ANNUAL REPORT OF THE ARIZONA GEOLOGICAL SURVEY FOR THE FISCAL YEAR 1988-89 (JULY 1, 1988-JUNE 30, 1989)

by

Larry D. Fellows
State Geologist

Arizona Geological Survey
Open-File Report 89-11

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

September 1, 1989

The Honorable Rose Mofford
Governor
State Capitol, West Wing
1700 W. Washington
Phoenix, Arizona 85007

Dear Governor Mofford:

Fiscal year 1988-89 was a two-milestone year for the Arizona Geological Survey! It marked the completion of both our first century of service and our first year as an independent State agency. I'm proud to submit this report, which is organized to reflect our statutory responsibilities of conducting geologic investigations and providing information to assist in the wise use of Arizona's lands and mineral resources.

Our program goals address the geologic setting, population growth areas, mineral and energy resources, hazards and limitations, information, and public service. This report contains a list of studies completed and a summary of service activities. Our constituents include governmental agencies, industry, professional groups, university faculty and students, earth science teachers, and the general public.

Since 1889 geologic mapping and mineral investigations have been essential program elements. During FY 1988-89 we published a major report (Bulletin 189) on the geology and mineral resources of the Buckskin and Rawhide Mountains just east of Parker. As a member of your Wilderness Technical Advisory Committee I enlisted the help of my staff to assess mineral potential in Bureau of Land Management Wilderness Study Areas and respond to draft wilderness bills.

The role of our agency has changed significantly since 1977 because of the increased need for geologic data brought about by population growth and development. Evidence of this change is prominent in this report, which lists investigations completed and assistance provided on subjects such as the Superconducting Super Collider, geologic mapping in the Phoenix and Tucson areas, subsidence and earth fissures due to groundwater pumping, flood hazards, earthquakes, recent faults, and landslides.

Please call on us for geologic information in general, or for specific information about any of the activities described in this report.

Respectfully yours,

Larry D. Fellows

Larry D. Fellows
Director and State Geologist

LDF:lc

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Summary of Activities

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

Information and Assistance

Our two major responsibilities, conducting investigations and providing information, go hand in hand. Information generated from investigations is added to the databases and is subsequently disseminated in response to inquiries; through talks, field trips, reviews, and displays; and through the publication program. Current emphasis is being placed on expanding the computerized databases and ultimately making them more "user friendly."

Inquiries. Geologic information and assistance were requested by individuals who wrote, telephoned, or visited the office to confer with geologists, purchase publications, or use the library and data files. During the year Arizona Geological Survey (AZGS) staff provided information and assistance to more than 4,200 persons and organizations.

Talks, Field Trips, and Reviews. AZGS geologists gave 36 talks on the geology of Arizona; led 15 field trips; reviewed geologic field work, manuscripts submitted for publication, and proposals submitted for funding; assisted 40 graduate students from 15 universities with their thesis or dissertation projects; and represented the agency by serving as members of committees and professional groups. Groups served in this manner include the Arizona Computer Oriented Geological Society, American Geophysical Union, American Institute of Mining Engineers, American Institute of Professional Geologists, Arizona Association for Learning In and About the Environment, Arizona Geological Society, Arizona Science Teachers Association, Association of American State Geologists, Association of Earth Science Editors, Association of State Floodplain Managers, Geological Society of America, and Society of Economic Geologists. Examples of the types of information and assistance provided are documented on pages 13-23.

Earth Science Education. Forty-four elementary and secondary schools in Arizona requested information or assistance. Five field trips were led and three talks were given by T.G. McGarvin for groups of earth science teachers.

Publications. The AZGS is charged by statue to publish, or otherwise make available, the results of all investigations it completes. A new Geologic Map of Arizona (Map 26), Geology and Mineral Resources of the Buckskin and Rawhide Mountains, West-Central Arizona (Bulletin 198), and four 12-page issues of *Arizona Geology*, a research and information quarterly, were printed; eight reports or maps were released in the Open-File Report series; and three reports and two abstracts were published by professional societies. Special Paper 4 and Bulletins 168, 180, 185, and 190 were reprinted. Twelve reports and maps were completed and submitted for publication. Reports and maps published, reprinted, placed on open file, or submitted for publication are listed on pages 25-32. Nine reports in advanced stages of completion are listed on page 32. An index of items included in *Arizona Geology* during Fiscal Year 1988-89 is on page 33. Revenue from the sale of publications, $35,412, will be used to print other reports and maps.

The Contributed Map Series, which replaced the Miscellaneous Map Series, was established to provide an outlet for geologic maps prepared by geologists not employed by the AZGS. Many of these maps are from theses and dissertations and would not otherwise be readily available to the public.

A 14-library depository network was established in cooperation with the Arizona Department of Library, Archives, and Public Records to make AZGS publications available for examination in libraries throughout the State.

Mineral and Energy Resources

Buckskin and Rawhide Mountains. Detachment-fault-related mineral deposits described in Bulletin 198, are a newly recognized class of metallic mineral deposit. Mineral deposits associated with the Buckskin-Rawhide fault have yielded more than 50 million pounds of copper and 15,000 ounces of gold, worth more than $50 million at 1988 prices. The nearby Copperstone mine, which went into production in 1987 and is now Arizona's largest gold producer, is also related to a detachment fault.

A primary purpose of the studies described in Bulletin 198 was to characterize the detachment faults and associated mineral deposits and clarify their origins. Improved understanding of the geology and mineral deposits of the Buckskin and Rawhide Mountains will, therefore, increase the possibility of future discoveries of economic mineral deposits both in the study area and in other parts of the State.

Mineral Potential in Wilderness Study Areas. Several bills to designate as wilderness all or portions of Wilderness Study Areas (WSA) administered by the U.S. Bureau of Land Management (BLM) in Arizona were introduced in the U.S. Congress. The McCain-DeConcini bill (S1080) would add 895,150 acres to the wilderness system. Congressman Udall introduced two bills: HR2570, which designates as wilderness 1,430,480 acres of public land, administered by the BLM, and HR2571, which would add 1,387,910 acres that are now National Wildlife Refuge lands.

AZGS geologists reviewed the geologic setting of the WSA's, assessed their mineral potential, and concluded that many areas recommended for wilderness status have moderate to high mineral potential. This conclusion is based on the nearly 20 person-years of geologic mapping and investigation they have done in western and southern Arizona since 1981, as well as on their knowledge of the geology in other areas.

Even though prospecting in Arizona and adjacent states has taken place for more than 100 years, not all mineral deposits have been discovered. This is borne out by the recent discovery of the Copperstone gold mine, which now produces 62,000 ounces of gold per year, as well as by the numerous major gold deposits that have been discovered in Nevada during the last 10 years. Many individuals and companies are now actively looking for gold in western Arizona.

Dr. L.D. Fellows served as a member of the Wilderness Technical Advisory Committee established by Governor Rose Mofford and presented these conclusions to the committee, as well as to the Interior and Insular Affairs Committee of the U.S. House of Representatives.

Mineral District Bibliographies. In 1983 the AZGS published Bulletin 194, entitled "Metallic Mineral Districts and Production in Arizona," which included a map of metallic mineral districts, defined for the first time by geologic criteria, and cumulative metallic mineral production for each district from the 1880's to 1981. The AZGS then initiated a series of county bibliographies, which include references to publications on each of the mineral districts identified. Three bibliographies (Circulars 24, 25, and 26) covering Cochise, Graham, Greenlee, La Paz, Mohave, Yuma, Pima, and Santa Cruz Counties, were published prior to 1989. This year the bibliography for Gila, Maricopa, Pinal, and Yavapai Counties was prepared by J.W. Welty and released as OFR 89-1, pending publication as a circular. In addition, an update to Circulars 24, 25, and 26 was prepared by Welty and released as OFR 88-22.

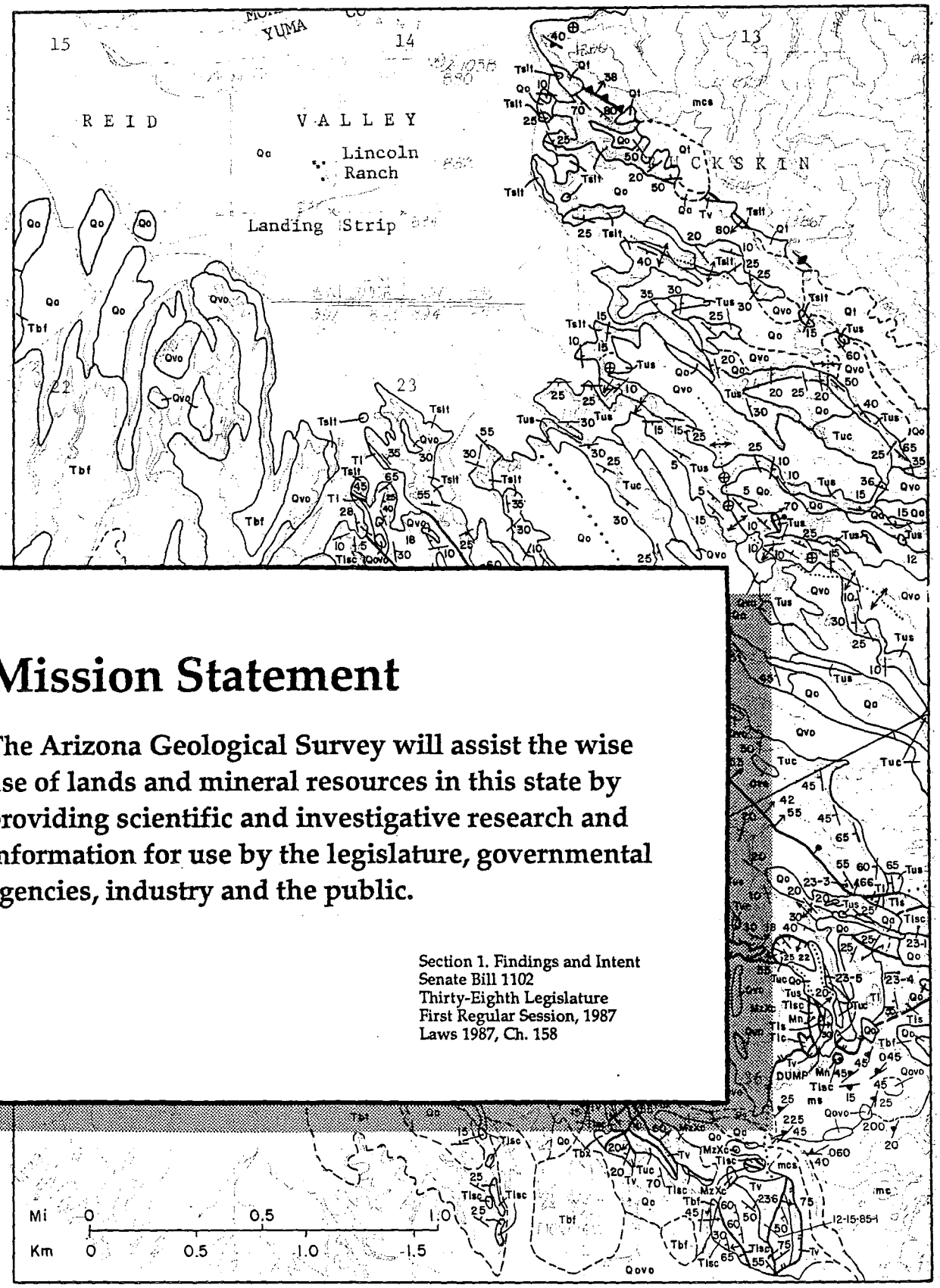
Huachuca Mountains Debris Flow. In July 1988, a debris flow threatened several homes near a tributary of Ash Creek at the southeastern end of the Huachuca Mountains in Cochise County. A forest fire the previous month denuded vegetation from the middle and upper portions of the drainage. During an intense thunderstorm, water runoff and fine-grained sediment from the steep slopes of the upper portion of the drainage formed a slurry, which entrained boulders from the stream channel. The slurry and boulders were deposited on an alluvial fan where the stream exits the mountains. Although houses on the alluvial fan were not seriously damaged, yards were rearranged as debris flowed among the houses. Before this event, debris flows had not been considered a serious threat in the area. The AZGS is conducting an investigation, directed by Dr. P.A. Pearthree, to (1) determine the physical properties of the debris flow; (2) assess the frequency of debris flows in that drainage; and (3) evaluate evidence for debris flows in other drainages in the Huachuca Mountains. Information derived from the study will enable AZGS staff to assess the extent of debris-flow hazards there.

Landslide Workshop. In May 1989, Dr. P.A. Pearthree organized and coordinated a workshop for evaluating landslide hazards in Arizona. Dr. E.E. Brabb from the U.S. Geological Survey Office of Earthquakes, Volcanoes, and Engineering in Menlo Park led the workshop and shared his expertise in landslide recognition and mapping. Representatives of the U.S. Forest Service, New Mexico Bureau of Mines and Mineral Resources, Nevada Bureau of Mines and Geology, and AZGS participated.

Brabb's principal objective was to teach the participants to evaluate landslide potential by defining the types and extent of landslide hazards in different areas. Such information may then be used to determine the types of larger-scale studies required in areas where landslides have occurred.

Knowledge of landslide occurrence in Arizona is limited because no systematic statewide survey has been conducted. The AZGS is beginning a program to inventory landslides in the State, building on the insights gained during the workshop.

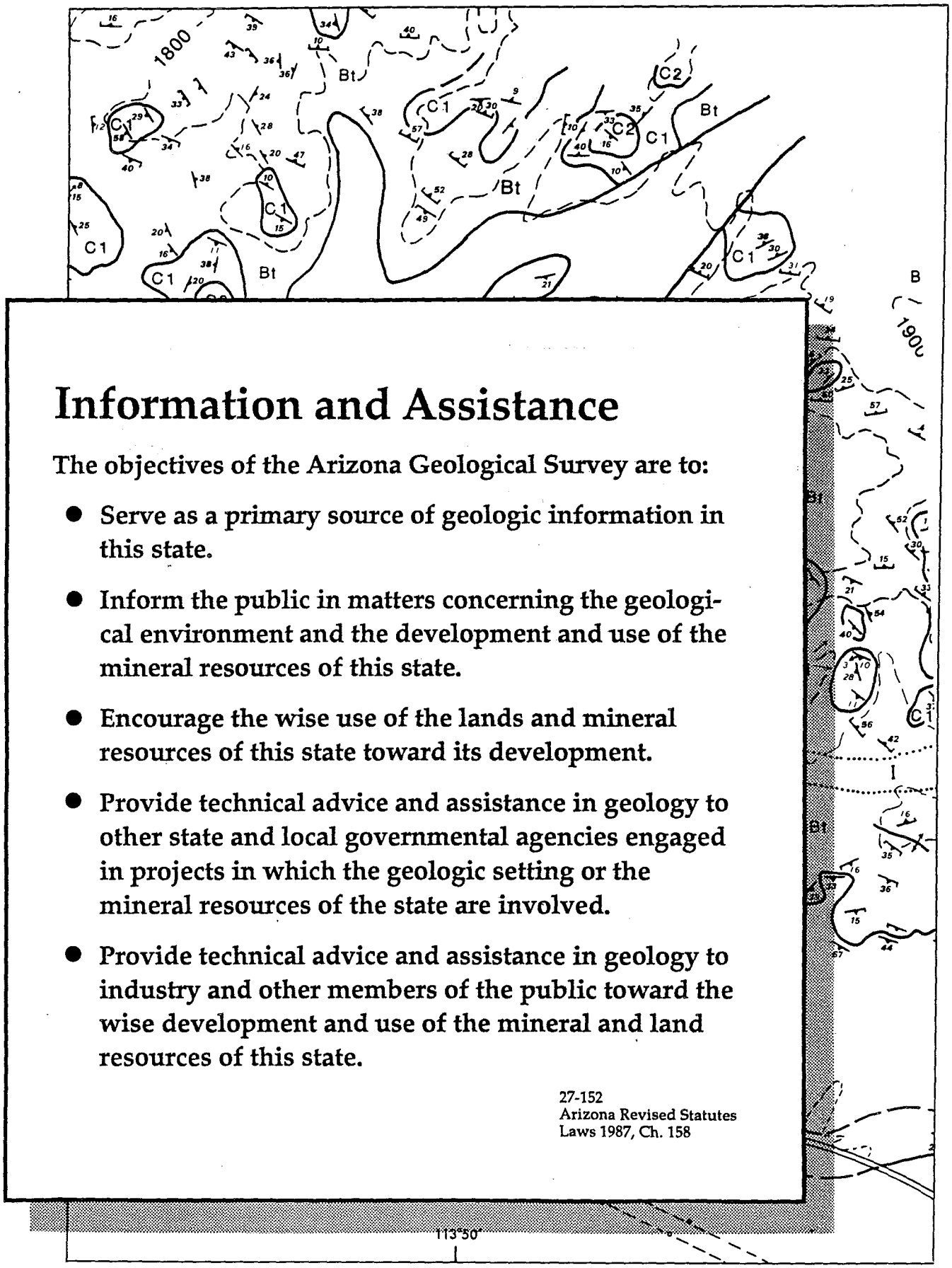
Supporting Data



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



Information and Assistance

The objectives of the Arizona Geological Survey are to:

- Serve as a primary source of geologic information in this state.
- Inform the public in matters concerning the geological environment and the development and use of the mineral resources of this state.
- Encourage the wise use of the lands and mineral resources of this state toward its development.
- Provide technical advice and assistance in geology to other state and local governmental agencies engaged in projects in which the geologic setting or the mineral resources of the state are involved.
- Provide technical advice and assistance in geology to industry and other members of the public toward the wise development and use of the mineral and land resources of this state.

27-152
Arizona Revised Statutes
Laws 1987, Ch. 158

GOVERNMENT AGENCIES
(and Associated Groups of Professionals)

Information and Assistance Provided

AZGS staff provided information and assistance to representatives of the following government agencies or units who visited our office, telephoned, wrote, or purchased publications:

State of Arizona
Office of Attorney General
Department of Commerce
  Superconducting Super Collider
Department of Corrections
Department of Economic Security
Commission on the Arizona Environment
Department of Environmental Quality
Game and Fish Department
State Land Department
Mine Inspector's Office
Department of Mines and Mineral Resources
Oil and Gas Conservation Commission
State Parks
Radiation Regulatory Agency
Department of Real Estate
Board of Technical Registration
Department of Transportation
Department of Water Resources

Agencies from Other States
California Division of Mines and Geology
Nevada Bureau of Mines and Geology
New Mexico Bureau of Mines and Mineral Resources
North Dakota Geological Survey
North Dakota Industrial Commission
Texas Bureau of Economic Geology
Utah Geological and Mineral Survey

Arizona County, City, and Other Government
Cochise County
Coconino Resource Center for Environmental Education, Natural Resource Conservation District
Maricopa County
City of Phoenix
Pima Association of Governments
Pima County Air Quality Control
Santa Cruz County Emergency Services
City of Scottsdale
Tucson Public Library
Tucson Department of Transportation
Tucson Water Department

United States Government
National Academy of Sciences
Army Corps of Engineers
Department of Energy
Environmental Protection Agency
Federal Emergency Management Agency
Fish and Wildlife Service
Forest Service
Geological Survey
Bureau of Indian Affairs
Jet Propulsion Laboratory
Bureau of Land Management
Lawrence-Berkeley Laboratory
Los Alamos National Laboratory
Bureau of Mines
National Park Service
Bureau of Reclamation
National Science Foundation
Soil Conservation Service
Yuma Proving Ground

Indian Nations
Hualapai
Navajo
Tohono O'odham

Other Nations
British Museum
Geological Survey of Japan

TALKS GIVEN

U.S. Department of Energy: Briefing to Secretary Herrington on the Maricopa SSC site. J.W. WELTY.

Association of State Floodplain Managers (Arid West Meeting, Las Vegas, October 1988): Geomorphology and flood hazard assessment in piedmont areas of Arizona. P. A. PEARTHREE.

Association of State Floodplain Managers, (National Meeting, Scottsdale, May 1989): A geomorphic perspective on management of flood hazards on desert piedmonts in the southwestern United States. P.A. PEARTHREE.

_____: Debris flow hazards in the Huachuca Mountains and southeastern Arizona. P.A. PEARTHREE.

U.S. Geological Survey: Mineral resource information at the AZGS; presented at Mineral Information Workshop in Sacramento, CA. J.W. WELTY.

Arizona Radiation Regulatory Agency: Distribution of rocks with above-normal uranium content; presented to group of county health department officials who met in Phoenix. L.D. FELLOWS.

Arizona Historical Society: What the rocks tell us--A geological history of Arizona. T.G. McGARVIN.

FIELD TRIPS LED

U.S. Forest Service (Advanced Minerals Management Course, Marana): Applied geology in Pinal County. L.D. FELLOWS.

_____, **(Minerals Administration Course, Marana):** Applied geology in Pinal County. L.D. FELLOWS.

REVIEWS

Governor Rose Mofford, Wilderness Technical Advisory Committee: L.D. FELLOWS served on the committee, purpose of which was to provide technical advice on wilderness bills. J.E. SPENCER, with assistance of other AZGS staff, reviewed BLM Wilderness Study Areas and assessed their mineral potential. Written testimony was presented to the U.S. House of Representatives Interior and Insular Affairs Committee.

Federal Emergency Management Agency and Pima Flood-Control District: P.A. PEARTHREE participated in a field review of flood-risk assessment procedures in the Tortolita fan area near Tucson.

INDUSTRY
(and Associated Groups of Professionals)

INFORMATION AND ASSISTANCE PROVIDED

AZGS staff provided information and assistance to representatives of 361 mineral exploration or mining companies, engineering and environmental geology firms, other companies, and consultants, who visited the office, telephoned, wrote, or purchased publications.

TALKS GIVEN

Arizona Geological Society: Advances in Arizona geology--a cook's tour of the new Geologic Map of Arizona. S.J. REYNOLDS.

_____: Geology and gold mineralization in the Kofa region, southwestern Arizona. M.J. GRUBENSKY.

_____: Geology and mineral deposits of west-central Arizona. J.E. SPENCER.

Society of Mining Engineers (Annual Meeting, Las Vegas, March 1989): Reconnaissance survey of background radioactivity in Arizona. L.D. FELLOWS.

REVIEWS

Arizona Geological Society: S.J. REYNOLDS participated in a field review of the "anatomy of a trap-door caldera," Tucson Mountains, led by the U.S. Geological Survey.

Mining Engineering: J.E. SPENCER reviewed a paper submitted for inclusion in this publication.

OTHER SERVICES

Arizona Geological Society: S.J. REYNOLDS served as coeditor of Digest 17, a member of the Publication Committee, and Vice-President for Programs; arranged the 1989 Spring Field Trip; and reviewed four manuscripts.

UNIVERSITY FACULTY AND STUDENTS

INFORMATION AND ASSISTANCE PROVIDED

AZGS staff provided information and assistance to faculty and students from the Arizona colleges and universities listed below and from 72 out-of-State and 10 foreign institutions who visited our office, telephoned, wrote, or purchased publications:

Arizona State University:
- Center for Environmental Studies
- Dept. of Electrical Engineering
- Dept. of Geology

Cochise College
Grand Canyon College
Maricopa College
Mesa Community College
Northern Arizona University:
- Arizona Earthquake Information Center
- Dept. of Geology

Phoenix College
Pima Community College
Scottsdale Community College
University of Arizona:
- Arizona State Museum
- Cancer Center
- Dept. of Atmospheric Science
- Dept. of Geosciences
- Dept. of Hydrology & Water Resources
- Dept. of Mining & Geological Engineering
- Graduate Library College
- Office of Arid Land Studies
- University Press

University of Phoenix
Yavapai College

TALKS GIVEN

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

Massachusetts Institute of Technology and Harvard University: Fluids and detachment faults: Mineralization, metasomatism, and structural aspects. S.J. REYNOLDS.

New Mexico Institute of Technology and New Mexico Bureau of Mines and Mineral Resources: Fluids and detachment faults--Mineralization, metasomatism, and structural aspects. S.J. REYNOLDS.

Northern Arizona University and U.S. Geological Survey: Mesozoic evolution of western Arizona. S.J. REYNOLDS.

Pima Community College: Debris flows and debris flow hazards in southern Arizona. P.A. PEARTHREE.

University of Arizona, College of Architecture: Implications of geology for architecture. P.A. PEARTHREE.

_____, **Department of Geosciences:** Application of Quaternary geology and geomorphology to seismic hazard analysis. P.A. PEARTHREE.

_____: Late Cenozoic tectonic evolution of Arizona. P.A. PEARTHREE.

_____: Middle Tertiary history of Arizona. S.J. REYNOLDS.

EARTH SCIENCE TEACHERS

Information and Assistance Provided

AZGS staff provided information and assistance to representatives of the 44 Arizona schools listed below who visited our office, telephoned, wrote, or purchased publications:

Amphitheater Public Schools, Tucson
Apache Junction High School
Camp Cooper, Tucson Unified School District
Canyon Del Oro High School, Tucson
Catalina Foothills School District, Tucson
Copper Creek School, Tucson
Coronado School, Tucson
Dietz School, Tucson
Emily Gray School, Tucson
Fickett Middle School, Tucson
Gallego School, Tucson
Gila Bend School District #24
Heritage School, Glendale
Hohokam Middle School, Tucson
Holladay Intermediate School, Tucson
Ironwood School, Tucson
Kino School, Tucson
Lake Havasu Public Schools
McClintock High School, Tempe
Manzo School, Tucson
Marana High School
Mesa Public Schools--Science Resource Center
Mesa Verde School, Tucson
Mingus-Union High School
Mohave Middle School
Mt. View High School, Tucson
Palo Verde High School, Tucson
Parker High School
Payson High School
Pierson Middle School, Nogales
Prescott Unified School District
Rancho Solano Private School, Phoenix
Rio Vista School, Tucson
Rogers School, Tucson
Sahuarita High School
Santa Rita High School, Tucson
Scottsdale Unified Schools
Sunnyside High School, Tucson
Sunnyside Jr. High School, Tucson
Thornydale School, Tucson
Thunderbird High School, Phoenix
Tucson High School
Tucson Unified School District, Home Bound Teleteaching
Wickenburg School District

Educational Associations:

Arizona Association for Learning in and about the Environment (AALE)
Arizona Science Teachers Association (ASTA)

TALKS GIVEN

Arizona Science Teachers Association Annual Meeting, Phoenix: Arizona's auriferous occurrences. T.G. McGARVIN.

Tucson Association of Museums and Smithsonian Institute: Geology unearthed. T.G. McGARVIN.

_____: Rock recipes. T.G. McGARVIN.

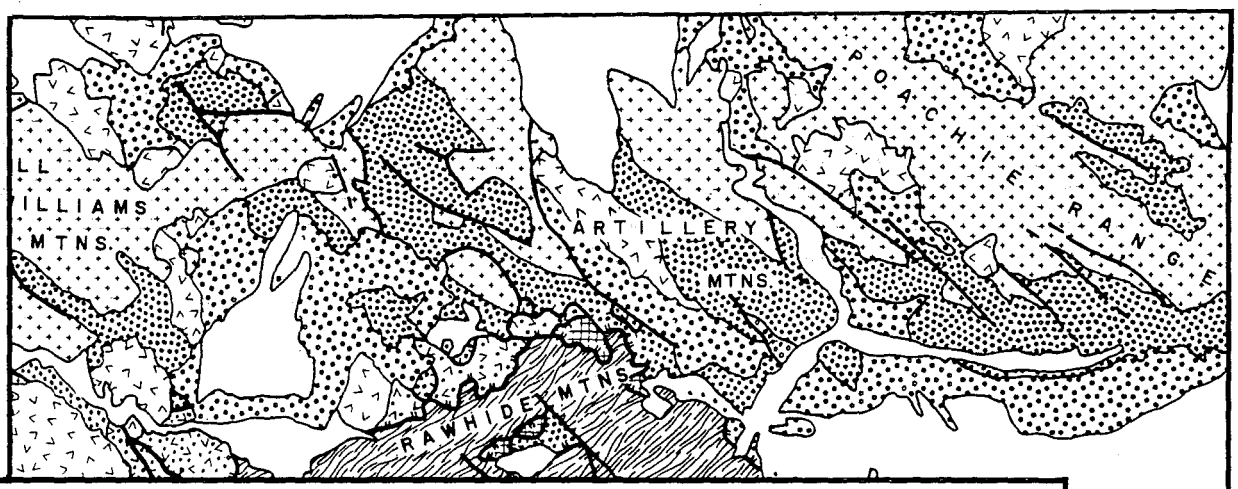
FIELD TRIPS LED

Western Tucson basin (three trips). T.G. McGARVIN.

Northern and eastern Tucson basin (two trips). T.G. McGARVIN.

OTHER SERVICES

National Science Foundation, Presidential Awards for Excellence in Science and Mathematics Teaching: L.D. FELLOWS served on selection committee for 1989 Presidential Awards Program.

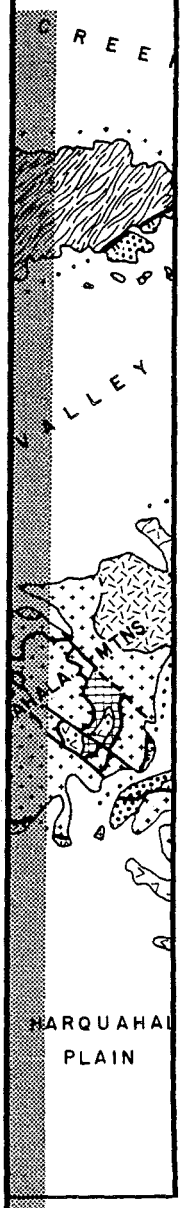


Research and Investigations

The Arizona Geological Survey shall:

- Investigate, describe and interpret the geological setting of this state, including its natural hazards and limitations, its natural attributes and its mineral resources.
- Perform and archive original research to promote public understanding of this state's geologic resources and natural setting.
- Conduct research and development activities concerning the exploration for the mineral resources of this state.
- Publish in the form of bulletins, circulars, maps and other related series or otherwise make available to state agencies, government officials, industry and the public the results of all geological and related research and investigation it undertakes.

27-152.01
Arizona Revised Statutes
Laws 1987, Ch. 158



Investigations Completed

Reports and maps completed, listed on following pages, are numbered consecutively for the purpose of preparing the index below. Some investigations relate to more than one category. Projects on which substantial progress was made, and which will be completed in FY 1989-90, are also listed, but are designated by letters. Authors' names that are capitalized and in bold type are AZGS employees or were employed on the specific project listed. Student employees are identified by an asterisk.

SUBJECT INDEX

Geologic Framework

1, 2, 3, 4, 5, 6, 8, 9, 13, 15, 22, 24, 32, 33, 35, 36, 39, 44, 45, 46, A, B, C, H

Geologic Maps

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Mineral and Energy Resources

1, 2, 5, 6, 7, 8, 17, 22, 29, 30, 31, 37, 38, 47, F

Natural Hazards and Limitations

18, 19, 24, 34, 41, 42, 43, B, D, E

Other

14, 16, 20, 21, 23, 34

PUBLISHED BY THE ARIZONA GEOLOGICAL SURVEY

Bulletins, Circulars, and Special Papers

1. BULLETIN 198: Geology and mineral resources of the Buckskin and Rawhide Mountains, west-central Arizona: J.E. SPENCER and S.J. REYNOLDS, editors, 1989, 280 p., 3 maps, scale 1:24,000, 1:42,850, and 1:100,000.

   Bulletin 198 includes 14 papers and 3 maps. Papers and maps authored or coauthored by AZGS geologists are listed below:

2. Introduction to the geology and mineral resources of the Buckskin and Rawhide Mountains, west-central Arizona: J.E. SPENCER and S.J. REYNOLDS, p. 1-10.

3. Pre-Tertiary rocks and structures in the upper plate of the Buckskin detachment fault, west-central Arizona: S.J. REYNOLDS and J.E. SPENCER, p. 67-102.

4. Tertiary structure, stratigraphy, and tectonics of the Buckskin Mountains: J.E. SPENCER and S.J. REYNOLDS, p. 103-167.

5. Geology and mineral deposits of the central Artillery Mountains: J.E. SPENCER, M.J. GRUBENSKY, J.T. DUNCAN*, J.D. SHENK*, J.C. Yarnold*, and J.P. Lombard*, p. 168-183.

6. K-Ar geochronology of Miocene extension, volcanism, and potassium metasomatism in the Buckskin and Rawhide Mountains: J.E. SPENCER, M. Shafiqullah, R.J. Miller, and L.G. Pickthorn, p. 184-189.

7. Mineralization in the central part of the Planet mineral district, northwestern Buckskin Mountains: N.E. Lehman and J.E. SPENCER, p. 215-222.

8. Geology of mineral deposits in the Buckskin and Rawhide Mountains: J.E. SPENCER and J.W. WELTY, p. 223-254.

9. Geology of postdetachment, Miocene volcanic rocks in the southwestern Buckskin Mountains, west-central Arizona: M.J. GRUBENSKY, p. 255-262.

10. Appendix A: Map-unit descriptions and cross sections for Plate 2: J.E. SPENCER, S.J. REYNOLDS, and N.E. Lehman, p. 263-269.

11. Plate 2: Geologic map of the Planet-Mineral Hill area, northwestern Buckskin Mountains, west-central Arizona J.E. SPENCER, S.J. REYNOLDS, and N.E. Lehman, scale 1:24,000.

12. Plate 3: Compilation geologic map of the Buckskin and Rawhide Mountains, west-central Arizona J.E. SPENCER, scale 1:100,000.

Open-File Reports (OFR)

23. OFR 88-13: Bibliographic conventions of the Arizona Geological Survey: K.C. HORSTMAN*, E.M. VANDENDOLDER and S.J. REYNOLDS, 1988, 22 p.

24. OFR 88-15: Reconnaissance assessment of Quaternary faulting in the Gila River region from San Carlos reservoir to Coolidge, Arizona: R.B. Scarborough and P.A. PEARTHREE, 1988, 12 p., 1 map, scale 1:250,000.

25. OFR 88-16: Index to published geologic maps of Arizona: T.G. McGARVIN, 1988, scale 1:1,000,000.

26. OFR 88-17: Geologic map of Quaternary and Upper Tertiary alluvium in the Phoenix North (30′ x 60′) Quadrangle, Arizona: K.A. DEMSEY*, 1988, scale 1:100,000.

27. OFR 88-18: Surficial geologic maps of the Tucson metropolitan area: M.A. McKITTRICK*, 1988, 12 maps, scale 1:24,000.

28. OFR 88-21: Late Cenozoic surficial deposits of the Tucson 1° x 2° Quadrangle, Arizona: P.A. PEARTHREE, M.A. McKITTRICK*, G.W. JACKSON*, and K.A. DEMSEY*, 1988, scale 1:250,000.

29. OFR 88-22: Additions to bibliographies for metallic mineral districts in Cochise, Graham, Greenlee, La Paz, Mohave, Pima, Santa Cruz, and Yuma Counties, Arizona: J.W. WELTY, 1988, 32 p.

30. OFR 89-1: Bibliography for metallic mineral districts in Gila, Maricopa, Pinal, and Yavapai Counties, Arizona: J.W. WELTY and L. Schnabel, 1989, 123 p.

PUBLISHED EXTERNALLY

Journal Articles

31. Geological Society of America *Bulletin*: K-metasomatism and detachment-related mineralization, Harcuvar Mountains, Arizona: M.S. RODDY*, S.J. REYNOLDS, B.M. Smith, and J. Ruiz, 1988, v. 100, p. 1627-1639.

32. *Geology*: Early Mesozoic uplift in west-central Arizona and southeastern California: S.J. REYNOLDS, J.E. SPENCER, Y. Asmerom, E. DeWitt, and S.E. Laubach, 1989, v. 17, p. 207-211.

33. *Journal of Geophysical Research*: Role of crustal flexure in initiation of low-angle normal faults and implications for structural evolution of the Basin and Range Province: J.E. SPENCER and C.G. Chase, 1989, v. 94, p. 1765-1775.

45. *Journal of Geophysical Research*: Miocene calc-alkaline magmatism, calderas, and crustal extension in the Kofa and Castle Dome Mountains, southwestern Arizona: M.J. GRUBENSKY and W.C. Bagby.

46. _____: Relationship between Mesozoic and Cenozoic tectonic features in west-central Arizona and adjacent southeastern California: J.E. SPENCER and S.J. REYNOLDS.

47. U.S. Geological Survey: Mineral resources of the Harcuvar Mountains Wilderness Study Area, La Paz and Yavapai Counties, Arizona: H. Drewes and others, including S.J. REYNOLDS and J.E. SPENCER, Bulletin.

IN ADVANCED STAGE OF COMPLETION
(Scheduled for completion in FY 1989-90)

A. Domino-style normal faults above a concealed detachment fault, Wickenburg Mountains, Arizona–Estimates of extension and of detachment position: J.E. Fryxell and S.J. REYNOLDS, to be submitted to *Geology*.

B. Map of fault ruptures, surficial deposits, and young volcanic rocks along the Toroweap fault zone, northwestern Arizona: G.W. JACKSON*.

C. Geometry of normal faults in layered rocks--An example from above the Buckskin detachment fault, Arizona: S.E. Laubach and S.J. REYNOLDS, to be submitted to *Geology*.

D. Analysis of debris-flow occurrence in the Huachuca Mountains: P.A. PEARTHREE and E.E. Wohl.

E. Progressive development of earth fissures in the Picacho basin, south-central Arizona: S. SLAFF*, G.W. JACKSON*, and P.A. PEARTHREE.

F. Availability of mineral-resource information in Arizona: J.W. WELTY, for inclusion in a U.S. Geological Survey Circular.

G. Surficial deposits in the southern and eastern portions of the Tucson metropolitan area: G.W. JACKSON*, 7 maps, scale 1:24,000.

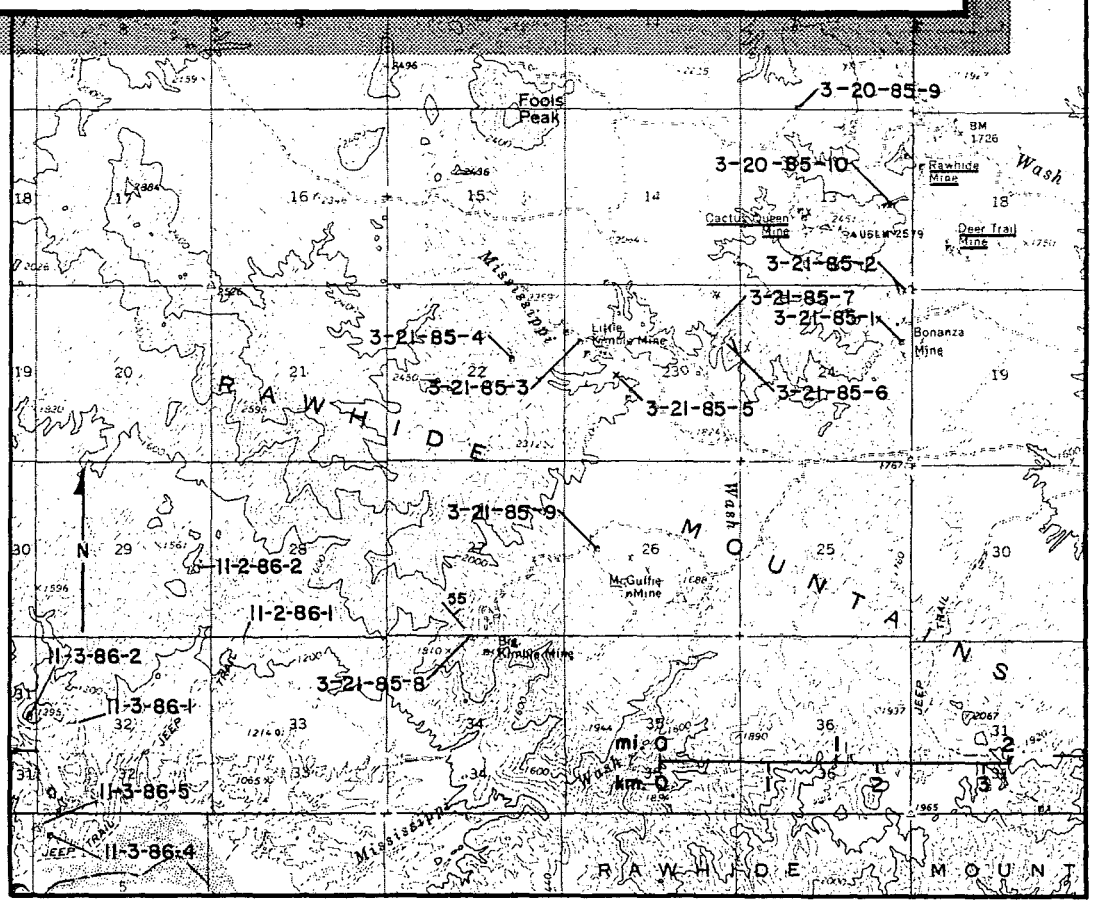
H. Petrology and stable-isotope systematics of mylonitization and detachment faulting, South Mountains, Arizona: B.M. Smith, S.J. REYNOLDS, H.W. Day, and R. Bodnar, to be submitted for publication in Geological Society of America *Bulletin*.

I. Late Cenozoic surficial deposits of the Phoenix South (30′ x 60′) Quadrangle, K.A. DEMSEY*, scale 1:100,000.

Organization and Personnel

The State Geologist may organize the Arizona Geological Survey into such administrative units, and employ such permanent, temporary, part-time and volunteer professional and support staff, as necessary to achieve the objectives and promote the policies prescribed by this article.

27-151.C.1
Arizona Revised Statutes
Laws 1987, Ch. 158



ORGANIZATION CHART
Arizona Geological Survey
June 30, 1989

STATE OF ARIZONA

Rose Mofford
Governor

ARIZONA GEOLOGICAL SURVEY

ADMINISTRATION

	FTE(a)
L. D. Fellows, Ph.D. Director and State Geologist	1.0
R. E. McDonnell Business Manager	1.0

INFORMATION

	FTE
L. E. Colton Clerk Typist III (Publication Sales Mgr.)	1.0
T. G. McGarvin Geologist I	1.0
D. M. Siewert Typist II	1.0
P. J. West Clerical Assistant	0.50
Library Assistant (d)	0.25
Student Aide (e)	0.25

GEOLOGIC INVESTIGATIONS

	FTE
P. A. Pearthree, Ph.D. Research Geologist	1.0
S. J. Reynolds, Ph.D. Research Geologist	1.0
J. E. Spencer, Ph.D. Research Geologist	1.0
Research Assistant (b)	1.0

PUBLICATION

	FTE
P. F. Corrao Commercial Artist Spvr.	1.0
S. F. Garner Commercial Artist II	1.0
E. M. VandenDolder Public Information Officer III (Geological Editor)	1.0
Editorial Assistant (c)	0.25

(a) Full-time equivalent

(b) Temporary, J. T. Duncan, G. W. Jackson, S. Slaff

(c) Temporary, N. Schmidt

(d) Temporary, A. E. Moss

(e) Temporary, K. A. Fulton, J. Hinkley, P. Kay, M. K. Miller

GEOLOGISTS AND SPECIALTY AREAS

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

- geology of Arizona
- geologic hazards and limitations
- administration

PHILIP A. PEARTHREE, Assistant Research Geologist; B.A., Oberlin College; M.S., University of Arizona; Ph.D. candidate, University of Arizona (Degree expected June 1990).

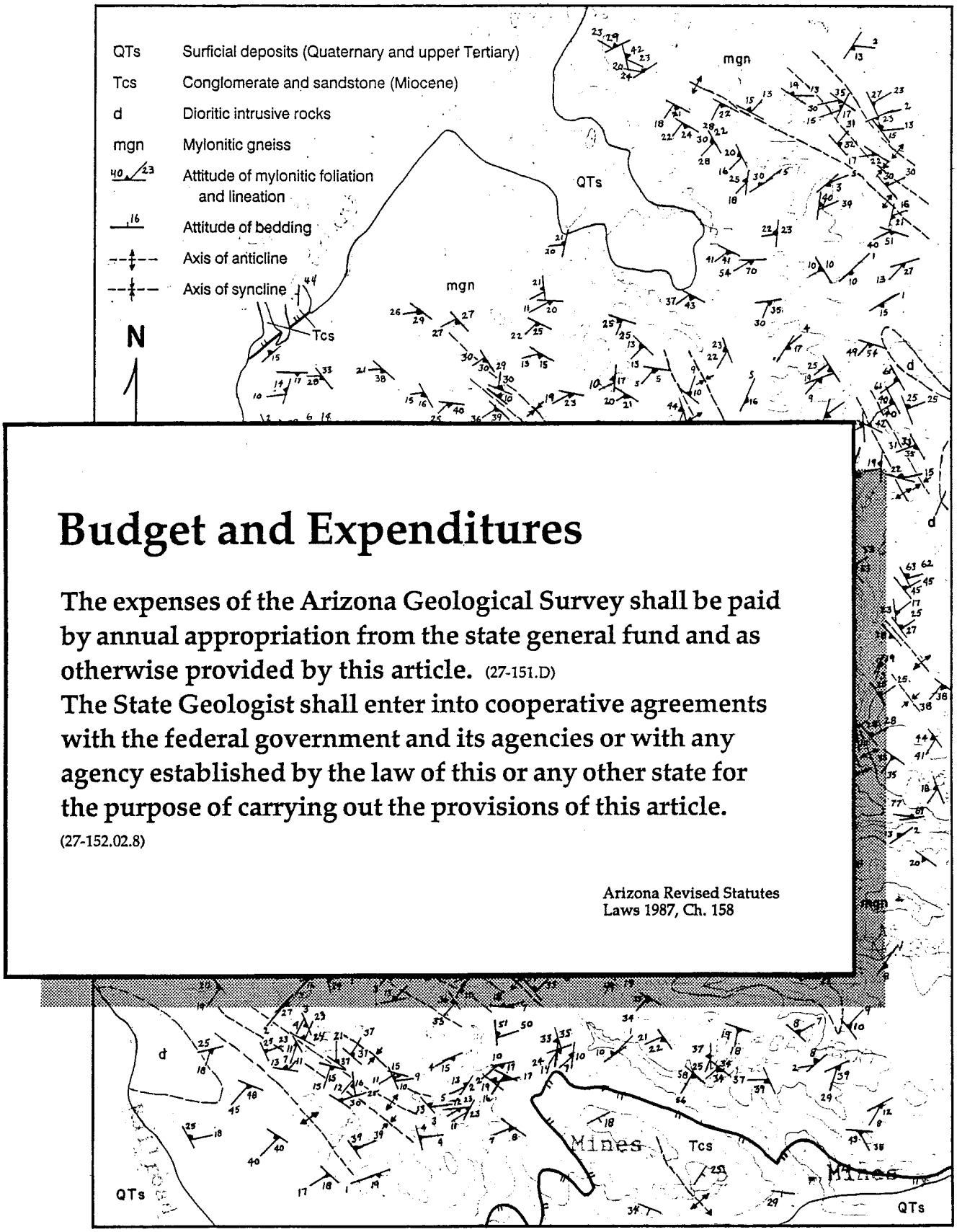
- geology of Arizona
- Quaternary and surficial geology
- seismotectonics and seismic hazard
- late Cenozoic geology of the Basin and Range Province
- geomorphology
- subsurface geology
- geologic mapping
- environmental geology

STEPHEN J. REYNOLDS, Associate Research Geologist; B.S., University of Texas at El Paso; M.S., University of Arizona; Ph.D., University of Arizona.

- geology of Arizona
- State geologic mapping project
- structural geology; analysis of rock fabric and fault movement
- Basin and Range Province
- computer applications
- base metals (copper, lead, zinc, molybdenum, etc.)
- geochemistry of granites

JON E. SPENCER, Assistant Research Geologist; B.S., University of California, Santa Cruz; Ph.D., Massachusetts Institute of Technology.

- geology of Arizona
- genesis of metallic mineral deposits
- Basin and Range Province
- structural geology
- geologic mapping
- precious metals (gold, silver)
- geochronology
- geophysics
- Tertiary rocks, structures, and mineral deposits



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

State Appropriation and Expenditures

Category	FY 1987-88 Budgeted	FY 1987-88 Spent	FY 1988-89 Budgeted	FY 1988-89 Spent	FY 1989-90 Budgeted
Personal Services	290,448	290,637	337,100	329,026	342,100[a]
ERE (Benefits)	46,547	45,198	76,100	67,340	66,500
Operations	28,100	27,838	93,900	98,563[b]	102,300
In-State Travel	4,200	4,337	5,900	4,477	6,100
Out-of-State Travel	1,800	1,800	4,500	4,319	4,700
Capital Equipment	1,525	1,525	14,200	22,664	13,300
TOTAL	$372,620	$371,335	$531,700	$526,389[c]	$535,000

(a) Includes 1.25% salary increase

(b) Includes rent and utilities, paid by University of Arizona in FY 1987-88

(c) Received $5,300 budget reduction at midyear

GEOLOGIC MAPPING-VULTURE MOUNTAINS

Description: Geologic mapping in Phoenix Quadrangle (1° x 2°), a 50-50 matched-funding project with the U.S. Geological Survey. U.S. Bureau of Land Management provided 392 color aerial photographs. Mapping was done in the Vulture Mountains.

Principal investigators: STEPHEN J. REYNOLDS, JON E. SPENCER, and LARRY D. FELLOWS

Amount of contract: $60,000

Duration of contract: March 1, 1988 to April 30, 1989

Amount spent in FY88-89: $45,599

Persons employed in FY88-89: MICHAEL J. GRUBENSKY

Reports and maps completed: M.J. GRUBENSKY and S.J. REYNOLDS, Geologic map of Vulture Mountains, in progress

SUPERCONDUCTING SUPER COLLIDER

Description: Determine geologic and hydrologic conditions at the Maricopa site. Prepare response to Department of Energy's (DOE) draft environmental statement. Brief DOE Secretary Herrington and Arizona's congressional delegation on character of the site. Participate in site selection debriefing after award was made. Move geologic data, maps, and reports to Arizona Geological Survey after project was completed.

Principal investigators: Peter Carruthers, University of Arizona, SSC Technical Committee Chairman and Richard Jacob, Arizona State University, Technical Committee Cochairman

Duration of contract: July 1, 1988 to January 31, 1989

Amount spent in FY88-89: $21,527

Persons employed in FY88-89: JOHN W. WELTY

Reports and maps completed:

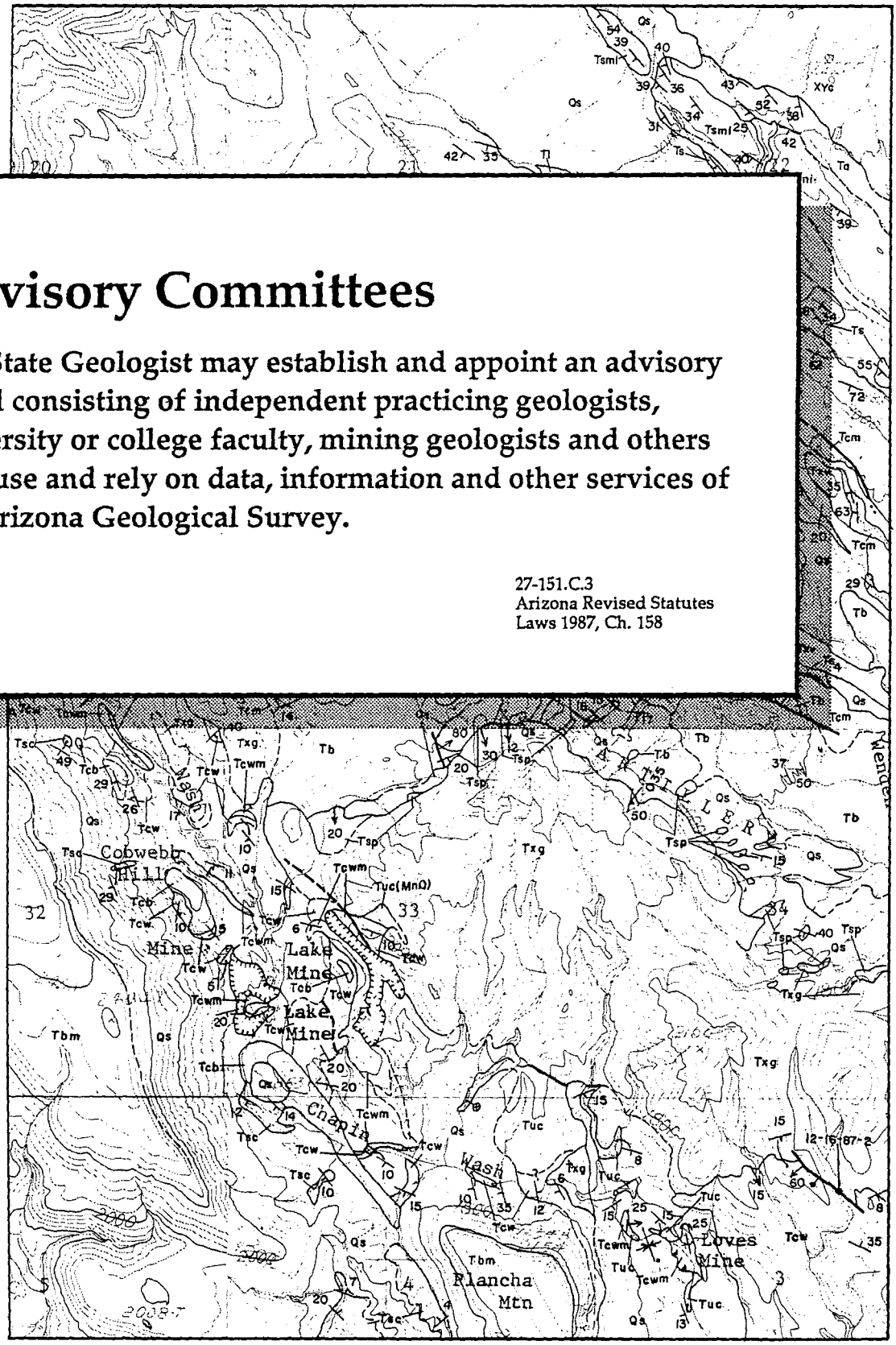
WELTY, J.W., 1988, Superconducting Super Collider (SSC) site selection in Arizona: Geological Society of America Abstracts with Programs, v. 20, no. 7, p. A22.

Brooks, S.J., 1988, Potential land surface subsidence at the Arizona Superconducting Super Collider (SSC) site, considering past, current, and possible future ground-water withdrawal: Arizona Geological Survey Open-File Report 88-20, 28p.

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



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. Péwé
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 Associates, Inc.
Phoenix

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

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

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

James D. Loghry
Consulting Geologist
Tucson

James N. Mayor
District Manager
Newmont Exploration Ltd.
Tucson

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