Arizona Geology

Vol. 32, No. 1
Spring 2002

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

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.

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, nonmetallic, 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.

ARIZONA GEOLOGICAL SURVEY AZGS

Arizona Has Salt

Steven L. Rauzi, Oil and Gas Administrator
Arizona Geological Survey

Two of the nine known salt deposits in Arizona are thicker than the Grand Canyon is deep. Total thickness of salt (comon table salt-sodium chloride) in the other seven deposits is unknown. Eighteen areas not yet explored are interpreted to have potential salt deposits in the subsurface.

Salt is the basis for two industries in Arizona – solution mining and subsurface storage. At the Morton Salt facility near Glendale subsurface salt is dissolved with fresh water and the brine is pumped into evaporating ponds. Salt harvested from the ponds is used for industrial and commercial purposes such as operating water treatment systems, de-icing highways, and making ice cream. Caverns dissolved in subsurface salt are used to store liquefied petroleum gas (LPG) at the Ferrellgas facility near Holbrook (Figures 1 and 2) and the AmeriGas facility near Glendale (Figures 2, 3, and 4). Both of the existing LPG-storage facilities are served by the Burlington Northern Santa Fe Railroad. Recent interest in building new gas-fired power plants in Arizona has focused attention on storing natural gas in the large subsurface salt deposits near Phoenix and Kingman.

The Arizona Geological Survey recently published Circular 30, *Arizona has salt!*, to summarize information about Arizona's salt deposits, including the literature, drilling, and gravity data that define the major deposits. Circular 30, announced on page 5 of this issue, also documents the relationship between gravity data and salt deposits, points to areas where additional deposits may be present, and shows the proximity of highways, railroads, and pipelines to the known and potential salt deposits.

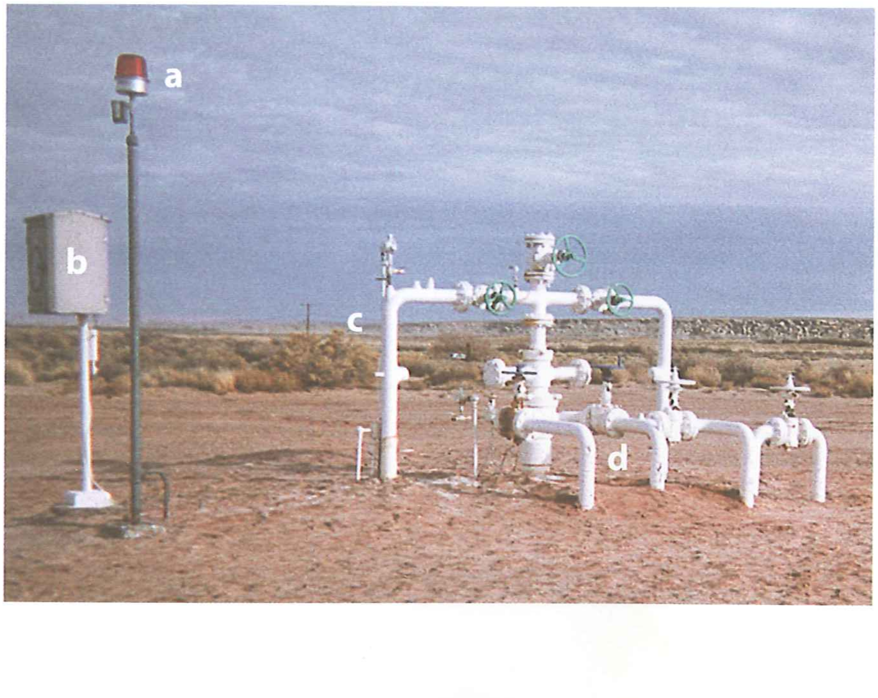

Figure 1. Wellhead at the Ferrellgas LPG-storage facility near Holbrook. (a) safety light, (b) pressure chart, (c) brine lines, (d) product lines. Eleven LPG-storage caverns are at this facility. Photograph by Richard Knudsen, Ferrellgas.

Distribution and thickness

Salt is present in all three physiographic regions in Arizona (Figure 2). Information about subsurface strata in the three regions comes primarily from gravity modeling, seismic surveys, and sparsely located drill holes.

The most extensive deposits are in the Colorado Plateau Province where salt underlies more than 3500 mi^2 in the Holbrook Basin. Salt there attains a maximum aggregate thickness of 655 ft and includes the potassium minerals sylvite, carnallite, and polyhalite near the top of the salt interval. The potassium-rich unit underlies about 600 mi^2, ranges up to 40 ft thick, and has an estimated potential of about 285 million tons of nearly 20 percent average grade K_2O.

The thickest known salt deposits are in the deep intermountain basins in the Basin and Range Province. Gravity data, seismic profiles, and a few deep drill holes indicate that the salt deposits in Mohave County north of Kingman and in Maricopa County west of Phoenix are at least 6,000 ft thick. They may be greater than 10,000 ft thick. As much as 100 mi^3 miles of salt may be present in the Hualapai Valley north of Kingman; more than 15 mi^3 may be in the Luke Basin west of Phoenix. These two salt deposits, and the anhydrite deposits in the Picacho Basin between Phoenix and Tucson, are among the thickest bedded evaporite deposits in the world.

Very little deep drilling has been done in Arizona. Statewide, the average drilling density is only about one well per 250 mi^2. In many of the basins in the Basin and Range Province the average drilling density is closer to one well per 400 mi^2. For this reason, the total extent and thickness of the massive salt deposits in the Basin and Range are not well defined. No drill holes have penetrated the entire thickness of the main mass of any of these salt deposits. Only a few holes have penetrated more than a few thousand feet of the salt. More drilling is needed to further define these salt bodies and shed light on the sedimentary units adjacent to and beneath the salt. These sedimentary units, like many others that are intimately associated with salt deposits around the world, may also have potential for oil and gas.

Age and origin

Marine and non-marine salt deposits are present in Arizona. Salt in the Holbrook Basin on the Colorado Plateau was deposited during the Permian period (285 to 245 million years ago). At that time east-central Arizona was an area of very low relief adjacent to open seas to the south. Salt was deposited in coastal areas that were inundated only occasionally and in which wave energy was low.

The thick deposits in the Basin and Range Province were deposited in a non-marine environment during Miocene time (15 to 12 million years ago). Prolonged periods of internal drainage, arid climate, and high evaporation rates resulted in the deposition of salts in closed basins.

Areas with potential salt deposits

The abundance of salt in Arizona, coupled with gravity anomalies that are associated with many of the salt deposits, suggest that salt may be present in less explored basins. Eighteen basins have gravity anomalies that are similar to the anomalies associated with the known salt deposits. Circular 30 includes descriptions of the available gravity data and seismic profiles, as well as information from sparsely located deep drill holes in the 18 basins. The abundance of salt in Arizona suggests that salt may also be present in basins other than the 18 described. As discussed in Circular 30, deeply buried salt deposits may be present in basins that do not have pronounced gravity anomalies.

Summary and conclusions

Salt is an abundant and valuable resource in Arizona. The potential to expand current facilities or develop new facilities in the nine known salt deposits is good. In addition, other salt deposits, currently untested, may be present beneath numerous areas of the state.

Recent interest in building new gas-fired power plants in Arizona has led two companies to investigate the feasibility of storing natural gas in Arizona salt. Copper Eagle Gas Storage, LLC (www.coppereaglegs.com) is evaluating the suitability of storing up to 5 billion ft^3 (Bcf) of natural gas in the Luke salt deposit west of Phoenix. Copper Eagle has drilled two stratigraphic holes to determine the characteristics of the salt for storage and the adjacent sedimentary units for disposal of brine. Core sampling of the salt has been completed. Test results of the core samples indicate that the physical qualities of the salt are similar to other salt formations in the country where natural gas is safely stored. Additional studies are in progress.

Desert Crossing Gas Storage and Transportation System, LLC (www.desert-crossing.com) is studying the feasibility of storing up to 10 Bcf of natural gas in the Red Lake salt deposit in the Hualapai Valley north of Kingman. The Desert Crossing facility would include multiple deep salt caverns and a pipeline upon completion. Initial studies are in progress.

Storing LPG and natural gas in Arizona's subsurface salt deposits has several benefits. Arizona is the only state in the Southwest with salt bodies large enough for storing large volumes of LPG and natural gas between the main sources of supply and regions of demand. Salt deposits in Arizona offer exceptional off-peak energy storage possibilities because of their proximity to interstate pipelines, railroads, and the several new natural

Salt Deposits in Arizona

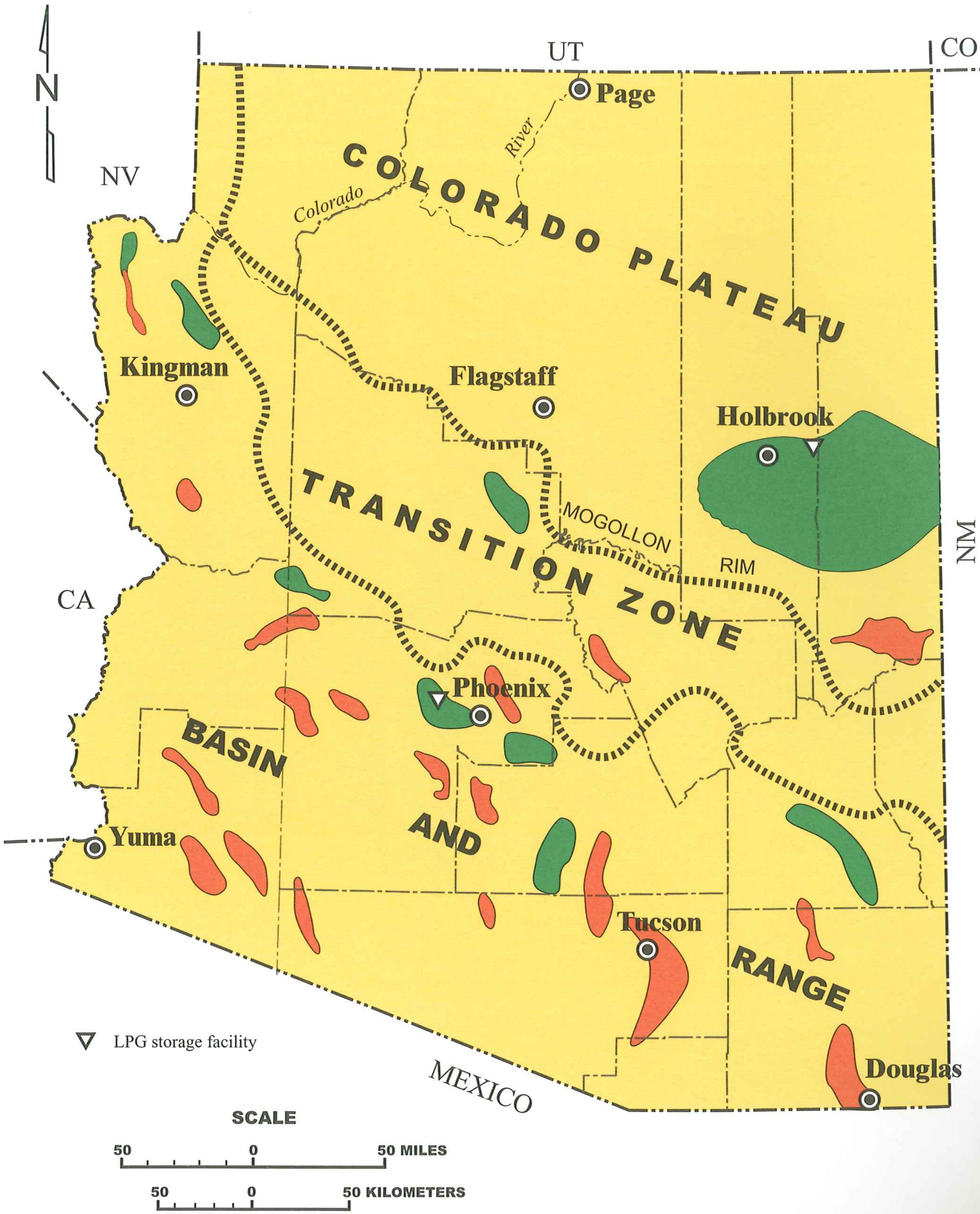

Figure 2. Known (shown in green) and potential (shown in orange) salt basins superimposed on physiographic regions in Arizona. Each basin is described in detail in Circular 30, *Arizona has salt!*

Figure 3. (Left) Rail walks at the AmeriGas LPG-storage facility near Glendale, where LPG is pumped from tank cars into storage caverns in salt. Railroad tank cars are used to transport butane and propane from refineries to the storage facility. Butane goes back to the refineries by rail, whereas most of the propane is distributed regionally by trucks. It takes about 1,500 rail cars to fill a 50-million-gallon storage cavern. The AmeriGas facility has three LPG-storage caverns about that size. Photograph by Steven L. Rauzi.

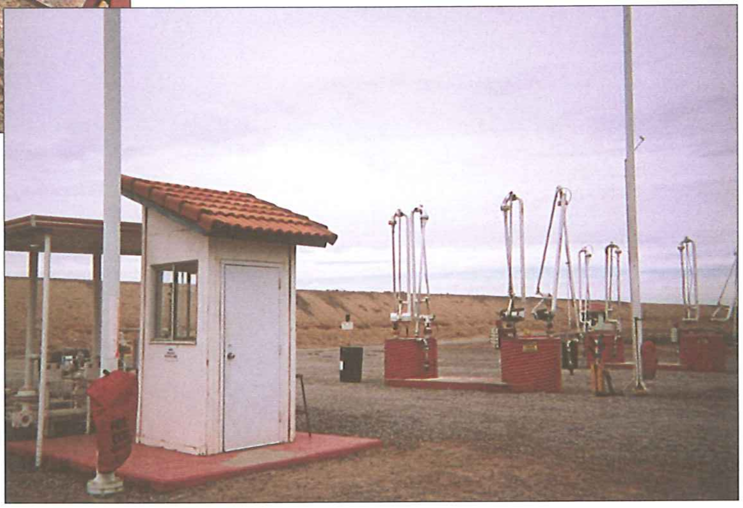

Figure 4. (Right) Truck racks at the AmeriGas facility near Glendale. Trucks are used to distribute propane to outlets in Arizona, California, Nevada, and Utah. A 50-million-gallon storage cavern has the capacity to fill about 5,000 trucks. Holding pond for brine is in background. Photograph by Steven L. Rauzi.

gas-fired power plants being built in Arizona. Salt-solution caverns provide an economic alternative to surface storage in steel tanks. The high deliverability of natural gas stored in salt caverns is a distinct advantage over storage in depleted oil and gas fields and aquifer reservoirs. Subsurface salt is ideal for gas storage because it is impermeable, making it impossible for gas to escape. Finally, special technology and expertise makes solution mining and cavern development in subsurface salt safe, efficient, and environmentally friendly.

Suggested References

Lysonski, J.C., Aiken, C.L.V., and Sumner, J.S., 1981, Complete residual Bouguer gravity anomaly maps: Arizona Geological Survey Open-file Report 81-24, 2 p., 23 sheets, scale 1:250,000.

Oppenheimer, J.M., and Sumner, J.S., 1980, Depth-to-bedrock map, Basin and Range Province, Arizona: Tucson, University of Arizona, Department of Geosciences, Laboratory of Geophysics, scale 1:1,000,000.

Neal, James T., and Rauzi, S.L., 1996, Storage opportunities in Arizona bedded evaporites: Arizona Geological Survey Open-File Report 96-27, 16 p.

Rauzi, S.L., 2000, Permian salt in the Holbrook Basin, Arizona: Arizona Geological Survey Open File Report 00-03, 21 p., 6 sheets, scale 1:250,000.

Rauzi, S.L., 2001, Arizona has oil and gas potential!: Arizona Geological Survey Circular 29, 40 p.

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

Richard, S.M., Reynolds, S.J., Spencer, J.E., and Pearthree, P.A., compilers, 2000, Geologic map of Arizona: Arizona Geological Survey Map M-35, scale 1:1,000,000.

SALT CAVERNS

Fourteen caverns have been constructed in subsurface salt in Arizona to store liquefied petroleum gas (LPG). Propane and butane are the most common types of LPG. The salt deposits used to store LPG in Arizona are hundreds or thousands of feet below the land surface.

The first step in constructing a storage cavern is to drill a hole to the top of the salt. A steel pipe is placed in the hole. Cement is forced down the pipe and up through the space between the pipe and sides of the hole. This pipe, called casing, protects groundwater and prevents the hole from collapsing. The hole is then drilled into the salt and a smaller-diameter pipe, called tubing, is placed in the hole. Fluid can be pumped into or out of the hole through either the tubing or the space between the tubing and final casing. A cavern is formed by pumping fresh water into the salt. Salt dissolves in fresh water until the water becomes saturated. The resulting salty brine is pumped out of the hole. As long as fresh water is pumped into the hole the salt continues to dissolve and the cavern continues to enlarge. The shape of the cavern is determined by controlling the amount and direction of fresh water that is pumped into the hole. A sonar tool is lowered into the cavern to measure its shape and size. After the desired size and shape have been attained, and a wellhead installed, the cavern is ready to store product. The cavern is filled with brine to prevent it from collapsing or becoming larger because of additional solution. A cavern is filled by pumping LPG down the annulus and displacing brine out of the tubing into holding ponds at the surface. When LPG is needed brine is pumped down the tubing and LPG is forced out of the cavern through the annulus.

JUST RELEASED

Arizona has Salt!: S.L. Rauzi, 2002, Arizona Geological Survey Circular 30 (C-30), 36 p. $10.00 plus shipping and handling

Data structure for the Arizona Geological Survey Geologic Information System-Basic Geologic Map Data v. 1.0: S.M. Richard and T.R. Orr, 2001, Arizona Geological Survey Open-File Report 01-09 (OFR 01-09), 52 p., 1 plate. $14.00 plus shipping and handling

A new earth fissure near Wintersburg, Maricopa County, Arizona: R.C. Harris, 2001, Arizona Geological Survey Open-File Report 01-10 (OFR 01-10), 22 p. $4.25 plus shipping and handling

Geologic description, sampling, and petroleum source-rock potential of the Awatubi and Walcott Members, Kwagunt Formation, Chuar Group of the Sixtymile Canyon section, Grand Canyon, Arizona: B.H. Wiley, C.M. Dehler, S.A. Ghazi, Lung-Chuan Kuo, and S.L. Rauzi, 2002, Arizona Geological Survey Open-File Report 02-01 (OFR 02-01), 84 p., 1 plate. $17.00 plus shipping and handling

Surficial geology and geomorphology of the Tinaja Altas area, Barry M. Goldwater Air Force Range, Yuma County, southwestern Arizona: T.H. Biggs, K.A. Demsey, and P.A. Pearthree, 2002, Arizona Geological Survey Open-File Report 02-02 (OFR 02-02), 21 p., 1 map, scale 1:24,000. $8.00 plus shipping and handling

Surficial geology and geomorphology of central Sauceda Valley, Barry M. Goldwater Air Force Range, Maricopa County, Arizona: K.A. Demsey, Andres Meglioli, T.H. Biggs, and P.A. Pearthree, 2002, Arizona Geological Survey Open-File Report 02-03 (OFR 02-03), 12 p., 1 map, scale 1:24,000. $9.00 plus shipping and handling

Shipping and handling charges are listed on back page.

PUBLICATION 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
	2.01 -	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
More than	200.01 -			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.

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.az.gov

Arizona Geology
Published by the Arizona Geological Survey

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

Return Service Requested