

1989-90
ANNUAL REPORT

by

Larry D. Fellows,
Director and State Geologist

Arizona Geological Survey
Open-File Report 90-11

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

This report is preliminary and has not been edited or reviewed for conformity
with Arizona Geological Survey standards



State of Arizona
Arizona Geological Survey

845 North Park Avenue, #100
Tucson, Arizona 85719
(602) 882-4795

Rose Mofford
Governor

Larry D. Fellows
Director and State Geologist

August 29, 1990

The Honorable Rose Mofford
Governor
State Capitol, West Wing
Phoenix, AZ 85007

Dear Governor Mofford:

Fiscal year (FY) 1989-90 was the first year of the *second century* that the Arizona Geological Survey and its predecessors have proudly served Arizonans. It is a pleasure to submit this summary of our accomplishments during the year. The first several pages highlight activities; lists of completed reports and maps follow, together with descriptions of services provided and names of groups assisted.

The Arizona Geological Survey has two major statutory goals: (1) to investigate, map, describe, and interpret the geologic setting of the State, including its geologic hazards and limitations and its mineral and energy resources; and (2) to inform government agencies, industry, and the public about them. As Arizona's population increases, additional demands are made on the State's land, water, mineral, and energy resources. Better knowledge of the distribution and character of these resources is required, therefore, in order for those responsible to make *informed* decisions about their use and management.

In many parts of the State, ground water has been pumped much faster than it has recharged, the land has subsided, and large cracks, called earth fissures, have developed. Subsidence and earth fissures have already affected the use of the land and ground water in many areas. Their impact will become more severe, however, as development increases in urban-fringe and other areas. Information about subsidence and earth fissures will, therefore, be crucial. This report describes geologic investigations of subsiding areas and other areas throughout the State that were completed by Arizona Geological Survey geologists during FY 1989-90.

Serving Arizonans during your administration has been a pleasure. We hope you enjoy retirement.

Respectfully yours,

Larry D. Fellows, Ph.D.
Director and State Geologist

Office of the Governor

PROCLAMATION

* CENTENNIAL CELEBRATION OF GEOLOGICAL SURVEY IN ARIZONA *

WHEREAS, the State of Arizona has been richly endowed with metallic and nonmetallic mineral resources, and the discovery and exploitation of these resources was, and continues to be, a major factor in the development and economy of the State and the Nation; and

WHEREAS, the State of Arizona has experienced substantial population increase since the 1950's and is projected to attract new residents at a rapid rate for many years; and

WHEREAS, wise management of the State's lands and mineral resources requires objective, scientific geologic data and assistance, which will become increasingly important as population growth causes the competition for and conflict over land and mineral resources to accelerate;

WHEREAS, the Arizona Geological Survey, an agency of the State of Arizona, and its predecessors, the Arizona Bureau of Geology and Mineral Technology (1977-1988), the Arizona Bureau of Mines (1915-1977), the University of Arizona "Bureau of Mines" (1891-1915), and the Office of the Territorial Geologist (1889-1912), have investigated Arizona's geological framework and mineral resources and have served as a major source of information and assistance since March of 1889;

NOW, THEREFORE, I, Rose Mofford, Governor of the State of Arizona, do hereby proclaim March, 1989 through March, 1990, as a

* CENTENNIAL CELEBRATION OF GEOLOGICAL SURVEY IN ARIZONA *

and I commend and congratulate the Arizona Geological Survey and its predecessors for one hundred years of outstanding contributions and service, and I challenge them to continue to investigate Arizona's geologic framework, mineral and energy resources, and geologic hazards and limitations in order to provide the level of information and service that will be required in the years to come.

IN WITNESS WHEREOF I have hereunto set my hand and caused to be affixed the Great Seal of the State of Arizona


GOVERNOR

DONE at the Capitol in Phoenix on this the fourteenth day of December in the Year of Our Lord One Thousand Nine Hundred and Eighty-nine and of the Independence of the United States of America the Two Hundred and Thirteenth.

ATTEST:


Secretary of State



Annual Report

The State Geologist shall make an annual report to the Governor on the progress and condition of the Arizona Geological Survey, of pertinent facts concerning this state's geologic setting, and of such other pertinent information as the State Geologist deems proper.

27-155
Arizona Revised Statutes
Laws 1987, Ch. 158

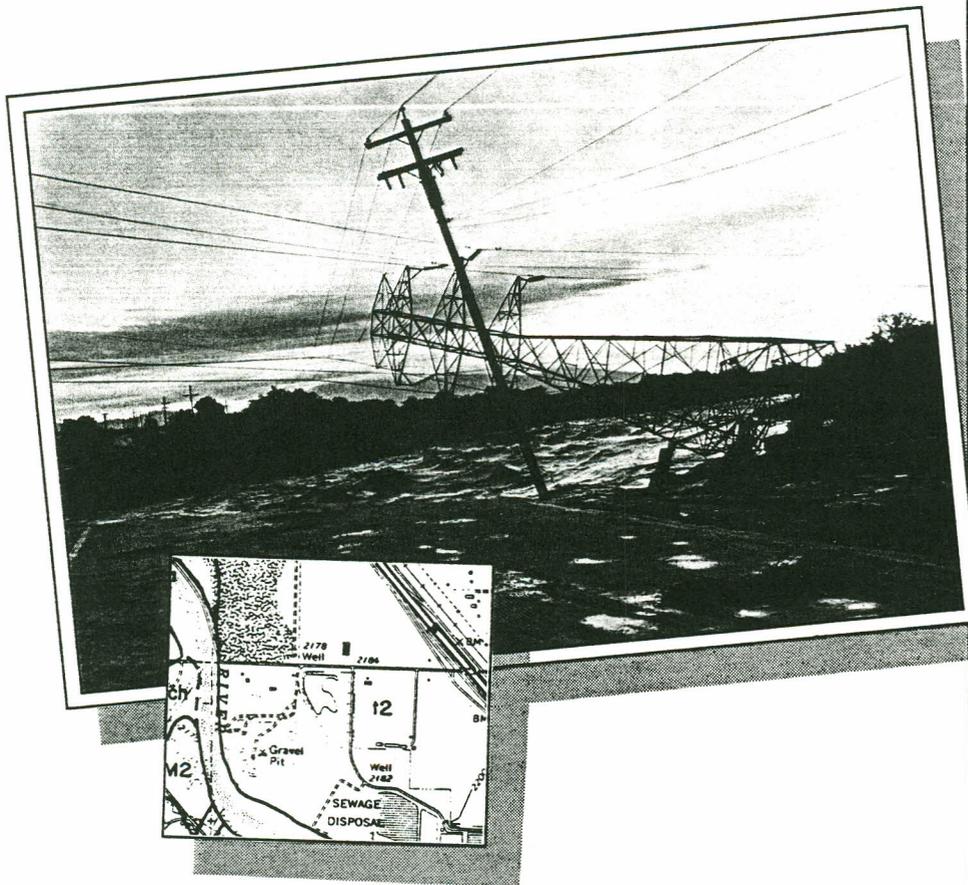


Table of Contents

Summary of Activities	1
Centennial Celebration	1
Geologic Framework and Mapping	1
Mineral and Energy Resources	2
Geologic Hazards and Limitations	2
Information and Assistance	4
Administration	6
Fiscal Year Accomplishments	7
Projects Completed	7
Information and Services Provided	10
Organization and Personnel	17
Budget and Expenditures	20
Advisory Committees	22
AZGS Location Map	24

Summary of Activities

CENTENNIAL CELEBRATION

Fiscal year (FY) 1989-90 marked the beginning of the *second century* that the Arizona Geological Survey (AZGS) and its predecessors have proudly served Arizonans. To commemorate this milestone event, Governor Rose Mofford proclaimed March 1989 through March 1990 as a "Centennial Celebration of Geological Survey in Arizona." The Arizona Territory was served intermittently by the Territorial Geologist from 1889 until statehood in 1912. Service to the State has been continuous since 1915, first by the Arizona Bureau of Mines, then the Arizona Bureau of Geology and Mineral Technology, and finally, the AZGS.

The AZGS conducts investigations and provides basic geologic information needed by the State of Arizona and its citizens. The topics or areas addressed during FY 1989-90 include geologic mapping, mineral and energy resources, and geologic hazards and limitations. The projects and activities completed and summarized in this report are partial indicators of the degree to which geologic investigations and information dissemination have progressed since Territorial Geologist days.

GEOLOGIC FRAMEWORK AND MAPPING

AZGS geologists study Arizona's total geologic setting, or framework, emphasizing the origin and character of rocks and rock-derived materials (gravel, sand, clay, and others) on the land surface and in the subsurface. Knowledge of these factors is critical to many users of land, water, mineral, and energy resources. Complete references to the reports and maps described below are shown on pages 7-10.

Phoenix Area

Geologic mapping and studies are in progress in the Phoenix quadrangle, which extends westward from Phoenix nearly to Quartzsite and southward from Wickenburg to Gila Bend. This area was selected for geologic study because it is complex, poorly understood, and extensively mineralized and because it contains major facilities, such as the Palo Verde Nuclear Generating Station, Central Arizona Project (CAP) canal, and New Waddell Dam. The AZGS and U.S. Geological Survey (USGS) have cooperated on the project since 1984 as part of the USGS' Cooperative Geologic Mapping Program (COGEMAP). The U.S. Bureau of Land Management assisted the project by providing the color aerial photographs that the geologists needed to prepare the maps.

During FY 1989-90, AZGS geologists finished mapping the New River area and the White Tank Mountains near Phoenix and the Little Horn Mountains farther west. A geologic map of the Vulture Mountains was published (Map 27), and work began on a comprehensive report of this area. Maps of the bedrock units in the Granite Wash Mountains and the surficial deposits in the southeastern quarter of the Phoenix quadrangle were released as Open-File Reports (OFR) 89-4 and 89-7, respectively.

Tucson Basin

In 1988 AZGS geologists began a new program to map the materials derived from the weathering of bedrock in adjacent mountains and deposited within the Tucson basin. Information about the distribution and character of these materials has been made available to the public. Such information is needed by those who assess potential geologic hazards and limitations (flooding, collapsing soils, landslides, earthquakes, land subsidence, etc.) before these individuals locate, design, and construct highways, bridges, office buildings, housing subdivisions, waste disposal facilities, and the like. Maps of eight 7 1/2-minute quadrangles were completed and released as OFR 89-2 and OFR 90-3 in FY 1989-90.

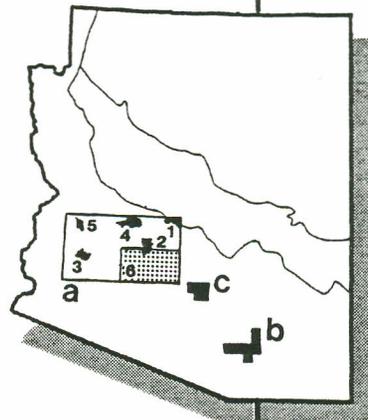
Pinal County

Mapping of surficial deposits and geologic hazards in the Picacho-Eloy-Toltec area was completed in conjunction with a study of earth fissures. Maps of five 7 1/2-minute quadrangles were released as OFR 90-2.

Mission Statement

The Arizona Geological Survey will assist the wise use of lands and mineral resources in this state by providing scientific and investigative research and information for use by the legislature, governmental agencies, industry and the public.

Section 1. Findings and Intent
Senate Bill 1102
Thirty-Eighth Legislature
First Regular Session, 1987
Laws 1987, Ch. 158



- AZGS projects on geologic framework and mapping.
- (a) Phoenix 1° x 2° quadrangle:
 - (1) New River Mountains;
 - (2) White Tank Mountains;
 - (3) Little Horn Mountains;
 - (4) Vulture Mountains;
 - (5) Granite Wash Mountains;
 - (6) Area of mapped surficial deposits.
 - (b) Tucson basin.
 - (c) Picacho-Eloy-Toltec area.

Bibliographies and Indexes

A list of more than 4,500 selected references on the geology and mineral resources of Arizona was released as OFR 89-5. This represents the first step toward preparation of a comprehensive bibliography. An index of geologic maps published in 1988 was released as OFR 89-3. Several bibliographies of mineral resource publications were also released and are described in another section.

Rock Cuttings and Cores

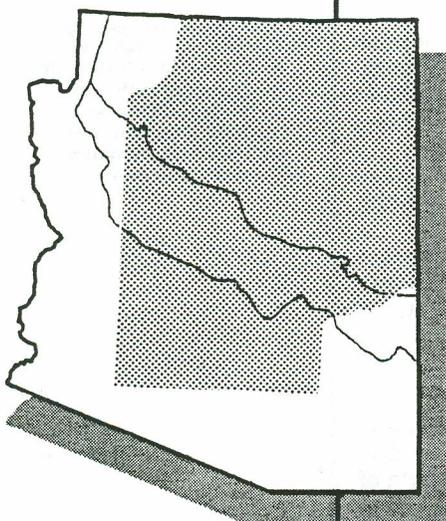
During the previous year, the U.S. Bureau of Mines (BOM), with the help of the Minnesota Air National Guard, shipped nearly 32,000 feet of diamond-drill core to the AZGS. These cores, all from Arizona, had been stored at the BOM's Twin Cities Core Repository, which was closed. Because the AZGS had no facility to store the cores, Mr. James Lichtenhan, mine superintendent at ASARCO's Mission Unit, allowed them to be stored temporarily in the desert on company property. In June 1990, they were moved into a warehouse in Tucson. Many of the cores will have to be reboxed to repair damage caused by sun and rain before they can be made available for public examination. In addition, shelves must be installed and the cores must be indexed and catalogued. Plans are underway to begin this task during FY 1990-91.

Arizona Geological Society Digest 17

S.J. Reynolds was coeditor of this comprehensive volume, *Geologic Evolution of Arizona*, which included five papers authored or coauthored by AZGS geologists, as well as the *Geologic Map of Arizona*, which was published in 1988 by the AZGS as Map 26.

MINERAL AND ENERGY RESOURCES

AZGS geologists conduct regional and mineral-district studies to determine the relationships between mineral deposits and the geologic framework of Arizona and, ultimately, to assess mineral resource potential in specific areas within the State. Mineral and energy resource data are added to the AZGS computerized information system.



AZGS projects on mineral and energy resources. Shaded area: Counties covered by Circulares 27 (Gila, Maricopa, Pinal, and Yavapai) and 28 (Apache, Coconino, and Navajo) in bibliographic series.

Bibliographies

In 1983 the AZGS defined metallic mineral districts in Arizona using geologic criteria, compiled cumulative mineral production data by district, and published these data in Bulletin 194. A series of county bibliographies that list primary and secondary references for each district was begun in 1986 (Circular 24). During FY 1989-90, this series was completed with the release of Circulares 27 (Gila, Maricopa, Pinal, and Yavapai Counties) and 28 (Apache, Coconino, and Navajo Counties).

Database

AZMIN, a digital database for Arizona's metallic mineral districts, was released as OFR 89-8. AZMIN databases and programs were developed on IBM-PC-compatible microcomputers through the use of dBase IV, a database-management program. AZMIN consists of 3 database files and 10 AZGS-developed data-manipulation programs that allow the user to search data or display them in various formats. AZMIN includes mineral-district locations, mine names, deposit classifications and ages, production figures, bibliographic information, and other data. This report, the first computer database the AZGS has released for sale, includes 42 printed pages of documentation and either high- or low-density floppy disks.

Energy Resources

The AZGS and Energy Office of the Arizona Department of Commerce initiated a cooperative project with two objectives: (1) to compile a 1:1,000,000-scale colored map that shows the location of energy resource areas and major production and storage facilities; and (2) to prepare a nontechnical summary on Arizona's major energy resources (coal, hydroelectric power, uranium, oil and gas, and geothermal energy). The map has been printed (Map 28), and an accompanying report will be completed in FY 1990-91.

GEOLOGIC HAZARDS AND LIMITATIONS

Some geologic processes and materials may be hazardous or may otherwise limit the use of land, water, mineral, and energy resources. Such limitations result from flooding, earthquakes, land subsidence and fissuring, caliche, thin soil cover, and the physical properties of some clay soils. It is essential to understand the nature of these limitations

INFORMATION AND ASSISTANCE

The two major statutory responsibilities of the AZGS—to conduct investigations and to provide information—are closely linked. Information derived from original investigations is added to databases, published in reports and maps, and provided to the public in talks, field trips, reviews, and displays. Major data users are government agencies, mineral exploration companies, geotechnical consulting firms, professional societies, university faculty, graduate students, earth science teachers, and the general public. Examples of information and assistance provided by AZGS staff members are listed on pages 10-16.

Information Requested

Geologic information and assistance were requested by individuals who telephoned, wrote, or visited the AZGS office to purchase publications, use the library and data files, or confer with geologists. More than 3,700 persons and organizations sought assistance. Revenue from the sale of publications totalled \$37,156, which was deposited in the printing fund and will be used to publish other reports and maps.

Publications Released

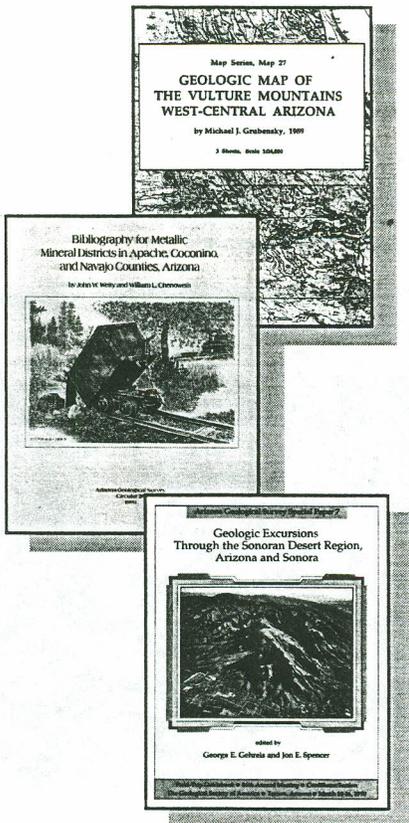
The AZGS is charged by statute to publish, or otherwise make available, the results of all investigations it completes. The following publications were released by the AZGS during FY 1989-90: bibliographies for metallic mineral districts in Gila, Maricopa, Pinal, and Yavapai Counties (**Circular 27**) and in Apache, Coconino, and Navajo Counties (**Circular 28**); a 202-page geologic guidebook through the Sonoran Desert region, Arizona and Sonora (**Special Paper 7**); a geologic map of the Vulture Mountains (**Map 27**); four 12-page issues of *Arizona Geology*; and 13 reports and maps in the Open-File Report series. In addition, 14 reports and 13 abstracts were published in professional journals and other non-AZGS volumes, and 8 reports and maps were completed and submitted for review or publication. A complete list of items published and submitted for publication is given on pages 7-10.

Arizona Geology

Four 12-page issues of *Arizona Geology* were published. The purpose of this publication is to inform readers about the geology of the State and its influence on Arizonans; publications or other materials related to the geology of Arizona; events, such as meetings, symposia, and conventions, that focus on geologic issues; and general activities of the AZGS. The circulation of *Arizona Geology* is approximately 2,600. Articles on the following subjects were included in the four issues published in FY 1989-90: earth fissures, earthquakes in Arizona, the Loma Prieta and northern Sonora earthquakes, geology of the Vulture gold mine, proposed wilderness legislation, registration of geologists, cooperative geologic mapping, the AZGS' centennial, Kartchner Caverns, the Gulf of California, Arizona's 1989 nonfuel mineral production, the future of economic geology in Arizona, recently completed theses and dissertations, new AZGS publications, and an index of *Arizona Geology* for 1971-89. A list of articles written by AZGS staff members is provided on page 8.

Talks, Field Trips, and Reviews

AZGS geologists gave 15 talks, led 17 field trips, and reviewed geologic articles and maps submitted for publication and proposals submitted for funding. They assisted 19 graduate students from 5 universities who were working on Arizona-related thesis projects and represented the agency as members of committees and professional groups.

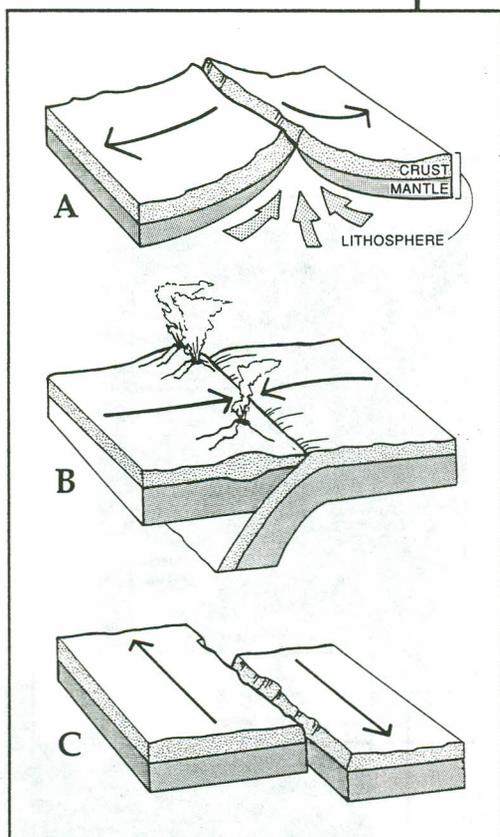


Selected AZGS publications released during FY 1989-90: Map 27 (top), Circular 28 (middle), and Special Paper 7 (bottom).



AZGS geologists P. A. Pearthree and S. J. Reynolds discuss areas of subsidence and earth fissures in Picacho basin with field-trip participants at the annual meeting of directors of western State geological surveys and U.S. Geological Survey representatives, held in Tucson October 22-25, 1989.

- OFR 90-3: JACKSON, G.W., 1990, Quaternary geologic map of the Corona de Tucson 7.5' quadrangle, Arizona: 6 p., scale 1:24,000.
- OFR 90-4: JACKSON, G.W., 1990, Tectonic geomorphology of the Toroweap fault, western Grand Canyon, Arizona: Implications for transgression of faulting on the Colorado Plateau: 67 p., scale 1:24,000, 2 sheets.



Three types of plate boundaries and relative plate motions. (A) Divergent (plates move away from each other): the process of sea-floor spreading creates new oceanic lithosphere; (B) Convergent (plates approach each other): the process of subduction destroys lithosphere and creates volcanoes; (C) Transform (plates slide past each other without approaching or diverging): transform faulting, such as that which occurs along the San Andreas fault, is the corresponding process. From *Arizona Geology* (v. 20, no. 2).

ARTICLES IN ARIZONA GEOLOGY

- FELLOWS, L.D., 1989, Environmental geology problems in the United States: v. 19, no. 3, p. 10.
- _____, 1989, Status of registration of geologists: v. 19, no. 3, p. 11-12.
- FELLOWS, L.D., and SPENCER, J.E., 1989, Proposed wilderness legislation: BLM Wilderness Study Areas: v. 19, no. 3, p. 1-3.
- PEARTHREE, P.A., 1989, AZGS hosts workshop on landslides in Arizona: v. 19, no. 3, p. 8.
- REYNOLDS, S.J., and GRUBENSKY, M.J., 1989, Cooperative geologic mapping in Arizona: 1989 COGEOMAP update: v. 19, no. 4, p. 11-12.
- SCHMIDT, Nancy, 1990, Plate tectonics and the Gulf of California region: v. 20, no. 2, p. 1-4.
- _____, 1990, Subject index to *Fieldnotes* and *Arizona Geology*, 1971-89: v. 20, no. 1, p. 10-12.
- SLAFF, Steven, 1989, Patterns of earth-fissure development: Examples from Picacho basin, Pinal County, Arizona: v. 19, no. 3, p. 4-5.
- SPENCER, J.E., REYNOLDS, S.J., GRUBENSKY, M.J., DUNCAN, J.T., and White, D.C., 1989, Geology of the Vulture gold mine: v. 19, no. 4, p. 1-4.
- Wallace, T.C., and PEARTHREE, P.A., 1989, The October 17, 1989 Loma Prieta (San Francisco) earthquake: v. 19, no. 4, p. 7.
- _____, 1989, Recent earthquakes in northern Sonora: v. 19, no. 3, p. 6-7.

Items Published by Professional Societies

BOOK

- Arizona Geological Society:
Jenney, J.P., and REYNOLDS, S.J., eds., 1989, Geologic evolution of Arizona: Digest 17, 866 p.

ARTICLES

- Arizona Geological Society:
Menges, C.M., and PEARTHREE, P.A., 1989, Late Cenozoic tectonism and landscape evolution of Arizona: Digest 17, p. 649-679.
- PEIRCE, H.W., 1989, Correlation problems of Pennsylvanian-Permian strata of the Colorado Plateau in Arizona: Digest 17, p. 349-368.

REYNOLDS, S.J., 1989, A new geologic map of Arizona: Digest 17, p. 863-866.

SPENCER, J.E., and REYNOLDS, S.J., 1989, Middle Tertiary tectonics of Arizona and adjacent areas: Digest 17, p. 539-573.

SPENCER, J.E., and WELTY, J.W., 1989, Mid-Tertiary ore deposits in Arizona: Digest 17, p. 585-607.

Association of State Floodplain Managers, Arid West Committee:

PEARTHREE, P.A., 1989, A geomorphic perspective on management of flood hazards on desert piedmonts in the southwestern United States, in *Partnerships: Effective flood hazard management*, Proceedings of the ASFPM annual meeting, Scottsdale, May 1989.

PEARTHREE, P.A., and Peartree, M.S., 1989, Geomorphology and flood hazard assessment in piedmont areas of Arizona, in *Proceedings of the ASFPM conference*, Las Vegas, October 1988.

Geology (Published by the Geological Society of America):

REYNOLDS, S.J., and Lister, G.S., 1990, Folding of mylonitic zones in Cordilleran metamorphic core complexes - Evidence from near the mylonitic front: v. 18, p. 216-219.

Journal of Geophysical Research:

SPENCER, J.E., and REYNOLDS, S.J., 1990, Relationship between Mesozoic and Cenozoic tectonic features in west-central Arizona and adjacent southeastern California: v. 95, p. 539-555.



Debris flow in the Huachuca Mountains, Cochise County. In July 1988, a significant debris flow threatened several homes in this area. A forest fire denuded vegetation from the upper drainage area. Runoff from a subsequent thunderstorm entrained boulders from the stream channel and deposited them near the residential area. AZGS geologists are currently assessing the extent of this geologic hazard in the Huachuca Mountains.

Arizona Department of Commerce, Energy Office:

DUNCAN, J.T., Energy resources map of Arizona, scale 1:1,000,000 (Contracted Project)

Geological Society of America *Bulletin*:

SPENCER, J.E., and REYNOLDS, S.J., Tectonics and mid-Tertiary extension along a transect through west-central Arizona.

Geology:

Lerch, M.F., Patchett, P.J., and REYNOLDS, S.J., Sr and Nd isotopic studies of Proterozoic rocks in west-central Arizona: Implications for Proterozoic tectonics.

Geomorphology:

Wohl, E.E., and PEARTHREE, P.A., Debris flows as geomorphic agents in the Huachuca Mountains of southeastern Arizona.

Norwegian Petroleum Society:

Laubach, S.E., Vendeville, B.C., and REYNOLDS, S.J., Patterns in the development of extensional fault block shapes from comparison of outcrop-scale faults and experimental physical models, *in* Larsen, R.M., ed., Structural and tectonic modeling and its application to petroleum geology.

Pima County Flood Control District:

PEARTHREE, P.A., DEMSEY, K.A., ONKEN, J.A., and VINCENT, K.R., A geomorphic assessment of fluvial behavior and flood-prone areas on the southern piedmont of the Tortolita Mountains, Pima County.

U.S. Geological Survey:

Carlson, Carl, and REYNOLDS, S.J., Arizona ages hypercard stack.

REYNOLDS, S.J., Geology of the Tucson and Nogales 1° x 2° quadrangles.

Project Proposals Funded

FELLOWS, L.D.: Arizona Department of Commerce, Energy Office: Energy resources map of Arizona: (\$6,205)

PEARTHREE, P.A.: Pima County Department of Transportation and Flood Control District: Potential flood hazard in alluvial fans in southern Tortolita Mountains (\$18,152)

_____: U.S. Bureau of Reclamation: Land subsidence study (\$1,474)

REYNOLDS, S.J.: U.S. Geological Survey: Cooperative geologic mapping in the Phoenix 1° x 2° quadrangle (\$40,000)

_____: Anniston (Alabama) Museum of Natural History: Rocks of Arizona (\$300)

_____: Arizona Geological Society: Membership database and mailings (\$1,500)

SPENCER, J.E.: Funded by the U.S. Environmental Protection Agency through the Arizona Radiation Regulatory Agency: Uranium occurrence in rocks in Arizona (\$28,769)

INFORMATION AND SERVICES PROVIDED

Talks Given (Abstracts Not Published)

Arizona Geological Society: Fluids and faults – Mineralization, metasomatism, and structural aspects. S.J. REYNOLDS

Arizona Geological Society and American Institute of Professional Geologists: One hundred years of service—The Arizona Geological Survey. L.D. FELLOWS

Arizona-Sonora Desert Museum, Tucson: Radon: A geologic hazard (two talks). J.E. SPENCER

Camp Cooper, Tucson: Mother Earth—The original recycler. T.G. McGARVIN

Colorado School of Mines, Golden, Colorado: Mineralization associated with large-displacement low-angle normal faults, west-central Arizona. J.E. SPENCER

FMC Gold Company, Las Vegas, Nevada: Mineral deposits related to large-displacement, low-angle normal faults in west-central Arizona. J.E. SPENCER

Grand Canyon College geology class: Geology of Arizona. L.D. FELLOWS

Lions Club, North Tucson Chapter: Arizona's gold. T.G. McGARVIN

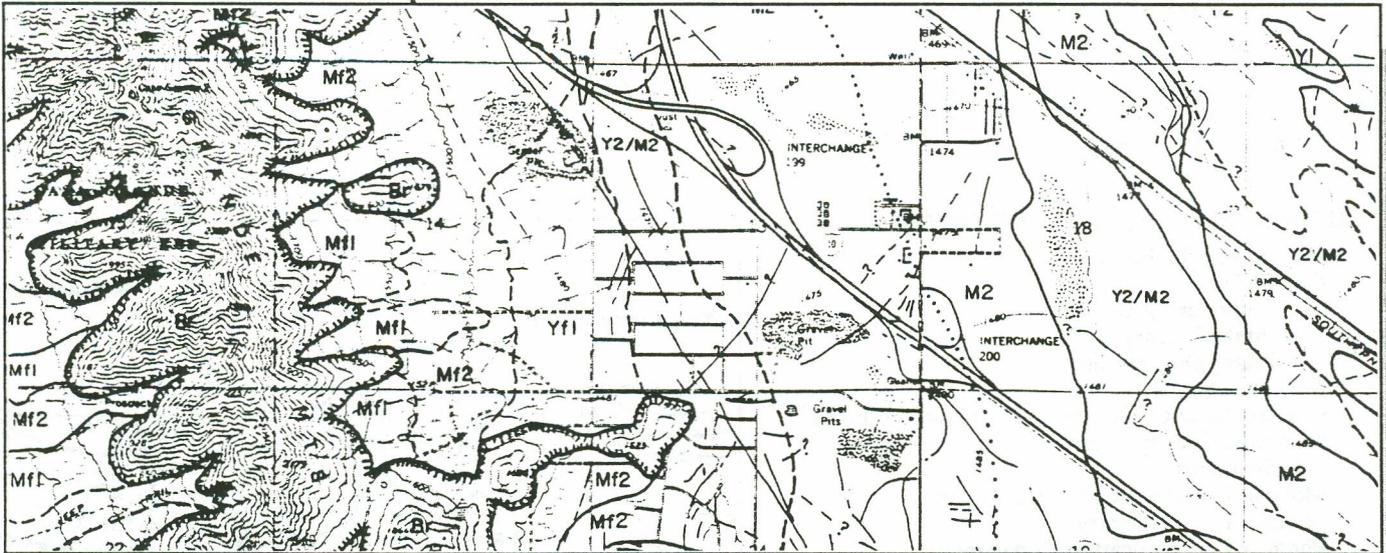
National Science Teachers Association meeting, Phoenix: Mineral mysteries and rock riddles—Methods of classroom identification. T.G. McGARVIN

New Mexico Bureau of Mines and Mineral Technology, Socorro, New Mexico: Cenozoic extensional tectonics and mineral deposits in west-central Arizona. J.E. SPENCER

Geological Society of America:

P.A. PEARTHREE and J.E. SPENCER each reviewed a manuscript being prepared for publication in *Geology*.

S.J. REYNOLDS and J.E. SPENCER each reviewed one manuscript being prepared as a Special Paper.



Surficial geologic map of part of Picacho basin. Through mapping and interpretation of Quaternary landforms, AZGS geologists have evaluated geologic hazards in the basin, including flooding, debris flows, earth fissures, and soil-related problems. From AZGS Open-File Report 90-2.

J.E. SPENCER reviewed one manuscript being prepared for publication in the *Bulletin*.

J.E. SPENCER served as Field Trip Committee Chairperson for the 1990 meeting of the Cordilleran Section in Tucson. As such, he prepared budgets for the 18 field trips that were given. P.A. PEARTHREE served as a member of the Field Trip Committee and organized transportation for the field trips.

Geomorphology:

P.A. PEARTHREE reviewed one manuscript being prepared for publication as part of the 21st annual Binghamton Geomorphology Symposium proceedings volume.

Journal of Geophysical Research:

S.J. REYNOLDS reviewed one manuscript being prepared for publication.

National Science Foundation:

J.E. SPENCER reviewed four proposals being considered for funding, and S.J. REYNOLDS reviewed five.

U.S. Geological Survey, National Earthquake Hazards Reduction Program:

P.A. PEARTHREE reviewed three proposals considered for funding.

Service on Thesis and Dissertation Committees

AZGS geologists served on eight thesis and dissertation committees: seven from the University of Arizona and one from the University of New Mexico. In addition, they assisted 11 other graduate students representing Arizona State University, California State University - Los Angeles, Monash University (Australia), and the University of Arizona.

Service on State Government Committees

Ad hoc Subsidence Committee: L.D. FELLOWS, member.

Commission on the Arizona Environment: L.D. FELLOWS, Advisory Council member.

Riparian Habitat Task Force: L.D. FELLOWS, member.

Service to Government Agencies

STATE OF ARIZONA

Arizona Highways magazine

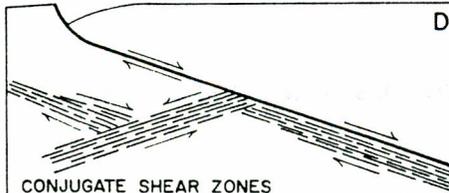
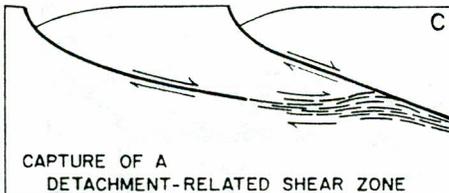
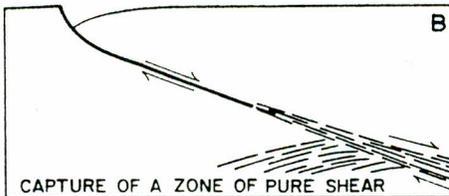
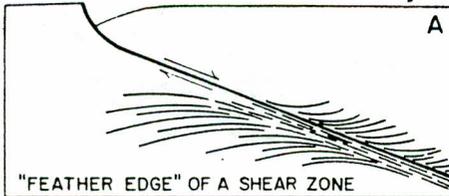
Department of Administration, Office of Risk Management

Department of Commerce, Arizona Energy Office

Department of Environmental Quality

Department of Mines and Mineral Resources

Menlo Park, Calif.
 MIO, Reno, Nev.
 Salt Lake City, Utah
 Tucson Field Office
 Tucson Water Resources Division
 Western Mineral Resources
 Western Regional Geology
 Lawrence-Berkeley Laboratories
 Luke Air Force Base, Engineering Design Section
 National Academy of Sciences
 National Park Service:
 Grand Canyon National Park
 Saguaro National Monument, West Unit
 Western Archeological Conservation Center



National Science Foundation
 Soil Conservation Service
 Treasury Department, Customs
 Service
 Yuma Proving Ground

OTHER COUNTRIES AND STATES

Anniston (Ala.) Museum of Natural
 History
 California Division of Mines and
 Geology
 Canadian Geological Survey
 Cleveland Museum, Ohio
 Cleveland Public Library, Ohio

Models for a ductile shear zone along a detachment fault. Determining the geologic events that created such features enables researchers to understand the origin of 15 geologically unusual mountain ranges in Arizona and to locate mineral deposits associated with them. From an article based on AZGS research and published in *Geology* (v. 18, p. 216-222).

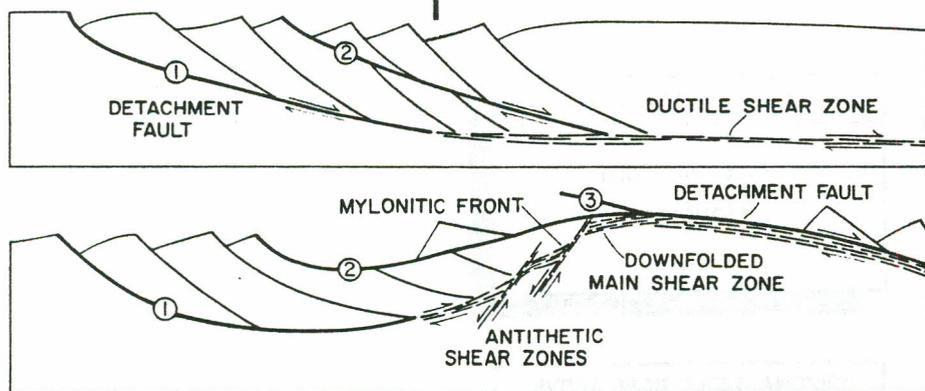
Midwest Library
 Nevada Agency for Nuclear Projects
 Nevada Bureau of Mines and Geology
 New Mexico Bureau of Mines and Mineral Resources
 San Bernardino County Museum, Calif.
 South Dakota Department of Natural Resources, Oil and Gas Division
 Texas Bureau of Economic Geology
 Utah Geological and Mineral Survey

Service to Educational Institutions

ARIZONA ELEMENTARY AND SECONDARY SCHOOLS

Amphitheater Public Schools, Tucson
 Apollo Middle School, Tucson
 Buckeye Elementary School, Buckeye
 Calabasas School, Santa Cruz County
 Carillo Intermediate School, Tucson
 Chaparral High School, Phoenix
 Cholla High School, Tucson
 Davis Bilingual Learning Center, Tucson
 Desert View High School, Tucson
 Estes Elementary School, Tucson
 Heritage Elementary School, Glendale
 Keeling School, Tucson
 Mesa Public Schools
 Mingus Union High School, Cottonwood
 Mission View Elementary School, Tucson
 Mountain View High School, Tucson
 Nadaburg Elementary School, Wittman
 Nash Elementary School, Tucson
 Peoria Unified School District
 Phoenix Union High School
 Roberts School, Tucson
 San Manuel School District, Science Coordinator
 Smith School, Tucson
 Thornydale Elementary School, Tucson

Southern Methodist University
 Stanford University
 State University of New York, Binghamton
 S.W. Missouri State University
 Texas A & M University
 University of California, Los Angeles
 University of California, Riverside
 University of California, Santa Barbara



University of Chicago
 University of Cincinnati
 University of Colorado
 University of Idaho
 University of Illinois
 University of Indiana
 University of Iowa
 University of Kansas
 University of Maryland
 University of Minnesota
 University of Nevada, Las Vegas
 University of Nevada, Reno
 University of New Mexico

Interpreted evolution of low-angle, normal shear zones along detachment faults. These areas of crustal extension in west-central Arizona are commonly associated with mineral deposits, including the recently discovered Copperstone deposit, which may contain more than 500,000 ounces of gold. AZGS research results of detachment faults have been summarized in numerous AZGS and other publications. From *Geology* (v. 18, p. 216-222).

University of Southern California
 University of Texas, Austin
 University of Texas, El Paso
 University of Utah
 University of Wyoming
 Utah State University
 Vanderbilt University
 Virginia Polytechnic Institute and State University
 Washington State University
 West Virginia University
 Western Michigan University
 Western New Mexico University

Service to the Public and Other Groups

Amerind Foundation
 Arizona Association for Learning in and About the Environment
 Arizona Mining Association
 Arizona Republic
 Arizona-Sonora Desert Museum
 Council of State Governments
 Desert Gold Diggers
 Hassayampa River Preserve
 Industrial Minerals Magazine
 International Archive for Economic Geology
 KSL, Salt Lake City (broadcasting station)
 Lions Club, Northwest Chapter
 National Geographic Society
 Nature Conservancy
 Old Pueblo Lapidary Club
 Tohono Chul Park
 Women's Auxiliary of the American Institute of Mining, Metallurgical, and Petroleum Engineers (WAAIME), Tucson Section

Budget and Expenditures

The expenses of the Arizona Geological Survey shall be paid by annual appropriation from the state general fund and as otherwise provided by this article.

(27-151.D)

The State Geologist shall enter into cooperative agreements with the federal government and its agencies or with any agency established by the law of this or any other state for the purpose of carrying out the provisions of this article.

(27-152.02.8)
Arizona Revised Statutes
Laws 1987, Ch. 158

Budget and Expenditures

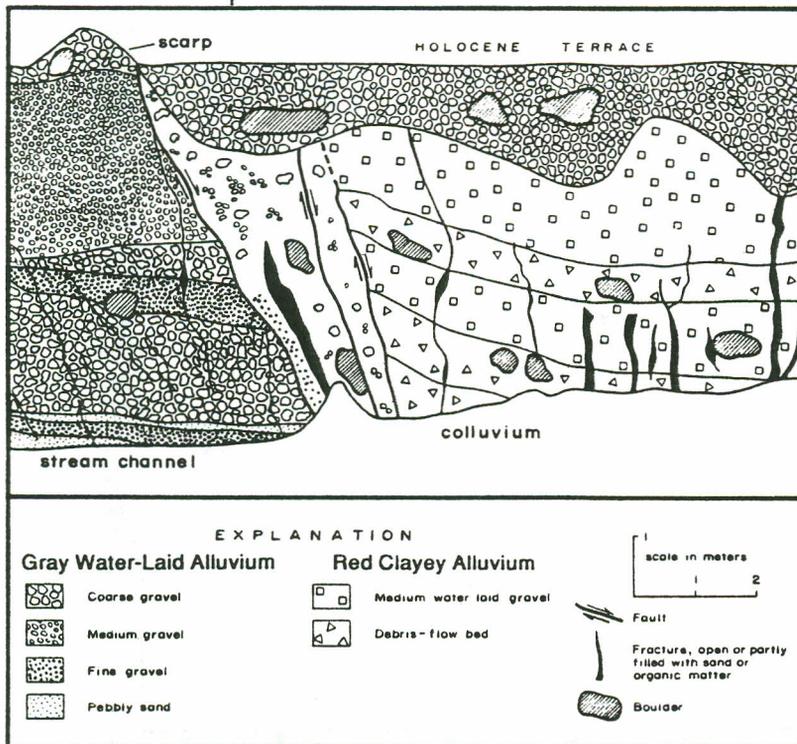
STATE APPROPRIATION AND EXPENDITURES

Category	FY 1988-89		FY 1989-90		FY 1990-91
	Budgeted	Spent	Budgeted	Spent	Budgeted
Personal Services	337,100	329,026	342,635	340,337	355,500 ^c
ERE (Benefits)	76,100	67,340	66,500	64,709	78,500
Operations	93,900	98,563	102,300	107,365	109,600
In-State Travel	5,900	4,477	6,100	5,228	6,700
Out-of-State-Travel	4,500	4,319	4,700	1,890	3,100
Capital Equipment	14,200	22,664	13,300	10,600	12,000
TOTAL	531,700	526,389^a	535,535	530,129^b	565,400

^a Received \$5,300 budget reduction at midyear

^b Received \$5,400 budget reduction at midyear

^c Includes 4.5% salary increase



Cross section of the Pitaycachi fault and alluvial deposits in Sonora, Mexico. The 1887 surface rupture, which shook Arizona and the Southwest with a 7.2-magnitude earthquake, occurred along the left fault. The other two faults and displaced alluvial sequences indicate that repeated ruptures have occurred in this area. From AZGS Special Paper 7.

Advisory Committees

The State Geologist may establish and appoint an advisory board consisting of independent practicing geologists, university or college faculty, mining geologists and others who use and rely on data, information and other services of the Arizona Geological Survey.

27-151.C.3
Arizona Revised Statutes
Laws 1987, Ch. 158

Advisory Committees

ENGINEERING AND ENVIRONMENTAL GEOLOGY ADVISORS

Kenneth M. Euge, R.G.
Geological Consultants
Phoenix

George A. Kiersch, R.G., P.E.
Kiersch Associates, Inc.
Tucson

R. Bruce Mack
Supervisor of Geohydrology
Salt River Project
Phoenix

Barbara H. Murphy
Dames & Moore
Phoenix

Stephen D. Noel, P.G.
President
Water Resources Assoc., Inc.
Phoenix

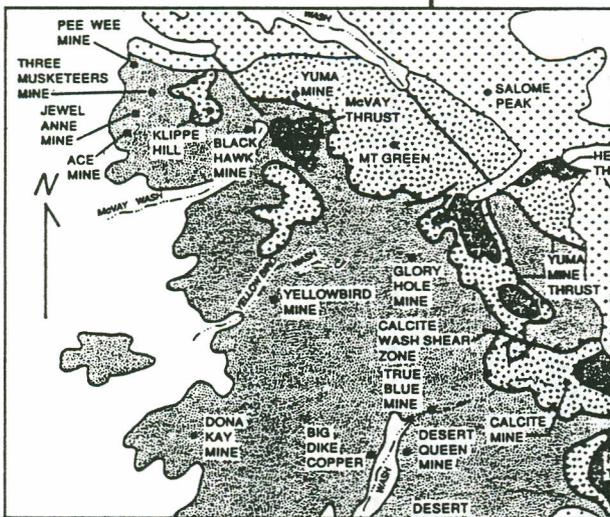
Troy L. Pewe
Consulting Geologist
Tempe

Frank S. Turek
Vice President
A-N West, Inc.
Phoenix

Ralph E. Weeks, P.G.
Vice President & Chief Geologist
Sergent, Hauskins & Beckwith
Phoenix

Gary D. Weesner
Hydrogeologist
Southwest Water and Mineral Resources
Phoenix

Wm. G. Wellendorf, P.G.
Director of Geosciences
Water Resources Assoc., Inc.
Phoenix



Major thrust plates, geographic features, and mines in the Granite Wash Mountains, one of the most geologically complex mountain ranges in western North America. Some deposits of gold, copper, and the industrial mineral kyanite are related to the major thrust faults. From AZGS Open-File Report 89-4.

Walter E. Heinrichs
President
Heinrichs Geo-exploration Co.
Tucson

Robert L. Hockett
Retired Senior Geologist
Magma Copper Co.
San Manuel

James D. Loghry
Consulting Geologist
Tucson

James N. Mayor
District Manager
Newmont Exploration Ltd.
Tucson

MINERAL RESOURCE ADVISORS

Daniel M. Aiken
Geologist
Cypress Sierrita Corp.
Green Valley

Russell M. Corn
Consulting Geologist
Tucson

Ted H. Eyde
President
GSA Resources, Inc.
Cortaro

Charles P. Miller
President
Miller Resources, Inc.
Tucson

Donald E. Ranta
U.S. Exploration Manager
Phelps Dodge Corp.
Tucson

E.M. Schern
Director of Engineering &
Geological Services
Phelps Dodge-Morenci, Inc.
Morenci

James D. Sell
Manager
Southwestern Exploration Dept.
ASARCO, Inc.
Tucson

Peter D. Tillman
Consulting Geologist
Tucson

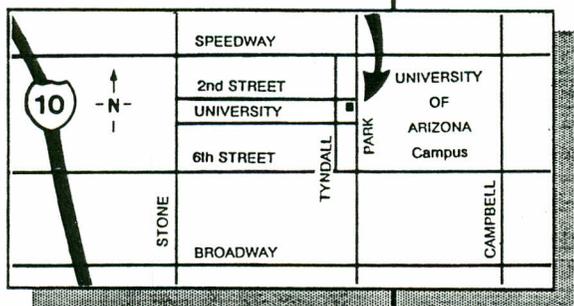
Barry Watson
Regional Manager
U.S. Borax
Tucson

Arizona Geological Survey

845 N. Park Ave.
Suite 100
Tucson, AZ 85719
(602) 882-4795

Information Services

- Answer requests for information and assistance
- Sell and distribute Arizona Geological Survey maps and reports
- Maintain public-access library of reports, books, maps, and other publications on the geology and mineral resources of Arizona
- Maintain public-access repository of rock cores, well cuttings, and related subsurface samples
- Educate public through lectures, displays, field trips, and quarterly publication, *Arizona Geology*
- *Arizona Geology*: Contains summaries of Arizona Geological Survey research, announcements of new publications, and articles on the geology of Arizona; free to U.S. residents



Office Hours: 8:00 a.m. to 5:00 p.m. Monday through Friday. A commercial parking lot is available behind the office building via Tyndall.