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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 Has Helium

Steven L. Rauzi
Larry D. Fellows
Arizona Geological Survey

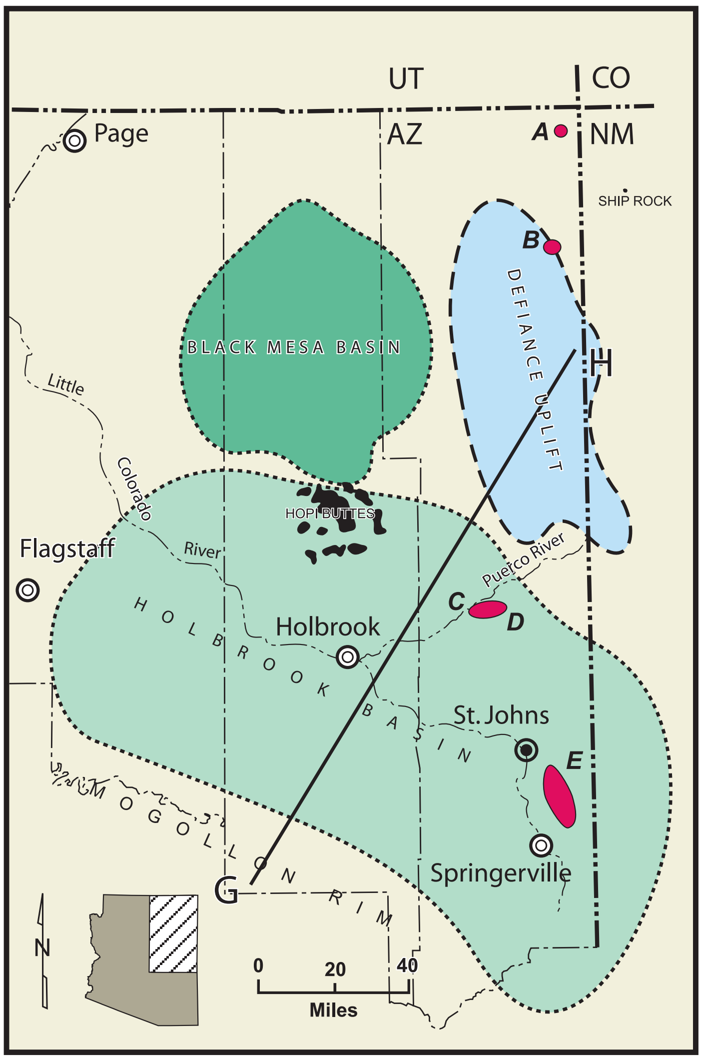

Figure 1. Index map of northeastern Arizona showing location of major geologic features and fields where helium has been produced or where significant concentrations of helium have been encountered in wells. (A) Tohache Wash field, (B) Dineh-bi-Keyah field, (C) Pinta Dome field, (D) Navajo Springs field, and (E) St. Johns-Springerville area. See Figure 2 for cross section G-H. The distance from G to H is about 150 miles.

In the 1960s and 1970s, some of the richest helium-bearing gas in the world was produced from wells in the Holbrook Basin in northeastern Arizona (Figure 1). Helium, a valuable gas that has many uses (Table 1), is commonly present in minute quantities in natural gas in wells. Most helium now produced in the United States is extracted from natural gas in wells in Wyoming, Utah, Colorado, New Mexico, Kansas, Oklahoma, and Texas. The only helium production in Arizona at this time is from wells in the Dineh-bi-Keyah oil field in the Four Corners area (Figure 1, B).

Helium in natural gas is generally considered to be of commercial value if its concentration is more than 0.3 percent. In the Holbrook Basin and Four Corners areas, helium concentrations range from trace amounts to as much as 10 percent. Both areas have high potential for discovery and production of helium.

The Amarillo Field Office of the U.S. Bureau of Land Management (formerly Amarillo Field Office of the U.S. Bureau of Mines) posted a helium price of $54.00 per thousand cubic feet for the period October 2003 through September 2004. Demand for

Table 1.

Helium has many uses because of its unique physical properties (small atom, extreme mobility, low boiling point and density, and completely inert). Some of the uses include:

- A refrigerant to provide the lowest temperatures attainable for cryogenic research
- A refrigerant used in superconducting sensing systems
- Purging and pressurizing fluid in aerospace applications
- Shield gas for welding and other forms of protective atmospheres
- Leak detection especially in high-pressure piping systems
- Coolant for high-temperature gas-cooled nuclear reactors
- Lifting gas for balloons and other lighter-than-air activities
- Mixed with oxygen to provide a safe breathing gas for deep-sea divers
- Excellent carrier gas in gas chromatography

helium is anticipated to grow at a rate of about 5 percent per year through at least 2004.

Rauzi (2003) summarized helium production and potential in Arizona, compiled reported occurrences, listed wells that have a high concentration of helium, and discussed the value of and expected increase in demand for helium. This article summarizes his findings.

Discovery and production. Helium was discovered in 1950 in a well drilled on the Pinta Dome (Figure 1,C) in search of oil. Although oil was not present, there was a large flow of gas. The gas did not burn and was allowed to flow unrestricted for about eight weeks. Those present indicated that the gas escaping from the well "roared like a jet engine" at an estimated initial rate of 24 million cubic feet per day. When U.S. Bureau of Mines tests showed that the gas was rich in helium the operator promptly shut the well in. (The helium content of that gas was 8 percent. At the current price of $54.00 per thousand cubic feet, about $105,000 worth of helium escaped into the atmosphere every day for eight weeks!)

Developmental drilling at Pinta Dome continued until 1959 In 1961 Kerr-McGee constructed a helium-extraction plant and started processing helium from the field. Processing from the Navajo Springs and East Navajo Springs fields began in 1964 and 1969, respectively. Decline in production required closure of the plant and abandonment of the fields in 1976. Nearly 9 billion cubic feet of gas that contained more than 700 million cubic feet of Grade-A helium (99.995 percent pure) were produced from the Pinta dome, Navajo Springs, and East Navajo Springs fields. The gas averaged 90 percent nitrogen, 8-10 percent helium, and 1 percent carbon dioxide.

Geology. Precambrian crystalline rocks (beneath the Coconino reservoir rocks) and sedimentary rocks with significant amounts of uranium minerals (above the reservoir rocks) are possible sources of the helium. If the helium is from the crystalline rocks it is primordial; if it is from the sedimentary rocks it is the product of radioactive decay of uranium minerals in those rocks. The source of the helium could be determined by analyzing the helium isotopes. Because no analyses have been made, however, the source of the helium is unknown. Regardless of its source, the helium migrated through pores and fractures and was trapped in the reservoir rocks.

Northeastern Arizona is part of the Colorado Plateau province, which is characterized by nearly flat-lying, relatively undisturbed, largely marine sedimentary rocks of Paleozoic and Mesozoic age (Figure 2 and Table 2). Younger volcanic rocks covered these strata near Flagstaff and Springerville. The Defiance and Kaibab uplifts and the Black Mesa basin are major structural features. The Mogollon Rim, a prominent escarpment, defines much of the southern edge of the Colorado Plateau. All past production of helium and current production of oil, natural gas, and carbon dioxide in Arizona is from rocks of Paleozoic age.

Numerous volcanic pipes and igneous dikes are present throughout the Four Corners region. The Hopi Buttes volcanic field covers an area of approximately 1,500 square miles in the northern Holbrook Basin (Figure 1). The distribution of helium appears to be related to the volcanic and intrusive rocks.

Holbrook Basin. The Pinta Dome, Navajo Springs, and East Navajo Springs fields are relatively small anticlinal structures. Wells in the Pinta Dome and Navajo Springs fields produced helium from the Coconino Sandstone (Permian age); several wells in the East Navajo Springs field produced helium from the Shinarump Conglomerate at the base of the Chinle Formation (Triassic age).

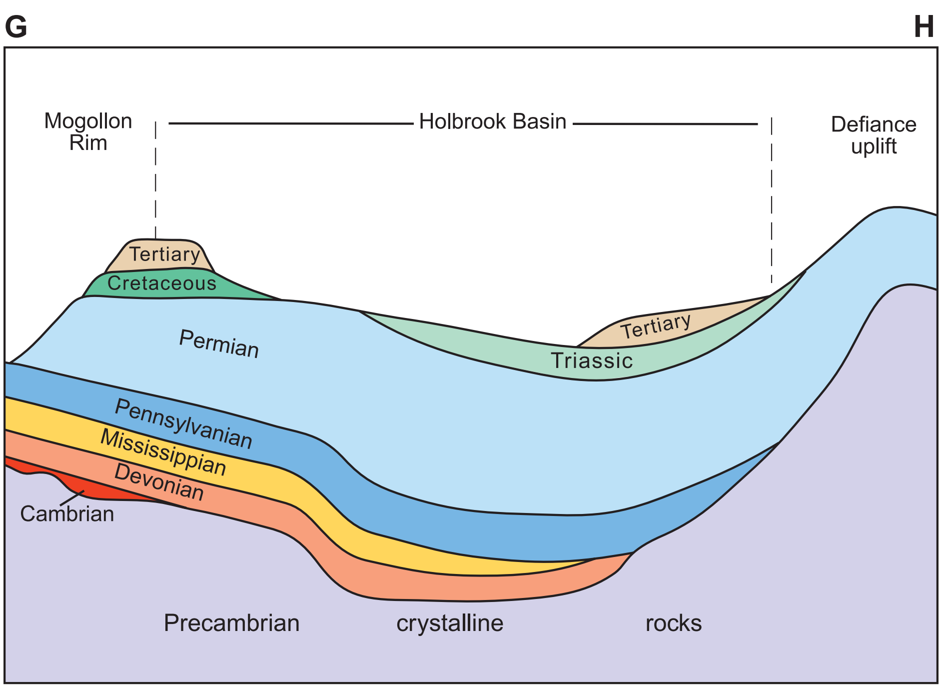

Figure 2. Diagrammatic northeast-southwest geologic cross section from the Mogollon Rim to the Defiance uplift (From Peirce, 1970). Figure 1 shows line of cross section. The distance from G to H is about 150 miles. Not to scale.

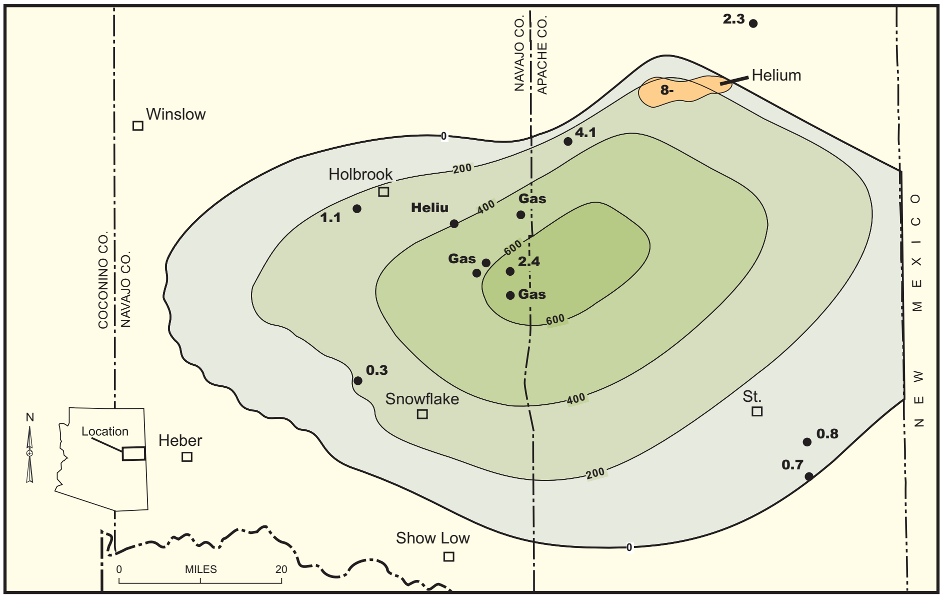

Figure 3. Holbrook Salt Basin showing the thickness of salt (in feet) and helium content (percent) of selected wells.

The first recorded report of helium-bearing gas in Arizona was from a non-productive oil test drilled a few miles southwest of Holbrook in 1927. A test of the Tapeats Sandstone (Cambrian age) at a depth of 3,500 ft was reported to have flowed 100,000 cubic feet of gas per day that contained 1.12 percent helium.

Shows of oil and gas have been reported in numerous wells in the Holbrook Basin. Gas analyses show that helium is present in many of them (Figure 3). High concentrations of helium were reported in at least three oil tests and in several holes that were drilled to delineate potash deposits in the Holbrook Basin in the 1960s and 1970s. The gas in some of the wells was not analyzed. In the 1960s and 1970s, some of the richest helium-bearing gas in the world was produced from wells in the Holbrook Basin. The nonflammable gas reported in these wells may have contained helium.

Four Corners area. Helium was produced from the Leadville Limestone (Mississippian age) in the Texaco #1 Navajo-Z in the late 1960s. This well, located in the Tohache Wash area near Teec Nos Pos in northern Apache County (Figure 1, A), was originally completed as an oil producer in rocks of Devonian age, but was recompleted as a helium producer after less than a year of low oil production. Gas from the Leadville Limestone contained approximately 6 percent helium, mixed mostly with nitrogen, methane, and carbon dioxide. Texaco abandoned the Tohache Wash field in 1969 because of technical and economic conditions. More than 385 million cubic feet of helium-rich gas were produced.

Kerr-McGee discovered oil in an igneous sill of Tertiary age at the Dineh-bi-Keyah field (Figure 1, B) in 1967. Gas associated with oil in the sill, which intruded strata of Pennsylvanian age, averaged 4.2 percent helium. Gas in the underlying McCracken Sandstone ranged from 4.8-5.6 percent helium. Kerr-McGee completed two gas wells in the Devonian strata but, in 1967, shut them both in because of lack of a market and pipeline.

In 1994, Kerr-McGee sold the Dineh-bi-Keyah field to Mountain States Petroleum, which started producing the helium-rich gas from the Devonian strata in 2003. Gas is shipped through a pipeline to the Newpoint Gas Services helium plant south of Ship Rock in New Mexico.

Although the highest reported helium concentrations in the Four Corners area were in the McCracken Sandstone (Devonian) and Leadville Limestone (Mississippian), helium in Casey (1983)

AGE		FORMATION	THICKNESS (FT)	GENERAL DESCRIPTION
Quaternary				Alluvium, sand and gravel
Tertiary		Bidahochi	0-180	Sandstone interbedded with mudstone and volcanic ash; bentonitic
Triassic	Upper	Chinle	650-850	Mudstone and claystone with some sandstone; some limestone and gypsum in upper portion; siltstone and conglomeratic sandstone (Shinarump) in lower portion
	Lower to Middle (?)	Moenkopi	125-150	Siltstone and mudstone; slightly
Permian	Lower	Coconino	250-325	Sandstone cemented with silica
Pennsylvanian (?)		Supai	1,700?	Sandstone, siltstone, and mudstone; some dolomitic limestone; thick interbedded evaporitic sequence in upper portion
Precambrian				Crystalline basement rocks

Table 2. Sedimentary rocks exposed at the surface and encountered in the subsurface in the Pinta Dome-Navajo Springs area, Apache County, Arizona.

Pennsylvanian-age strata ranged from 0.34-1.10 percent. Helium-rich gas was also reported from strata of Permian and Triassic age. At least sixteen wells have encountered helium-rich gas in the Four Corners area of Arizona.

Nonflammable gas from drill-stem and other tests in several wells was not analyzed. Nonflammable gas from strata of Devonian and Mississippian age in the Four Corners area probably contains helium.

Areas with potential for helium production. All known helium occurrences in Arizona are adjacent to the Defiance uplift. Production of helium from the Pinta Dome area, high concentrations in several wells drilled to delineate potash deposits southeast of Holbrook, and presence in wells between St. Johns and Springerville demonstrate that subsurface conditions are favorable for the generation and entrapment of helium throughout the Holbrook Basin. Structural and stratigraphic traps near deep-seated intrusive rocks throughout the basin, and especially along the margins of the Defiance uplift, may have exceptional potential for the entrapment of helium.

Areas with greatest potential for discovery of helium-rich gas are in or near fields that are already known to contain helium-rich gas. Abandoned fields may have potential for re-entry and production of additional helium reserves. Past production from Mississippian strata at the Tohache Wash field and shows in Devonian, Mississippian, and Pennsylvanian strata demonstrate favorable conditions for the generation and entrapment of helium in the Four Corners area. Helium is currently being produced from the McCracken Sandstone (Devonian) in the Dineh-bi-Keyah field. High concentrations of helium in Mississippian strata at the East Boundary Butte field makes that shut-in field a promising candidate for re-entry and production of helium.

Casey (1983) pointed out that because the Texaco #1 Navajo-Z in the Tohache Wash field was abandoned because of *technical and economic conditions*, additional reserves may remain in the ground.

We expect that the current high price and anticipated demand for helium will justifiably result in a renewed search for helium in Arizona.

Summary of available information. Rauzi's review of helium production and potential in Arizona, announced on page 5 of this issue, makes reference to 23 previously published reports, some of which are mentioned below.

Masters (1960), chief geologist with Kerr-McGee Oil Industries, described the geology, helium reserves, and history of discovery and development of the Pinta Dome field. Dean (1960), vice-president of Eastern Petroleum Company, summarized the helium potential of the Navajo-Chambers area in light of the significant helium accumulations in the Four Corners area of Arizona, New Mexico, Colorado, and Utah. Dunlap (1969) explained the subsurface geology of the Pinta Dome-Navajo Springs helium fields and tabulated basic well data used in structure maps and cross sections that accompanied his report. Peirce and others (1970) tabulated wells that had shows of oil, gas, and helium in the Four Corners area of Arizona. Allen (1978a, 1978b) compiled basic statistics about the geology, discovery well, drilling and completion practices, and reservoir data for the Pinta Dome and Navajo Springs fields. C.W. Spencer (1978) listed similar statistics for the Tohache Wash helium field near Teec Nos Pos in the Four Corners area. J.E. Spencer (1983) summarized helium resources and production in Arizona, described the geology of the helium fields, and discussed the origin of helium. Casey (1983) summarized helium resources and production in the Four Corners area. He discussed the geology of helium relative to the most important reservoir beds. Pacheco (2003) summarized world production and reserves and discussed demand, trends, and issues.

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Allen, W.E., 1978a, Navajo Springs (Helium), *in* Fassett, J.E., ed., Oil and gas fields of the Four Corners area, v. 1: Four Corners Geological Society, pp. 80-84.

Allen, W.E., 1978b, Pinta Dome (Helium), *in* Fassett, J.E., ed., Oil and gas fields of the Four Corners area, v. 1: Four Corners Geological Society, pp. 85-89.

Casey, T.A., 1983, Helium potential of the Four Corners area, *in* Fassett, J.E., ed., Oil and gas fields of the Four Corners area, v. 3: Four Corners Geological Society, pp. 749-754.

Dean, J.W., 1960, Helium potential of the Navajo-Chambers area, Apache County, Arizona: Interstate Oil Compact Commission Committee Bulletin, v. 2, no. 2, pp. 33-48.

Dunlap, R.E., 1969, The geology of the Pinta Dome - Navajo Springs helium fields, Apache County, Arizona: Tucson, University of Arizona, M.S. thesis, 73 p.

Masters, John, 1960, Pinta Dome helium gas reserves: Interstate Oil Compact Commission Committee Bulletin, v. 2, no. 2, pp. 33-48.

Pacheco, Norbert, 2003, Helium: U.S.Geological Survey Mineral Commodity Summaries, pp. 80-81.

Peirce, H.W., Keith, S.B., and Wilt, J.C., eds. , 1970, Coal, oil, natural gas, helium, and uranium in Arizona: Arizona Bureau of Mines Bulletin 182, 289 p.

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

Spencer, C.W., 1978, Tohache Wash area (Helium), *in* Fassett, J.E., ed., Oil and gas fields of the Four Corners area, v. 1: Four Corners Geological Society, pp. 92-93.

Spencer, J.E., 1983, Helium resources and production in Arizona: Arizona Bureau of Geology and Mineral Technology Fieldnotes, v. 13, no. 2, p. 6-7, 15-16.

It's Time to Make More Maps

The Arizona Geological Survey (AZGS) completed seven geologic maps in September as part of the Statemap component of the National Cooperative Geologic Mapping Program (NCGMP). Four maps are near Green Valley, south of Tucson, and include the Pima mining district. The others are on the west side of the San Pedro River south of Benson and include Kartchner Caverns State Park. Three maps in the Green Valley area have been digitized and are listed in the "Just Released" section below.

The new mapping season is in progress. Mapping is being done in the Vail area southeast of Tucson, on the west side of the White Tank Mountains west of Phoenix, and in the Bullhead city area along the Colorado River in western Arizona. A digital database will be compiled to represent the geology of the Phoenix metro area. Total funding awarded for this project was $210,700. The AZGS will provide an equal amount of in-kind service from its general fund appropriation, as required by the NCGMP, making the total cost of the project about $422,000.

The Arizona Geologic Mapping Advisory Committee determines areas to be mapped. Committee members are: Al Burch (U.S. Bureau of Land Management), Charles D. Graf (AZ Department of Environmental Quality), William M. Greenslade (Southwest Groundwater Consultants, Inc.), Barbara H. Murphy (Clear Creek Associates), Nicholas M. Priznar (AZ Department of Transportation), Frank Putnam (AZ Department of Water Resources), Michael J. Rice (AZ State Land Department), and Ralph E. Weeks (AMEC Earth & Environmental).

The advisory committee met in September and recommend the following areas: 1) San Pedro River between Benson and Sierra Vista, 2) lower Hassayampa River southwest of the White Tank Mountains west of Phoenix, and 3) Yuma. The AZGS submitted a proposal to the U.S. Geological Survey to complete seven quadrangle maps within these areas. Proposals are reviewed in late November and awards are announced afterward.

During the last five fiscal years (1999-2003, inclusive) the AZGS received $945,000 from the NCGMP and provided an equal amount in-kind service from the AZGS general fund appropriation. The total five-year expenditure for geologic mapping was $1,900,000.

AZGS advisory committees and customers regularly tell us to give high priority to making new geologic maps. Using funding from the NCGMP, other contracted projects, and the AZGS general fund appropriation, AZGS staff produced 83 geologic maps and digital products during the past five fiscal years.

Jon E. Spencer, whose specialty is mapping bedrock units, has primary responsibility for the mapping program. Philip A. Pearthree is the lead geologist for mapping surficial geology. Stephen M. Richard, also a bedrock mapper, oversees the preparation of digital products, for which he receives assistance from Erin M. Moore. During the past year Charles A. Ferguson, Bradford J. Johnson, Todd C. Shipman, and Ann M. Youberg were contracted to do geologic mapping.

Just Released

Review of helium production and potential in Arizona: Rauzi, S.L., 2003, Arizona Geological Survey Open-File Report 03-05 (OFR 03-05), 29 p. $5.00 plus shipping and handling.

Is asbestos present in Agua Fria River sand and gravel?: Harris, R.C., 2003, Arizona Geological Survey Open-File Report 03-06 (OFR 03-06), 15 p. $3.00 plus shipping and handling.

Additional desiccation cracks near Wintersburg, Maricopa County, Arizona: Harris, R.C., 2003, Arizona Geological Survey Open-File Report 03-07 (OFR 03-07), 17 p. $3.25 plus shipping and handling.

Geologic map of the Samaniego Peak 7.5' Quadrangle, Pima County, Arizona: Johnson, B.J., Ferguson, C.A., Pearthree, P.A., and Stavast, W.A., 2003, Arizona Geological Survey Digital Geologic Map 30 (DGM 30), 1 CD-ROM that includes a 1: 24,000-scale geologic map and 21-p. text. $15 plus shipping and handling. (A paper copy of the map and text are available for $15.75 and $3.75, respectively, plus shipping and handling.)

Geologic map of the Batamote Hills 7.5' Quadrangle, Pima County, Arizona: Ferguson, C.A., Johnson, B.J., and Shipman, T.C., 2003, Arizona Geological Survey Digital Geologic Map 32 (DGM 32), 1 CD-ROM that includes a 1:24,000-scale geologic map and a 31-p. text. $15.00 plus shipping and handling. (A paper copy of the map and text are available for $18.00 and $5.25, respectively, plus shipping and handling.)

Geologic map of the Esperanza Mill 7.5' Quadrangle, Pima County, Arizona: Spencer, J.E., Ferguson, C.A., Richard, S.M., and Youberg, Ann, 2003, Arizona Geological Survey Digital Geologic Map 33 (DGM 33), 1 CD-ROM that includes a 1:24,000-scale geologic map and a 10-p. text. $15.00 plus shipping and handling. (A paper copy of the map and text are available for $18.00 and $2.00, respectively, plus shipping and handling.)

Geology and production history of the Moonlight uranium-vanadium mine, Navajo County, Arizona: Chenoweth, W.L., 2003, Arizona Geological Survey Contributed Report 03-E (CR 03-E), 18 p. $3.25 plus shipping and handling.

Please refer to ordering instructions on back page.

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MARK YOUR CALENDAR

The Tucson Gem and Mineral Society will present the Golden Anniversary Tucson Gem and Mineral Show February 12-15, 2004 at the Tucson Convention Center. The show features gems, minerals, jewelry, and gifts. Dealers from the U.S. and many other countries will be present. For details click on the Society's website (www.tgms.org). The Arizona Geological Survey (AZGS) will have a booth in the Convention Center. We invite you to stop at our office or visit our booth.

The Arizona Section of the American Institute of Professional Geologists will hold a quarterly meeting at the AZGS office the morning of February 14 (Saturday). Visitors are welcome to attend.

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