Consultants, Inc.)
Barbara H. Murphy, Chair (Clear Creek Associates)
Nicholas M. Priznar (Arizona Department of Transportation)
Frank Putman (Arizona Department of Water Resources)
Michael J. Rice (Arizona State Land Department)
Ralph E. Weeks (AMEC Earth & Environmental).

National Geologic Map Database project. Stephen M. Richard is a member of the North American Data Model Steering Committee. The purpose of the committee is to coordinate and review efforts to develop a data model, science language, and interchange mechanisms for exchange of geologic map data between state and federal geological survey data providers and data consumers in the public and private sector.

Richard is also a member of the workgroup established to develop a standard digital geologic map data model. Version 1.0 of the model was published on the world wide web (http://geology.usgs.gov/dm/steering/teams/design/NADM-C1.0/NADMC1_0.pdf). The workgroup took the lead in final editing and document preparation. The document was submitted for a joint USGS-GSC open-file report.

Richard adapted and expanded the science language terms that were developed by working groups of North American Data Model Steering Committee. The terms will be used as the science vocabulary in the National Geologic Map database. He also developed the relational database implementation of NADM-C1 model for the National Geologic Map database. These activities support ongoing development of a 1:24,000-scale geologic map database for the Phoenix metropolitan area.

Richard was the author of one article and co-author of another that described geologic databases and terminology. These articles were included in U.S. Geological Survey Open-File Report 03-471.

Piedmont flood hazards in Maricopa County. The AZGS has cooperated with floodplain management agencies to use geologic mapping to help define flood-prone areas on desert piedmonts for the past 15 years. Active alluvial fans, where runoff spreads widely and may form new channels during floods, are areas of primary concern. AZGS geologists Philip A. Pearthree, Ann M. Youberg, and Todd C. Shipman mapped the surficial geology of the Waterman Wash watershed and are working with the Flood Control District of Maricopa County to delineate piedmont flood hazards there. They also released a report (Open-File Report 04-02) on alluvial-fan flooding along Tiger Wash in western Maricopa and eastern La Paz counties.

Giant desiccation cracks. The prolonged drought has caused the soil and subsoil to dry out and form giant polygonal cracks similar to mud cracks, but on a much larger scale. AZGS geologist Raymond C. Harris studied the cracks near Wintersburg in Maricopa County and released a report that describes them (Open-File Report 03-07). He also completed a study of the distribution of these cracks throughout Arizona. The results of that study were summarized in Open-File Report 04-01. Ray found that the distribution of these giant cracks is much more extensive than was originally known.

Asbestos in Arizona. The AZGS learned that a resident of the Sun City area had publicly alleged that a sand and gravel operator was releasing dust that contained asbestos fibers into the atmosphere. Because AZGS staff were unaware of any asbestos deposits in that drainage basin, Raymond C. Harris did a literature search to determine whether any asbestos minerals had been described there. He also reviewed publications that dealt with asbestos deposits and occurrences throughout the state. Harris found no scientific reports of asbestos minerals in the Agua Fria drainage and no geologic indicators of asbestos (Open-File Report 03-06). Asbestos was produced commercially for many years in the Globe area in the Salt River drainage. Minor occurrences are known in several other areas as well.

Miscellaneous basin studies. AZGS staff began compiling information on the geologic character of selected deep alluvial basins, including structural history, stratigraphy, geologic controls on ground-water quality, and potential geologic hazards. Raymond C. Harris is the principal investigator of this project, which will continue if funding is available. William R. Drake, Stevan Gyetvai, Lizbeth C. Green, and Kevin C. Horstman also worked on the project.

Advanced volcanology field course. During the past decade, AZGS geologist Charles Ferguson has mapped and described many of Arizona's complex volcanic fields as part of the National Cooperative Geologic Mapping Program. Based on experience gained from this work, he developed a field course ("Whole Lava Love") that is focused on teaching practical aspects of field volcanology. The course, which has been associated with formal courses taught at the University of Arizona and Arizona State University, has been offered during the Christmas holiday season. Participants representing industry, academia, and government have come from every inhabited continent. Because of Charles' experience and expertise in field volcanology, spectacular exposures of varied volcanic rocks, and Arizona's mild climate, the course has been highly successful.

Relationships among fires, soil geochemistry, and geomorphology in Cochise County. 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. During the past year, Thomas H. Biggs, a faculty member at the University of Virginia, and Philip A. Pearthree mapped the surficial geology of portions of Fort Huachuca that include burned and unburned areas. Geochemical analyses of soil samples from the burned and unburned areas were made. Results of this research were presented as a poster at a professional meeting in Tucson. The final report will be submitted to the U.S. Forest Service and Fort Huachuca staff early in fiscal year 2005. The report will be released by the AZGS after the Forest Service has reviewed it.

6 INFORMATION AND SERVICE

Geology Information Center. Staff, primarily Thomas G. McGarvin and Richard A. Trapp, answered requests for information about Arizona geology. Rachel A. Aragon and Maricella M. Moreno, who sold reports and maps, filled and mailed ninety-four percent of mail orders the same day the orders were received. The Arizona Geological Survey (AZGS) has formal cooperative agreements to distribute publications of the Arizona Geological Society and U.S. Geological Survey.

Publication sales totaled $70,567, an increase of $7,442 (11.8 percent) from FY 2003. The increase in sales is attributed to the improved economy and the release of new non-technical reports. Revenue from publication sales is used to purchase books and maps for resale and to print and distribute publications.

Geology library and databases. The AZGS maintains a non-circulating library that is open to the public. The library, managed by Thomas G. McGarvin, contains all AZGS publications, as well as the following items: theses and dissertations on Arizona geology; reports by Arizona state agencies; publications of state geological surveys in adjacent states; U.S. Geological Survey publications, maps, and open-file reports; and numerous publications by other governmental agencies and professional societies.

AZGEOBIB is a database that contains more than 13,200 bibliographic citations on Arizona geology. The database is key-worded by subject and geographic area. AZGS staff members 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 in the project area. Richard A. Trapp, Information Technology Manager, maintains the databases.

Website. The AZGS web site (**www.azgs.az.gov**) includes information about the agency, geology of Arizona, and publications for sale. Links to other geology-related agencies and groups are provided. Rose Ellen McDonnell is the webmaster.

Arizona Geology. The AZGS published four six-page issues of *Arizona Geology* to describe geologic processes, resources, and features that impact land management and the economy of Arizona, publicize new geologic maps and reports, and highlight other activities that pertain to the geology of Arizona. Feature articles described potential helium resources, distribution of asbestos minerals in Arizona, giant desiccation polygons caused by drying of the soil, and geology of the Sedona area. The latter was written because *USA WEEKEND*, the magazine that comes in your Sunday newspaper, named the Sedona area ("Red Rock Country") as "the most beautiful place in America."

Down-to-Earth (DTE) publications. These publications are written for those who have had no formal education or training in geology, but have a strong interest in and curiosity about geologic processes and features. Many state and national parks were created to preserve spectacular geologic features. The AZGS released three books in this series:

DTE 15, *Roadside geology: Wupatki and Sunset Crater Volcano National Monument.* This book includes descriptions and color photographs of 14 geologic features formed by volcanic action, including cinder cones, lava domes, aa flows, squeeze-ups, hornitos, and xenoliths. Sara L. Hanson, Professor of Geology at Adrian College in Adrian, Michigan, wrote the book. She was assisted by staff at Sunset Crater and Wupatki National Monuments. Sarah was a participant in the Geologist-in-the Park Program sponsored by the Geological Society of America (GSA) and the National Park Service (NPS). She was also supported by the GeoCorps America Program sponsored by the GSA and the NPS.

DTE 16, *A guide to the geology of the White Mountains and the Springerville volcanic field, Arizona.* This book includes descriptions of 26 geologic features that were formed by volcanic eruptions or glaciers. Several rock formations that were present before volcanic activity began are also described. This project was done cooperatively with John V. Bezy, a retired geologist. Staff at the Apache-Sitgreaves National Forest provided assistance.

DTE 17, *A guide to the geology of Sabino Canyon and the Catalina Highway.* John V. Bezy, author, described 11 geologic features in Sabino Canyon and 14 that can be observed along the Catalina Highway, which ends on top of Mt. Lemmon. Eileen J. Hill, Store Manager of the Sabino Canyon and Palisades Visitor Centers,

Public Lands Interpretive Association, provided assistance and support. Staff of the Coronado National Forest also assisted.

Earth science education. Thomas G. McGarvin, the AZGS' primary contact with science and earth science teachers, assisted teacher groups in incorporating local geology into their courses. He conducted a workshop at the Fall 2003 Conference of the Arizona Science Teachers Association in which he described publications available from the AZGS, primarily the Down-to-Earth series, which could be applied to the classroom by earth-science educators. Tom also led several field trips tailored for educators to see basic geologic features and discuss them in context within their geologic setting.

Service to community and professional groups. AZGS geologists are asked occasionally to provide special assistance to governmental agencies, professional societies, universities, and public groups. This assistance included giving talks, leading field trips and workshops, serving on panels, reviewing technical aspects of applications or proposals for funding, reviewing the geologic content of manuscripts submitted for publication, and other assistance.

AZGS staff gave 12 talks and led 18 field trips during the year. A list of the talks given, field trips led, and other assistance provided is attached as Appendix I, page 13 (A paper copy of the text and map is available for $15.00 plus shipping and handling.).

OIL AND GAS CONSERVATION COMMISSION

The Commission. The Arizona Oil and Gas Conservation Commission (OGCC), which regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources, is attached to the Arizona Geological Survey (AZGS). The AZGS provides administrative and staff support. The Governor appoints five members of the commission; the sixth, 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 Mark Winkleman, State Land Commissioner.

Steven L. Rauzi, the Oil and Gas Administrator, issues permits to drill, monitors drilling, inspects completed wells, compiles drilling and production data, maintains well files, and does other duties on behalf of the OGCC. The Commission met three times.

Production, refining, and storage. Oil production in calendar year (CY) 2003 totaled 47,289 barrels from 16 producing wells, down from 63,417 barrels from 20 wells in 2002. Gas production in CY 2003 increased to 443 million cubic feet from nine producing wells. CY 2002 production was 304 million cubic feet from seven wells. CO_2 production totaled 159 million cubic feet from one producing well in 2003, down from 217 million cubic feet in 2002. Commercial production of CO_2 started in July 2002.

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 used as a storage and transfer site for asphalt products

Liquefied petroleum gas (LPG) transferred through storage wells west of Phoenix and at Adamana in CY 2003 included 85 million gallons in receipts and 80 million gallons in deliveries. In CY 2002, 90 million gallons were received and 122 million gallons were delivered. About 35 million gallons of LPG were in storage at yearend, up from the 29 million gallons the year before. Fourteen storage wells in subsurface salt are in use.

Leasing. In CY 2003, 481,000 acres were under lease for oil and gas exploration, up from 438,000 acres in 2002.

State Trust Land under lease in December 2003 totaled 376,000 acres, up from 324,000 acres in December 2002. Public land under lease in December 2003 totaled 105,000 acres, down from 114,000 acres in December 2002. The State Land Department administers leasing on State Trust Land. The U.S. Bureau of Land Management administers leasing on public lands.

Drilling. Six permits to drill were issued and two holes were drilled in FY 2004. Clayton Williams Energy drilled a hole in search of gas north of Flagstaff. No gas was discovered and the well was transferred to the landowner for use as a water well.

Ridgeway Arizona Oil Corporation drilled in search of carbon dioxide between St. Johns and Springerville. The company was evaluating the hole as of July 1, 2004.

Inspection and enforcement. Staff made semiannual inspections of 14 hydrocarbon-storage wells west of Phoenix and at Adamana and witnessed the cementing of surface casing on the wells drilled by Clayton Williams and Ridgeway. Inspections are conducted to ensure that wellhead valves, safety alarms, and emergency shutdown systems are working properly and that cement is circulated back to the surface.

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

Carbon dioxide update. Ridgeway Arizona Oil Corporation announced discovery of carbon dioxide (CO_2) in a well in the St. Johns and Springerville areas in southern Apache County in August 1994. The company drilled 15 wells before the end of May 1997. At a meeting of the House of Representatives Natural Resources Committee in Springerville in August 1999, Ridgeway representatives estimated that initial development to supply CO_2 for enhanced oil recovery would require two to three years and about 200 wells. The company informed meeting attendees that as many as 1,195 wells would eventually be drilled over the 25-40 year life of the project.

Ridgeway produced CO_2 from one well in 2002-03. Production was piped to a liquids plant near Tucson Electric Power Company's Springerville Generating Station. At the end of FY 2004 (June 30, 2004) a total of 16 wells had been drilled. Three were completed as gas wells and are shut in, four were temporarily abandoned, and eight were plugged and abandoned. The most recently drilled well is being evaluated.

Southwest Regional Partnership on Carbon Sequestration. The AZGS was awarded $87,797 by the U.S. Department of Energy to investigate potential sites in Arizona where carbon dioxide could be safely sequestered or stored in subsurface rock formations. The New Mexico Bureau of Geology and Mineral Resources, the state geological survey, is the project coordinator. The state geological surveys of Colorado, Oklahoma, Utah, and Arizona, as well as other organizations, are also participants.

Subsurface investigations. S.L. Rauzi prepared a report on helium production and potential in Arizona, which was released as AZGS Open-File Report 03-05. The report was summarized in the Winter 2003 issue of *Arizona Geology*, the AZGS newsletter. Similar reports on oil and gas potential and salt were completed in previous years.

PERSONNEL [1]

Office of the Director

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

Rose Ellen McDonnell, Assistant Director of Administration
B.S., University of Arizona

Geologists

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

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

Erin M. Moore[2], Geologist I
B.S., University of Arizona
M.S., University of California at Davis

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

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

Support Staff

Mary E. Redmon[3], Administrative Assistant III
Mary N. Andrade[4], Administrative Assistant III
Rachel A. Aragon[5], Administrative Assistant I
Maricella M. Moreno[6], Secretary

10 Contracted Geologists and Student Assistants[7]

Monisha J. Banerjee, Laboratory Technician
Thomas H. Biggs, Research Geologist
Stephen B. DeLong, Project Geologist
William R. Drake, Project Geologist
Charles A. Ferguson, Research Geologist
Lizbeth C. Greene, Project Geologist
Stevan Gyetvai, Project Geologist
Raymond C. Harris, Research Geologist
Kevin C. Horstman, Research Geologist
Bradford J. Johnson, Research Geologist
Michael K. Mahan, Project Geologist
Erin M. Moore, Geologist II
Stephen M. Richard, Research Geologist
Todd C. Shipman, Geologist II
Ann M. Youberg, Geologist II

[1] Geologists and support staff who were paid from the General Fund appropriation and were on the payroll on June 30, 2004, except as otherwise noted. The Arizona Geological Survey is authorized to employ 12.25 full-time-equivalent staff members from the General Fund appropriation.

[2] Promoted to Geologist II October 13, 2003 (State funded half time and contract funded half time)

[3] Resigned September 12, 2003

[4] Promoted to Administrative Assistant III, July 1, 2003

[5] Promoted to Administrative Assistant I, July 1, 2003

[6] Hired August 4, 2003

[7] Paid from contracted projects funded by other agencies or groups during Fiscal Year 2004 to complete a specific product or service within a specified period of time.

EXPENDITURES

GENERAL FUND EXPENDITURES

Category	FY 2003 Expended	FY 2004 Expended	FY 2005 Budgeted
Personal Services	430,559	427,646	431,800
Benefits	89,419	97,698	104,700
Operations	213,607	214,493	219,600
In-State Travel	39,329	36,624	40,600
Out-of-State Travel	1,081		
Capital Equipment	775	3,123	
TOTAL	**774,770**	**779,584**	**796,700**

PRINTING REVOLVING FUND

PUBLICATIONS	FY 2004 Expended
Arizona Geological Survey	46,941
Arizona Geological Society	1,728
U.S. Geological Survey	24,877
Other Publications	1,589
TOTAL	**75,135**

CONTRACTED PROJECTS

Project Fund Source	Principal Investigator	Personal Services	Benefits	Professional Services	In State Travel	Out State Travel	Operations	Equipment	Other Costs	TOTAL
Geologic Mapping USGS	Spencer	136,578	32,967		2,819		13,820		20,835	207,019
Fort Huachuca Fire on Soil USFS	Pearthree	4,103	424				12,159			16,686
Carbon Sequestration DOE	Rauzi	12,492	3,460			1,260	6,211	1,157		24,580
National Geologic Database USGS	Richard	27,870	8,827							36,697
Gila Oil Well Gila Valley NRCD	Harris	3,621	975							4,596
Marsh Station Statistical Research, Inc.	Pearthree	493	51							544
Waterman Wash Engineering and Environmental Consultants, Inc.	Pearthree	23,314	4,666		633					28,613
Land Resources Arizona State Land Department	Harris	71,821	11,049	2,250	1,741		3,945	4,381	22,591	117,778
Gamma-ray Spectrometer Survey Environmental & Earth Science Consultants	Harris	457	141		154					752
TOTAL		**280,749**	**62,560**	**2,250**	**5,347**	**1,260**	**36,135**	**5,538**	**43,426**	**437,265**

Service to Constituents

American Geophysical Union: Reviewed a manuscript submitted for publication in *Tectonics*

American Institute of Professional Geologists, Arizona Section: Co-leader of a field trip to observe the influence of the Luke salt on urban development

_____: Co-leader of a field trip along the Catalina Highway to Mt. Lemmon, Santa Catalina Mountains, to observe structural geology and related features

Arizona Department of Environmental Quality: Reviewed a report on ambient water quality in Detrital Valley, northwest Arizona

Arizona Department of Transportation: Co-leader of a field trip that was given to attendees of the 2003 meeting of the Interstate Technical Group on Abandoned Underground Mines

Arizona Floodplain Management Association: Gave a talk on the geologic development of the lower Colorado River

Arizona Geological Society: Served as a member of the steering committee to plan a 2007 symposium

_____: Gave a talk on the geologic development of the lower Colorado River

Arizona Rock Products Association: Gave a talk on the AZGS geologic mapping program

Arizona Science Teachers Association: Gave a talk at the annual meeting of the Association on information available from the AZGS

Arizona State Parks: Led a field trip to review the newly released geologic map of the Kartchner Caverns area

_____: Prepared an inventory of digital geologic data available for State Parks

Computers and Geosciences: Reviewed a manuscript that was submitted for publication in this journal.

Geological Society of America: Reviewed a manuscript being prepared for publication in *Geology*

_____: Reviewed three manuscripts being prepared for publication in a Special Paper

Graham County Engineer, Safford: Reviewed reports and participated in a field review of a project that was done in cooperation with Graham County

Melbourne University, Victoria, Australia: Led a field trip for a professor and graduate student who were collecting Arizona rock samples for analysis.

National Aeronautics and Space Administration : Led a field trip for personnel to observe earth fissures and giant desiccation cracks near Wintersburg and in the Harquahala basin.

National Science Foundation: Reviewed three project proposals that were submitted for funding

Pima County Flood Control District: Served as vice-chair of the advisory committee

Pueblo Optimists Club, Tucson: Gave a talk on the purpose and activities of the Arizona Geological Survey

Structural Engineers Association of Arizona: Gave a talk on seismic hazard in Arizona

Sun City Rockhounds Club, Sun City: Gave a talk on the geology of Arizona

Sunsites Gem and Mineral Club, Sunsites: Gave a talk on the geologic history of Cochise County

Tohono Chul Park, Tucson: Gave a talk about the geology of the Tucson area to docents-in-training

Tucson Gem and Mineral Society: Served on the show committee for the 2004 Gem and Mineral Show

_____: Gave a talk on geologic information for rock and mineral collectors

Tucson Unified School District, D.T. Smith Science Center: Led a field trip for a group of teachers to observe the geology of the Tucson area

U.S. Department of Energy: Reviewed two manuscripts being prepared for publication

U.S. Forest Service: Provided information about post-fire flood damage in Romero Canyon in the Santa Catalina Mountains

University of Arizona, Department of Geosciences: Led a field trip at the 2004 GEODAZE event to observe the Pirate fault and debris-flow deposits in the Santa Catalina Mountains

_____: Led 3 field trips for a volcanology class

_____: Served on Ph.D. and M.S. advisory committees

University of Texas at Austin: Led a field trip to the Santa Catalina and Rincon Mountains for a graduate student who was starting a M.S. thesis project.

U.S. Geological Survey: Served on the advisory panel for the Earth Surface Processes Research Institute

_____: Served as a review panel member for the Earthquake Hazards Reduction Program

Western National Parks Association, Tucson: Gave two talks on the geology of Catalina State Park

Wings Over Willcox, Willcox: Led field trips (three) to Fort Bowie, Chiricahua Mountains, and the Willcox Playa

Verde River Day, Cottonwood: Led two field trips to observe the geology of the Verde River as viewed from Dead Horse Ranch State Park

MAPS AND REPORTS COMPLETED

ARIZONA GEOLOGICAL SURVEY (AZGS) – FY 2004

ARIZONA GEOLOGY

What makes "Red Rock Country" beautiful?: L.D. Fellows, v. 33, n. 3, p. 1-4.

Arizona has helium: S.L. Rauzi and L.D. Fellows, v. 33, n. 4, p. 1-4

Asbestos in Arizona: R.C. Harris, v. 34, n. 1, p. 1-4

Giant desiccation cracks in Arizona: R.C. Harris, v. 34, n. 2, p. 1-4.

DIGITAL GEOLOGIC MAPS

DGM 30. Geologic map of the Samaniego Peak 7.5' Quadrangle, Pima County, Arizona: Johnson, B.J., Ferguson, C.A., Pearthree, P.A., and Stavast, W.A., 2002, AZGS Digital Geologic Map 30, CD-ROM that includes one 1: 24,000-scale geologic map and 21-p. text.

DGM 31. Geologic map of the Twin Buttes 7.5' Quadrangle, Pima County, Arizona: Richard, S.M., Spencer, J.E., Youberg, Ann, and Johnson, B.J., 2003, AZGS Digital Geologic Map 31, CD-ROM that includes one 1:24,000-scale geologic map.

DGM 32. Geologic map of the Batamote Hills 7.5' Quadrangle, Pima County, Arizona: Ferguson, C.A., Johnson, B.J., and Shipman, T.C., 2003, AZGS Digital Geologic Map 32, CD-ROM that includes one 1:24,000-scale geologic map and 31-p. text.

DGM 33. Geologic map of the Esperanza Mill 7.5' Quadrangle, Pima County, Arizona: Spencer, J.E., Ferguson, C.A., Richard, S.M., and Youberg, Ann, 2003, AZGS Digital Geologic Map 33, CD-ROM that includes one 1:24,000-scale geologic map and 10-p. text.

DGM 34. Geologic map of the Benson 7.5' Quadrangle, Cochise County, Arizona: Youberg, Ann, Skotnicki, S.J., Shipman, T.C., and Ferguson, C.A., 2004, AZGS Digital Geologic Map 34, CD-ROM that includes one 1:24,000-scale geologic map.

DGM 35. Geologic map of the McGrew Spring 7.5' Quadrangle, Cochise County, Arizona: Shipman, T.C. and Ferguson, C.A., 2003, AZGS Digital Geologic Map 35, CD-ROM that includes one 1:24,000-scale geologic map.

DGM 36. Geologic map of the Huachuca City 7.5' Quadrangle, Cochise County, Arizona: Pearthree, P.A., 2003, AZGS Digital Geologic Map 36, CD-ROM that includes one 1:24,000-scale geologic map.

DOWN-TO-EARTH

DTE 15. Roadside geology: Wupatki and Sunset Crater Volcano National Monuments: Hanson, S.L., 2003, AZGS Down-to-Earth 15, 32 p.

DTE 16. A guide to the geology of the White Mountains and the Springerville Volcanic Field, Arizona: Bezy, J.V. and Trevena, A.S., 2003, AZGS Down-to-Earth 16, 56 p.

DTE 17. A guide to the geology of Sabino Canyon and the Catalina Highway: Bezy, J.V., 2004, AZGS Down-to-Earth 17, 45 p.

OPEN-FILE REPORTS

OFR 03-05. Review of helium production and potential in Arizona: Rauzi, S.L., 2003, AZGS Open-File Report 03-05, 29 p.

OFR 03-06. Is asbestos present in Agua Fria River sand and gravel?: Harris, R.C., 2003, AZGS Open-File Report 03-06, 15 p.

OFR 03-07. Additional desiccation cracks near Wintersburg, Maricopa County, Arizona: Harris, R.C., 2003, AZGS Open-File Report 03-07, 17 p.

OFR 03-08. U-Pb isotope geochronologic data from 23 igneous rock units in central and southeastern Arizona: Spencer, J.E., Isachsen, C.E., Ferguson, C.A., Richard, S.M., Skotnicki, S.J., Wooden, J., and Riggs, N.R., 2003, AZGS Open-File Report 03-08, 40 p.

OFR 03-09. Modal mineralogy of some granitic rocks from eastern Maricopa and northern Gila counties, Arizona: Spencer, J.E., Skotnicki, S.J. and Richard, S.M., 2003, AZGS Open-File Report 03-09, 18 p.

OFR 04-01. Giant desiccation cracks in Arizona: Harris, R.C., 2004, AZGS Open-File Report 04-01, 93 p.

OFR 04-02. Geomorphology and hydrology of an alluvial fan flood on Tiger Wash, Maricopa and La Paz Counties, west-central Arizona: Pearthree, P.A., Klawon, J.E., and Lehman, T.W., 2004, AZGS Open-File Report 04-02, 40 p.

CONTRIBUTED MAPS AND REPORTS

(These maps and reports, prepared by geologists not employed by the AZGS, were released by the AZGS.)

CONTRIBUTED MAPS

CM 04-C. Geologic map of the northern Hualapai Mountains, Mohave County, Arizona: Siwiec, B.R., 2004, AZGS Contributed Map 04-C, scale 1:24,000.

CM 04-D. Geologic maps and cross sections of selected areas in the Rawhide and Buckskin Mountains, La Paz and Mohave Counties, Arizona: Scott, R.J., 2004, AZGS Contributed Map 04-D, several map scales.

CONTRIBUTED REPORTS

CR 03-C. The geology, leasing, and production history of the uranium-vanadium mines on Eurida Mesa, Apache County, Arizona: Chenoweth, W.L, 2003, AZGS Contributed Report 03-C, 24 p.

CR 03-D. The geology, leasing, and production history of the Rattlesnake No. 1/Shorty No. 1 uranium-vanadium mine, Apache County, Arizona: Chenoweth, W.L., 2003, AZGS Contributed Report 03-D, 14 p.

CR 03-E. Geology and production history of the Moonlight uranium-vanadium mine, Navajo County, Arizona: Chenoweth, W.L., 2003, AZGS Contributed Report 03-E, 18 p. (This report supersedes CR 95-D.)

PUBLISHED OUTSIDE OF THE AZGS

Damon, P.E, and Spencer, J.E., 2001, K-Ar geochronologic survey of the Hopi Buttes volcanic field, *in* Young, R.A. and Spamer, E.E, eds., Colorado River origin and evolution: Grand Canyon, AZ, Grand Canyon Association, p. 53-56.*

Fenton, C.R., Webb, R.H., Pearthree, P.A., Cerling, T.E., Poreda, R.J., Nash, B.P., 2001, Cosmogenic ^{3}He dating of western Grand Canyon basalts: Implications for Quaternary incision of the Colorado River, *in*

Young, R.A. and Spamer, E.E, eds., Colorado River origin and evolution: Grand Canyon, AZ, Grand Canyon Association, p. 147-152.*

Patchett, P.J., and Spencer, J.E., 2001, Application of Sr isotopes to the hydrology of the Colorado River system waters and potentially related Neogene sedimentary formations, *in* Young, R.A. and Spamer, E.E, eds., Colorado River origin and evolution: Grand Canyon, AZ, Grand Canyon Association, p. 167-171.*

Richard, S. M., 2003, Geologic Map Database Implementation in the ESRI Geodatabase Environment, *in* Soller, D.R., ed., Digital mapping techniques - 2003 Workshop proceedings: U.S. Geological Survey Open-File Report 03-471.

Richard, S. M., Matti, J.C., and Soller, D.R., 2003, Geoscience terminology development for the National Geologic Map Database, *in* Soller, D.R., ed., Digital mapping techniques – 2003 Workshop proceedings: U.S. Geological Survey Open-File Report 03-471.

Spencer, J.E., and Pearthree, P.A., 2001, Headward erosion vs. closed-basin spillover as alternative causes for the integration of the lower Colorado River, *in* Young, R.A. and Spamer, E.E, eds., Colorado River origin and evolution: Grand Canyon, AZ, Grand Canyon Association, p. 215-219.*

Spencer, J.E., Peters, Lisa, McIntosh, W.C., and Patchett, P.J., 2001, $^{40}Ar/^{39}Ar$ geochronology of the Hualapai Limestone and Bouse Formation and implications for the age of the Lower Colorado River, *in* Young, R.A. and Spamer, E.E, eds., Colorado River origin and evolution: Grand Canyon, AZ, Grand Canyon Association, p. 89-91.*

*This book, which carries a 2001 copyright date, was released in June 2004.

TALKS AND POSTERS PRESENTED AT MEETINGS

Biggs, T.H., Pearthree, P.A., Florkowski, L.N., and Lee, P.J., 2004, The effects of fire events on soil geochemistry in semi-arid grasslands, *in* Connecting mountain islands and desert seas: Biodiversity and management of the Madrean Archipelago II, p. 20.

Boisvert, Eric, Brodaric, Boyan, Hastings, J.T., Johnson, Bruce, McDonald, James, Richard, S.M., presenter, Schweitzer, Peter, and Weisenfluh, G.A., 2003, NORTON: A proposed North American Geologic Map data conceptual model: Geological Society of America *Abstracts with Programs*, v. 35, no. 6, p.368. This paper was presented at the annual meeting of the Geological Society of America in Seattle, November 2003.

Harris, R.C., 2004, Desiccation polygons in southern Arizona. This was a poster presentation at the Shlemon Specialty Conference on Earth Fissures, El Paso, Texas, April 2004. The Engineering Geology Foundation and the Association of Engineering Geologists sponsored the conference. Conference materials were published on a CD.

Richard, S.M., presenter, Spencer, J.E., Orr, T., Ferguson, C.A., and Dickinson, W.R., 2003, Evidence for 35-50 km displacement on the Cloudburst-Suizo detachment fault system north of Tucson, Arizona, and restoration of a Mesozoic high-angle fault system: Geological Society of America *Abstracts with Programs*, v. 35, no. 6, p. 27. This was a poster presentation at the annual meeting of the Geological Society of America in Seattle, November 2003.

Richard, S.M., presenter, Soller, D.R., Matti, J.C., 2003, Geoscience terminology development for the National Geologic Map Database: Geological Society of America *Abstracts with Programs*, v. 35, no. 6, p. 278. This was a poster presentation at the annual meeting of the Geological Society of America in Seattle, November 2003.

Richard, S.M., presenter, Soller, D.R., Craigue, Jon, and Hastings, J.T., 2003, Data entry tool for the National Geologic Map Database. This paper was presented at the Digital Mapping Techniques Conference hosted by the Oregon Department of Geology and Mineral Industries in Portland in May 2004.

MAPS UPDATED

DIGITAL GEOLOGIC MAPS

Geologists occasionally add detail to parts of the map, re-configure formation contacts, or reinterpret rock relationships. Whenever a map is modified the version number is changed correspondingly. The following changes were made to digital geologic maps:

DGM 18. Fortified Peak Quadrangle, version 2.0: a cross section and new geochronologic information were added; the area covered by the inset map (1:12,000 scale) was extended.

DGM 19. Durham Hills Quadrangle, version 1.1: a cross section was added and minor changes were made; no new mapping.

DGM 21. Oro Valley Quadrangle, version 2.0: additional new mapping at Pusch Peak and Pima Canyon, one cross section, and 3 radiometric age dates were added; one age for biotite granite of Alamo Canyon was revised.

DGM 22. Chief Butte Quadrangle, version 1.1: a cross section and new geochronological information were added; no new mapping.

DGM 23. North of Oracle Quadrangle, version 2.0: additional mapping of the porphyritic granite near the town of Oracle was added.

OIL AND GAS MAPS

OG 02. Annual oil, gas, and helium production in Arizona 1954-2003: Rauzi, S.L., 2004, Arizona Geological Survey Oil and Gas Publication 02, 18 p.

OG 15. Dineh-Bi-Keyah oil field, Apache County, Arizona: Rauzi, S.L., 2004, Arizona Geological Survey Oil and Gas Publication OG 15, scale 1:63,360. (OGCC Pool Series Map P 2)

OG 35. Oil and natural gas occurrence in Arizona: Rauzi, S.L., 2004, Arizona Geological Survey Oil and Gas Publication OG 35, chart. (OGCC Chart C 1) [published annually]

MANUSCRIPTS SUBMITTED FOR EXTERNAL PUBLICATION

Moore, J., Adams, M., Allis, R., Lutz, S., and Rauzi, S., Mineralogical and geochemical consequences of the long-term presence of CO_2 in natural reservoirs: An example from the Springerville-St. Johns field, Arizona and New Mexico, U.S.A.: submitted for publication by the U.S. Department of Energy.

Pelletier, J.D., Mayer, Larry, Pearthree, P.A., House, P.K., Demsey, K.A., Klawon, J.E., and Vincent, K.R., An integrated approach to alluvial-fan flood-hazard assessment with numerical modeling, field mapping, and remote sensing: Application to the southern Tortolita and Harquahala piedmonts, Arizona: Geological Society of America Bulletin.

White, S.P., Allis, R.G., Bergfeld, D., Moore, J.N., Chidsey, T.C., Morgan, C., McClure, K., and Rauzi, S.L., Evaluating the seal integrity of natural CO_2 reservoirs of the Colorado Plateau: submitted for publication by the U.S. Department of Energy.