



Vol. 31, No. 3
Fall 2001

Arizona Geology

Published by the Arizona Geological Survey

THE STATE AGENCY FOR
GEOLOGIC INFORMATION

MISSION

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

ACTIVITIES

GEOLOGIC MAPPING.

Map and describe the origin and character of rock units and their weathering products.

HAZARDS AND LIMITATIONS.

Investigate geologic hazards and limitations such as earthquakes, land subsidence, flooding, and rock solution that may affect the health and welfare of the public or impact land-and resource management

ENERGY AND MINERAL RESOURCES.

Describe the origin, distribution, and character of metallic, non-metallic, and energy resources and identify areas that have potential for future discoveries.

OIL AND GAS CONSERVATION COMMISSION.

Assist in carrying out the rules, orders, and policies established by the Commission which regulates the drilling for and production of oil, gas, helium, carbon dioxide, and geothermal resources.

PUBLIC INFORMATION.

Inform the public by answering inquiries, preparing and selling maps and reports, maintaining a library, databases, and a website, giving talks, and leading fieldtrips.

Chiricahua Monument And Fort Bowie

Larry D. Fellows
Director and State Geologist

Geologic processes formed the spectacular scenery in the Chiricahua National Monument. Clouds of red-hot ash, pumice, rock fragments, and gases were ejected violently from a volcano about 26.9 million years ago. This mixture settled on the ground and the particles fused together, compacted, and cooled to form rock. The gas was squeezed out during compaction. This volcanic debris, which blanketed a 1,200-square-mile area, is more than 800 feet thick in the monument. Geologists named it the Rhyolite Canyon Tuff. Weathering processes caused the rock to disintegrate and decompose along vertical cracks (joints). In much of the monument the once-continuous layer is now a series of huge, irregularly shaped columns (Figure 1.) Well-developed hiking trails wind among them.

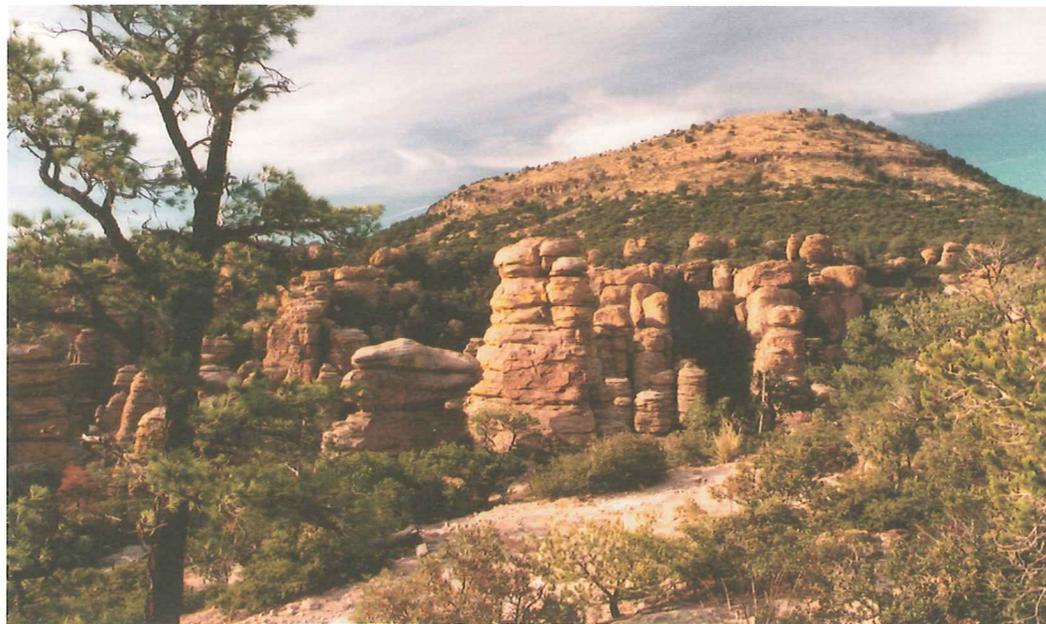


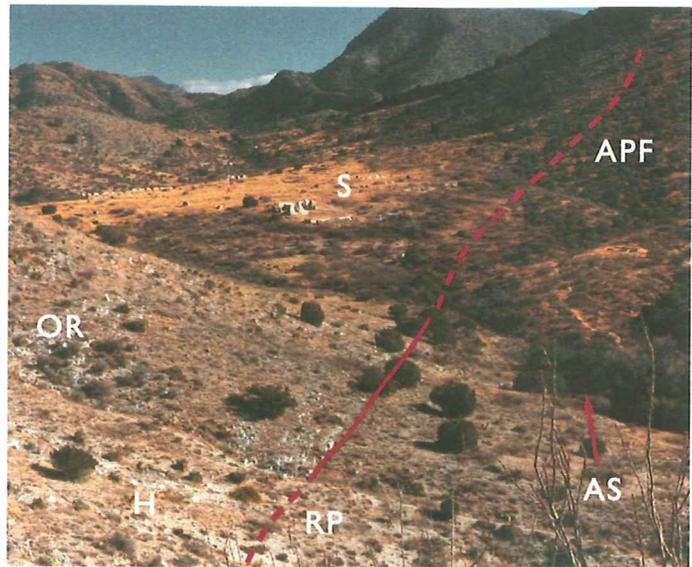
Figure 1. View from the Echo Canyon trail toward Sugarloaf Mountain (right background). Pinnacles of the Rhyolite Canyon Tuff are present in the center of the photograph.

continued from page 1

The Arizona Geological Survey released *Rocks in the Chiricahua National Monument and the Fort Bowie National Historic Site* (Down-to-Earth 11) to describe the fascinating geologic history and features within these preserves. The book, listed under "Just Released" on page 5, replaced Down-to-Earth 8, which is out of print. John V. Bezy, National Park Service, wrote the book specifically for those with little, if any, knowledge of geology. The book includes descriptions of 10 features along the Sugarloaf Mountain Trail and nine along the Echo Canyon Loop. Color photographs illustrate the features.

Geology directly influenced historical events that occurred in what is now the Fort Bowie National Historic Site, about 10 miles northwest of the Chiricahua National Monument "as the crow flies." Immigrants traveling west relied on Apache Spring for drinking water. Because Apaches used the water for a long time before the immigrants started coming, serious conflicts occurred. Fort Bowie was established to protect the immigrants. The conflicts culminated with the Battle of Apache Pass in 1862.

Fort Bowie was built on a gentle slope (S) within the Apache Pass fault zone (right). A veneer of sediment, eroded from the mountain to the south, underlies the slope and covers bedrock. The western margin of the slope is bounded by the Apache Pass fault (APF). The Rattlesnake Point granodiorite (RP), about 1,375 million years old, is on the southwest side of the fault. The Horquilla limestone (H), about 300 million years old, is on the northeast. The limestone, which resisted weathering and erosion



more than the granite, forms Overlook Ridge (OR) immediately north of the fort.

From the parking area a trail leads southeastwardly past Apache Spring, across the Apache Pass fault, to the visitor center near the ruins of the fort. The trail then goes northwestwardly up Overlook Ridge, which is underlain by limestone, to an observation point from which to observe the battle site. The trail continues across the Apache Pass fault and connects with the main trail that returns to the parking lot.

MINERAL POTENTIAL IN EASTERN PIMA COUNTY

Minerals provide the raw materials that enable society to function. Pima County is endowed with substantial mineral wealth, including copper, molybdenum, sand, gravel, limestone, and clay. The county also has potential geothermal resources. Six major copper deposits are present in the county. The Mission-Pima deposit has been mined for 40 years and the Silver Bell deposit for more than 100 years.

Mining provides significant revenue to Pima County. Last year the copper industry paid employees who reside there more than \$88 million in wages. The industry paid \$10 million in taxes to local governments in the Tucson metropolitan area. In addition, copper producers bought almost \$186 million worth of products and services from businesses in Pima County last year. Because Tucson is a regional trade center, other indirect personal and business income was generated from persons who live outside of the metropolitan area and in adjacent counties.

The sand and gravel industry provides materials that are essential for construction of new businesses, private residences, highways, and streets. Seven million tons of sand and gravel are produced annually in the Tucson area. Although dollar figures are not available, the sand and gravel industry contributes signifi-

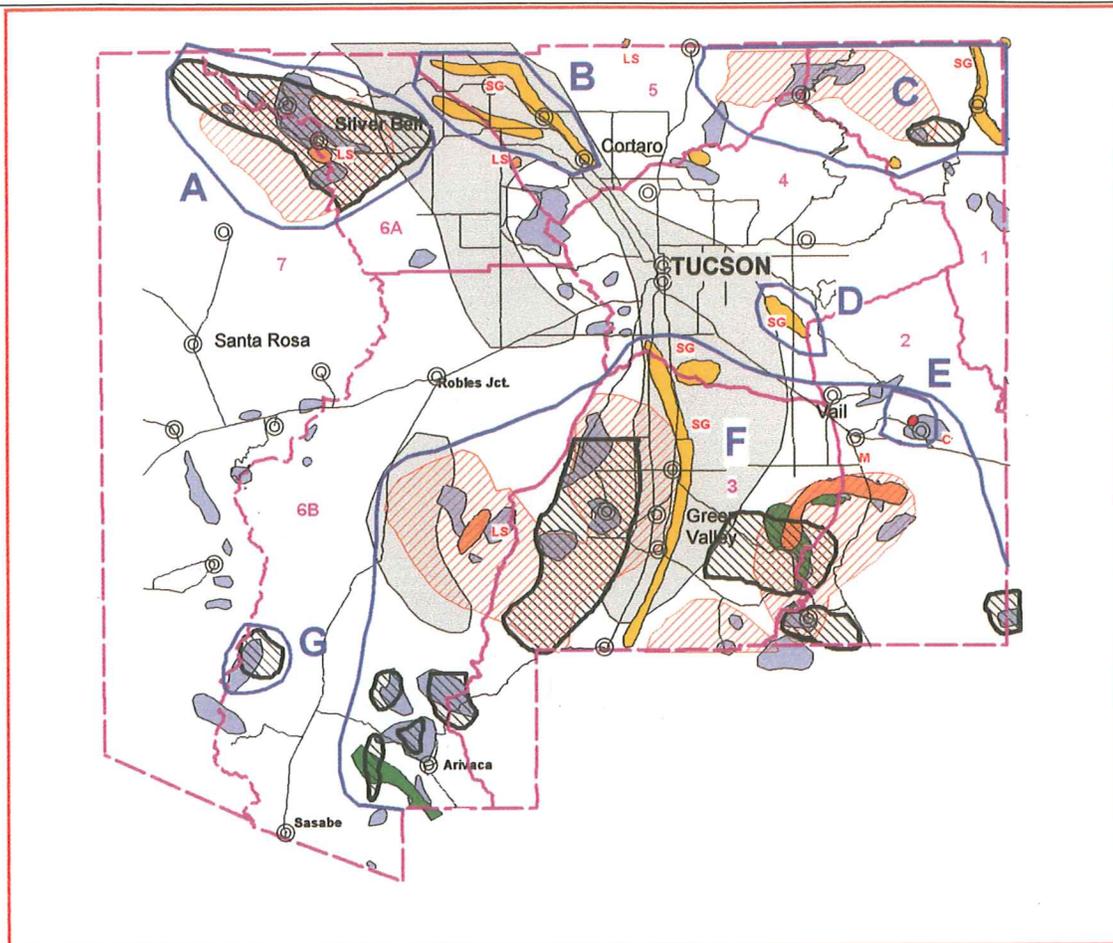
cant revenue to Pima County as wages paid to employees and for services and products purchased in the area.

This assessment, coordinated by Charles P. Miller, was prepared by the Southwestern Minerals Exploration Association (SMEA), a group of exploration and mining geologists. Most SMEA members have spent most of their professional careers in the southwestern United States. The nine members who provided information about specific mineral districts in this report have a combined total of more than 330 years of experience.

The authors convey an essential piece of information for planners—an inventory of mineral resource potential in eastern Pima County. The assessment is based on data derived from many experienced private-sector geologists and from information in publications produced by state and federal governmental agencies. The report includes maps that show areas with copper and molybdenum anomalies, copper prospects, copper deposits, porphyry copper potential, non-metallic mineral potential, and geothermal potential. The map on page 3 of this issue shows areas interpreted to have mineral potential.

The SMEA report was provided to the Arizona Geological Survey for release as Contributed Report 01-B. The report, listed under "Just Released" on page 5, is available for purchase.

MINERAL POTENTIAL OF EASTERN PIMA COUNTY



Mineral Potential

-  Tracts permissible for porphyry copper deposits USGS OFR 90-276
-  Tracts favorable for the presence of undiscovered mineral deposits U.S.G.S. Bulletin 2083
-  Zones of porphyry copper alteration and mineralization defined by members of the Southwestern Minerals Exploration Association.
-  Tracts favorable for sand and gravel defined by members of Southwestern Minerals Exploration Association
-  Tracts favorable for limestone deposits defined by members of Southwestern Minerals Association
-  SDCP Plan Boundary
-  Tracts favorable for marble deposits defined by members of Southwestern Minerals Exploration Association
-  Tracts favorable for clay deposits defined by members of Southwestern Minerals Exploration Association
-  Pima County Mining District Arizona Geological Survey
-  Low Temperature Geothermal Waters
-  Areas favorable for exploration and discovery of porphyry copper deposits, sand and gravel deposits and other un-discovered mineral deposits



Charles P. Miller
Project Coordinator
July 15, 2001

SEAMLESS TOPOGRAPHIC MAPS ON CD-ROM

National Geographic recently released Seamless U.S. Geological Survey (USGS) Topographic Maps of Arizona on CD-ROM. This 8 CD-ROM set includes all of the major series of USGS maps, including Generalized Reference Map, National Atlas Series, 1:500,000 Map Series, 1:100,000 Map Series, and 7.5' Map Series. More than 1900 7.5' maps (1:24,000 scale) cover Arizona.

The included TOPO! Software makes it easy to create the perfect map. One can zoom through different map series that show increasing levels of detail; add custom text, symbols, and routes to the maps; select the exact area needed, and print a custom, photo-quality map on any ink-jet, laser printer, or plotter.

TOPO! provides scanned versions of the actual paper 1:24,000-scale USGS maps, the most detailed maps available for outdoor enthusiasts, hobbyists, and professionals. Enhanced 3 D digital shading emphasizes changes in elevation, making the maps more readable and easier to use. Precise referencing ensures pixel-level accuracy for GPS and vector data overlay. True-color imaging uses millions of colors to optimize maps for viewing and printing. High-resolution 30-meter digital-elevation data provide the best elevation profiling and spot readings.

System requirements: Microsoft Windows 95, 98, 2000, NT; 16 MB of memory; double speed CD-ROM drive; 256-color monitor; 486 DX/66MHz PC or higher.

Supported printers: Works with all color and black & white printers supported by Windows.

Supported GPS receivers: Works with most popular handheld receivers manufactured by Garmin, Eagle, Lowrance, and Magellan. Direct link requires input/output capabilities and a PC cable (sold separately).

Seamless USGS Topographic Maps on CD-ROM, produced by National Geographic, can be purchased at the Arizona Geological Survey for \$99.95 plus \$7.60 sales tax if ordered in or shipped to Arizona. To have the eight-CD-ROM set mailed, there is an additional \$10.75 charge for shipping and handling.

CONVENTIONAL PAPER TOPOGRAPHIC MAPS

If you need paper topographic maps, the Arizona Geological Survey (AZGS) sells them as part of the Earth Science Information Center maintained cooperatively with the U.S. Geological Survey (USGS).

7.5' Map Series. The AZGS has complete statewide coverage of all 7.5' quadrangles (1,951) in Arizona. These maps are produced by the USGS at 1:24,000 scale (1 inch equals 2,000 feet). Each map is about 22 x 27 inches, shows land-surface elevations by use of contour lines, and costs \$4.85 plus tax.*

100 K Series. One inch on the map equals 100,000 inches (1.58 miles) on the ground. The map dimensions are 23.75 x 44.5 inches. Metric contours are used to depict land-surface elevations. \$7.00*

500 K Series. One inch on this map equals 500,000 inches (about 7.9 miles) on the ground. Contours are draped over shaded relief. The contour interval is 500 feet. This 46 x 54 inch map sells for \$7.00.*

*Please refer to ordering instructions on page 5.

OTHER ARIZONA MAPS

Geologic map of Arizona (Map 35). A full-color wall map that shows rock formations and surficial material units. Scale 1:1,000,000. \$5.00.*

Arizona geologic highway map (Map 33). This map, designed to be carried in your car, is printed on waterproof stock on both sides. One side is a geologic map that is very similar to the Geologic Map of Arizona (Map 35). The other side includes information about the Grand Canyon, mineral resources, etc. Scale 1:1,000,000. \$10.00.*

Earthquake hazards map (Map 34). It shows earthquake epicenters and active faults, and includes tabular information about 45 young faults. A small inset map shows interpreted earthquake hazard zones in Arizona. Scale 1:1,000,000. \$6.00.*

Metallic mineral districts (Map 18). Also included in Bulletin 194, this map is available separately. It depicts the ages and types of mineral deposits. Scale 1:1,000,000. \$7.00*

Oil and gas potential map (POS 2). This poster-sized map, 18 x 24 inches, uses color patterns to show areas interpreted to have oil and gas potential. \$3.00.*

* Please refer to ordering instructions on page 5.

JUST RELEASED

Rocks in the Chiricahua National Monument and the Fort Bowie National Historic Site: Bezy, J.V., 2001, Arizona Geological Survey Down-to-Earth 11, 48 p. \$7.95 plus shipping and handling.

Please refer to pages 1-2 of this issue for a description of this report. Down-to-Earth 11 superseded Down-to-Earth 8, which is out of print.

Surficial geology and geoarchaeology of San Cristobal and Growler Valleys, Barry M. Goldwater Air Force Range, southwestern Arizona: Pearthree, P.A., Freeman, A.K.L., and Demsey, K.A., 2001, Arizona Geological Survey Open-File Report 01-01, 40 p., 3 sheets, scale 1:100,000 and 1:24,000. \$26.00 plus shipping and handling.

This project was undertaken to provide a geologic and geomorphic framework for an archaeological survey that was conducted for the U.S. Air Force by SWCA, Inc. and Arcadis Geraghty and Miller.

Geology and geomorphology of 12 small watersheds in the Peloncillo Mountains, central portion of the Malpai Borderlands project area, Hidalgo County, New Mexico: Youberg, A.M. and Ferguson, C.A., 2001, Arizona Geological Survey Open-File Report 01-05, 22 p., scale 1:12,000. \$6.50 plus shipping and handling.

The purpose of this study was to provide geologic information the U.S. Forest Service needed to conduct an experiment to compare effects of two burning seasons on native vegetation, wildlife, surface water flow, slope stability, and erosion.

Stratigraphic nomenclature of the Miocene Superstition volcanic field, central Arizona: Ferguson, C.A. and Trapp, R.A., 2001, Arizona Geological Survey Open-File Report 01-06, 103 p. \$13.00 plus shipping and handling.

The purpose of this report is to list, describe, and classify all previously named mid-Tertiary stratigraphic units in the Superstition volcanic field and correlate them with units in the newly defined stratigraphic framework.

Geologic spatial data for the Roskruge and Waterman Mountains and western Avra Valley area, Pima County, Arizona: Ferguson, C.A., Gilbert, W.G., Orr, T.R., Pearthree, P.A., Richard, S.M., Skotnicki, S.J., Spencer, J.E., and Youberg, A.M., 2001, Arizona Geological Digital Information Series 19, 1 CD ROM. \$30.00 plus shipping and handling.

Field trip guide to Sabino Canyon and the Mount Lemmon Highway, Pima County, Arizona: Force, E.R., 2001, Arizona Geological Survey Contributed Report 01-A, 35 p. \$6.00 plus shipping and handling.

The main purpose of this trip is to acquaint the traveler with rock types and features in the Santa Catalina Mountains.

Mineral potential of eastern Pima County, Arizona: Southwestern Minerals Exploration Association, 2001, Arizona Geological Survey Contributed Report 01-B, 24 p., 9 figs., 1 table. \$12.00

Please refer to pages 2 and 3 of this issue for a brief description of the report.

ORDERING INFORMATION

You may purchase publications at the AZGS office or by mail. Address mail orders to AZGS Publications, 416 W. Congress St., Suite 100, Tucson, AZ 85701. Orders are shipped by UPS, which requires a street address for delivery. All mail orders must be prepaid by a check or money order payable in U.S. dollars to the Arizona Geological Survey or by Master Card or VISA. Do not send cash. Add 7.6% sales tax to the publication cost for orders purchased or mailed in Arizona. Order by publication number and add these shipping and handling charges to your total order:

Shipping & Handling CHARGES

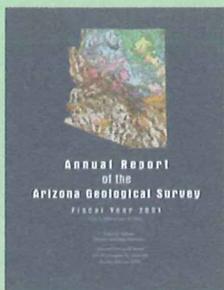
In the United States

Less than	\$2.00, add	\$1.00
	2.00 - 10.00, add	3.50
	10.01 - 20.00, add	5.00
	20.01 - 30.00, add	6.25
	30.01 - 40.00, add	7.00
	40.01 - 50.00, add	8.50
	50.01 - 100.00, add	10.75
	101.01 - 200.00, add	15.00
If it's over	200.00, call	

Other countries, request price quotation

Shipping and handling charges include insurance. For rolled maps, add \$1.00 for a mailing tube.

If you purchase Open-File Reports, Contributed Maps, or Contributed Reports at the AZGS office, please allow up to two days for photocopying.



ANNUAL REPORT ARIZONA GEOLOGICAL SURVEY FY 2001

Arizona Geological Survey employees collected and archived information and informed and assisted the public in the following ways during Fiscal Year 2001:

- Answered thousands of requests for geologic information or assistance
- Sold 9,380 geologic reports and maps (Nineteen of every 20 mail orders were returned the same day.)
- Prepared and released 31 new reports and maps on Arizona geology, including
Geologic Map of Arizona (Map 35) Arizona Has Oil and Gas Potential!
(Circular 29)
Guide to Geologic Features at Petrified Forest National Park
(Down-to-Earth 10)
Rocks in the Chiricahua National Monument and Fort Bowie National Historic Site (Down-to-Earth 11)
Sixteen geologic maps, including eight in the Phoenix-Tucson corridor,
Twelve applied geology studies in population-growth or potential economic-development areas, and
Six digital geologic maps and three spatial data products
- Released four 6-page issues of *Arizona Geology*, the agency's newsletter
- Presented 22 talks, workshops, and fieldtrips
- Expended \$196,238 on projects done under contract with federal and other state agencies

The complete annual report may be viewed on the Arizona Geological Survey web site (www.azgs.state.az.us). The report includes a complete list of all items published during the year, descriptions of major projects, and information about agency staff and budget. The report is an Adobe® Acrobat® (.pdf) file and may be downloaded at no charge.

Arizona Geology

is published quarterly by the Arizona Geological Survey (AZGS), an Executive Branch agency of the State of Arizona, Jane Dee Hull, Governor. Please address comments, subscription requests, and address changes to the AZGS at 416 W. Congress St., Suite 100, Tucson, AZ 85701. Phone: (520) 770-3500. Visit our website at:

www.azgs.state.az.us

Larry D. Fellows
Director and State Geologist

Rose Ellen McDonnell
Assistant Director of Administration

Layout by
John A. Birmingham
Copyright © 2001

PUBLICATION ANNOUNCEMENTS

For many years we have announced the release of new geologic reports and maps in *Arizona Geology*, which is published four times per year. That means some publications may be available for several months before our customers know about them.

We now plan to notify our readers by e-mail when new items are available for purchase or review. If you would like to receive these periodic announcements, please e-mail McDonnell_Rose@pop.state.az.us and ask to have your name added to the list.



ARIZONA GEOLOGICAL SURVEY
416 West Congress, Suite 100
Tucson, AZ 85701
(520) 770-3500

Return Service Requested

NON PROFIT ORG.

U.S. POSTAGE

PAID

TUCSON, ARIZONA

PERMIT NO. 3088