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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.

HELLO "NORM"

Jon E. Spencer, Senior Geologist
Arizona Geological Survey

Uranium is present in very small quantities in all rock and soil. The nucleus of all uranium atoms is unstable and changes to a different element when particles are ejected from the nucleus by a natural process called *radioactive decay*. When a uranium atom first undergoes radioactive decay it becomes less stable and begins a sequence of about a dozen decays before ending at lead, which is stable. This sequence of decays is called a *decay series*. Although thorium is also radioactive and decays through a similar decay series, much less is known about its geologic associations. This is probably because, unlike uranium, it has not been the target of much mineral exploration and mining. Potassium is a very common element in the earth that is also radioactive. Potassium, however, is only weakly radioactive in part because each atom decays only once and it does not have a decay series. **Geologic materials that contain high concentrations of uranium or thorium are referred to as naturally occurring radioactive materials (NORM)**.

In the late 1970s the U.S. Department of Energy made a reconnaissance airborne survey of uranium and thorium in the United States as part of its National Uranium Resource Evaluation (NURE) program. Figure 1, on page 2, is a highly generalized and reduced NURE map that shows the concentration of uranium in Arizona.

In the 1980s the U.S. Environmental Protection Agency funded states to evaluate indoor-radon levels. Radon, a radioactive daughter product of uranium, is a major source of human radiation exposure. Homes and other buildings situated on rock or soil that have above-average concentrations of uranium have greater potential for elevated levels of indoor radon. The Arizona Geological Survey (AZGS) participated in this program for nine years.

Figure 1 clearly shows that the concentration of uranium and its daughter products in Arizona is highly variable. NORM are concentrated in specific rock and sediment types, including some granite and volcanic rocks as well as sediment that was originally deposited in lakes. The prominent northwest-trending yellow band in northeastern Arizona coincides with the outcrop area of the Chinle Formation. The yellow to red colors in much of southwestern Arizona coincide with the Basin and Range province, where many of the rock units exposed in the mountain ranges have elevated uranium levels.

The average concentration of uranium in rock and soil samples analyzed by AZGS geologists is about 1.6 parts per million (ppm). The NURE map shows that 98.3 percent of Arizona's land surface is made up of rock and soil that have less than 4.5 ppm uranium. In the other 1.7 percent of the State, rock and soil at the surface have uranium concentrations greater than 4.5 ppm (not counting unsurveyed areas). These areas underlain by NORM are of interest partly because some mining and industrial processes produce materials in which radioactive elements are concentrated. These *Technologically Enhanced* NORM (TENORM) are presently of interest to regulatory agencies, which must understand NORM before they can properly identify TENORM.

This article is a summary of an 11-page report [Naturally occurring radioactive materials (NORM) in Arizona] that I prepared. The AZGS released it as Open-File Report 02-13, which may be purchased from the AZGS for $4.00 plus shipping and handling costs.

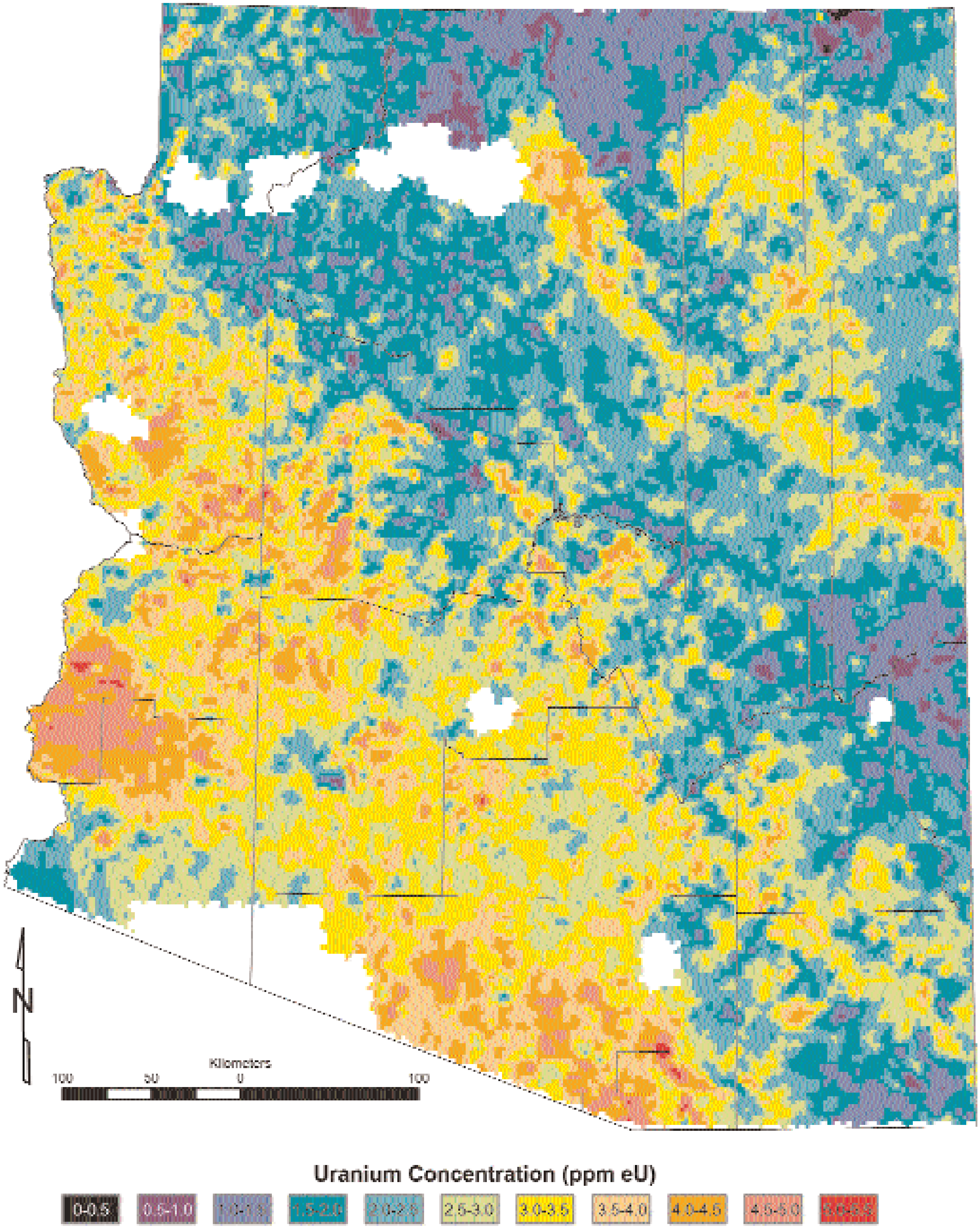

Figure 1. Uranium concentration in Arizona rock and soil. Data acquired by U.S. Department of Energy National Uranium Resource Evaluation (NURE). Distributed by U.S. Geological Survey. Map compiled by Arizona Geological Survey, 2002. Digital layout by A. Youberg, April 2003.

HOLBROOK BASIN: CORRELATION AND RESOURCES

Steven L. Rauzi and Larry D. Fellows
Arizona Geological Survey

Introduction. Sedimentary rocks of Permian age (290 to 248 million years ago) crop out in the Sedona area and Grand Canyon. Rocks of the same age are in the subsurface in the Holbrook salt basin, more than a hundred miles to the east, although they are substantially thicker and different in composition (Figure 1). Because these rocks contain salt, potash, helium, and carbon dioxide (CO_2) in the Holbrook basin, Rauzi (2003) studied them to assess potential for future discoveries. After studying logs of more than 250 wells in the Holbrook basin, he correlated the rock units with rocks in two previously measured sequences in the outcrop area - one near Sedona and the other in Grand Canyon. This article is a summary of the correlations he made, a brief explanation of how the rocks in the Holbrook basin relate to the mineral and energy resources, and an assessment of resource potential in the Permian-age rocks in the Holbrook basin. Because of space limitations, the authors provide little discussion about the extensive work that was done by previous investigators and the valuable contributions they made toward improving understanding of these rocks.

Subsurface investigations. Arizona's oil and gas laws require an operator to submit a sample of all rock cuttings and a copy of all well logs, tests, and surveys from a drilled well to the Arizona Geological Survey (AZGS), which administers and provides staff support for the Arizona Oil and Gas Conservation Commission (OGCC). Well information is available for public inspection after the required confidentiality period has ended. The AZGS currently has record files for 1,095 wells that were drilled for oil, gas, helium, CO_2, and geothermal resources in Arizona.

Geologists characterize subsurface rock units by using information from wells, including rock cuttings and cores that were obtained during drilling and various types of "logs" that were made after drilling was completed. Cores are used to determine properties of rock such as porosity (amount of pore space in a rock), permeability (how easily fluids move through the pore spaces), fluid saturation (percentage of water, oil, etc. in the pore spaces), and pressure. A special tool is lowered into a well to produce a well log. While the tool is slowly being retrieved it measures electrical, radioactive, sonic, or other properties of the rock. Gamma ray and neutron logs are especially useful in correlating different kinds of rock from well to well, and commonly over great distances.

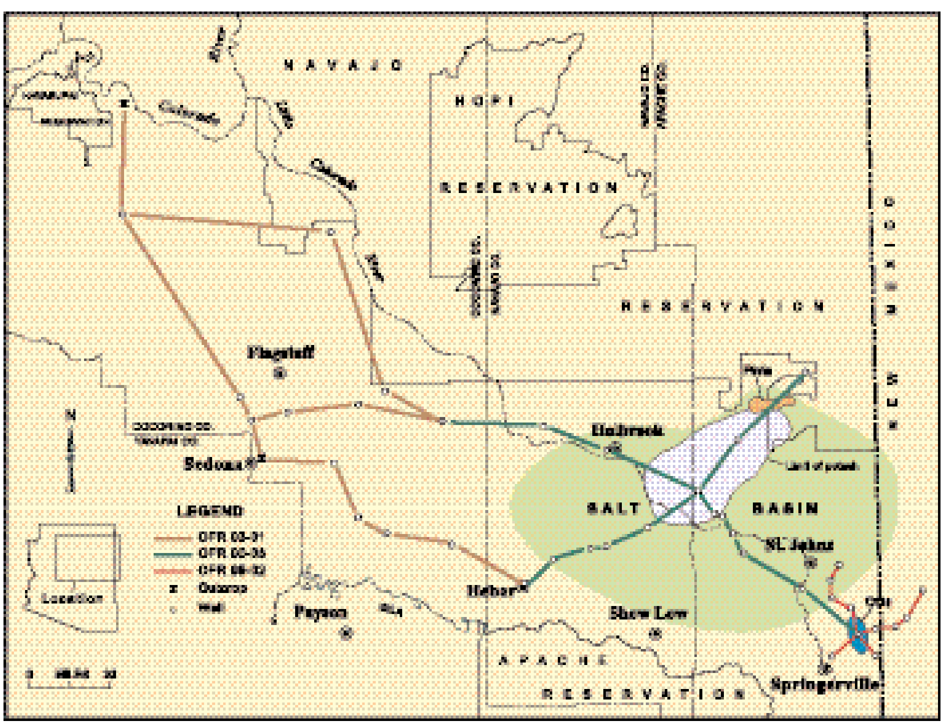

Figure 1. Map showing location of Holbrook salt basin and cross sections in Open-File Reports 03-01, 00-03, and 99-02.

Many geologists have described and correlated the Permian-age rock units that crop out in Grand Canyon and the Sedona area. Most of this work involved attempts to trace the outcrop units into the subsurface. Peirce (1989) and Rauzi (2003) began with the subsurface units in the Holbrook basin and traced them westward into the Sedona area and Grand Canyon, where they crop out.

Peirce (1989) based his correlations primarily on analysis of rock cuttings from wells, although he did not publish detailed log correlations. Rauzi (2003) used geophysical logs from wells, drilled largely since the 1960s, to make subsurface correlations. He showed that distinctive curve breaks on the gamma ray and neutron curves can be easily correlated throughout the Holbrook basin, and extended the correlations into outcrop sections that other geologists had previously measured and described.

Rauzi (1999) correlated strata in 27 wells in the St. Johns and Springerville areas. He concluded that the nomenclature Winters (1963) established to subdivide the Supai Formation could easily be used in geophysical logs throughout southern Apache and Navajo counties. Winters (1963) described and subdivided the Supai from outcrops immediately south of the Holbrook basin. In the

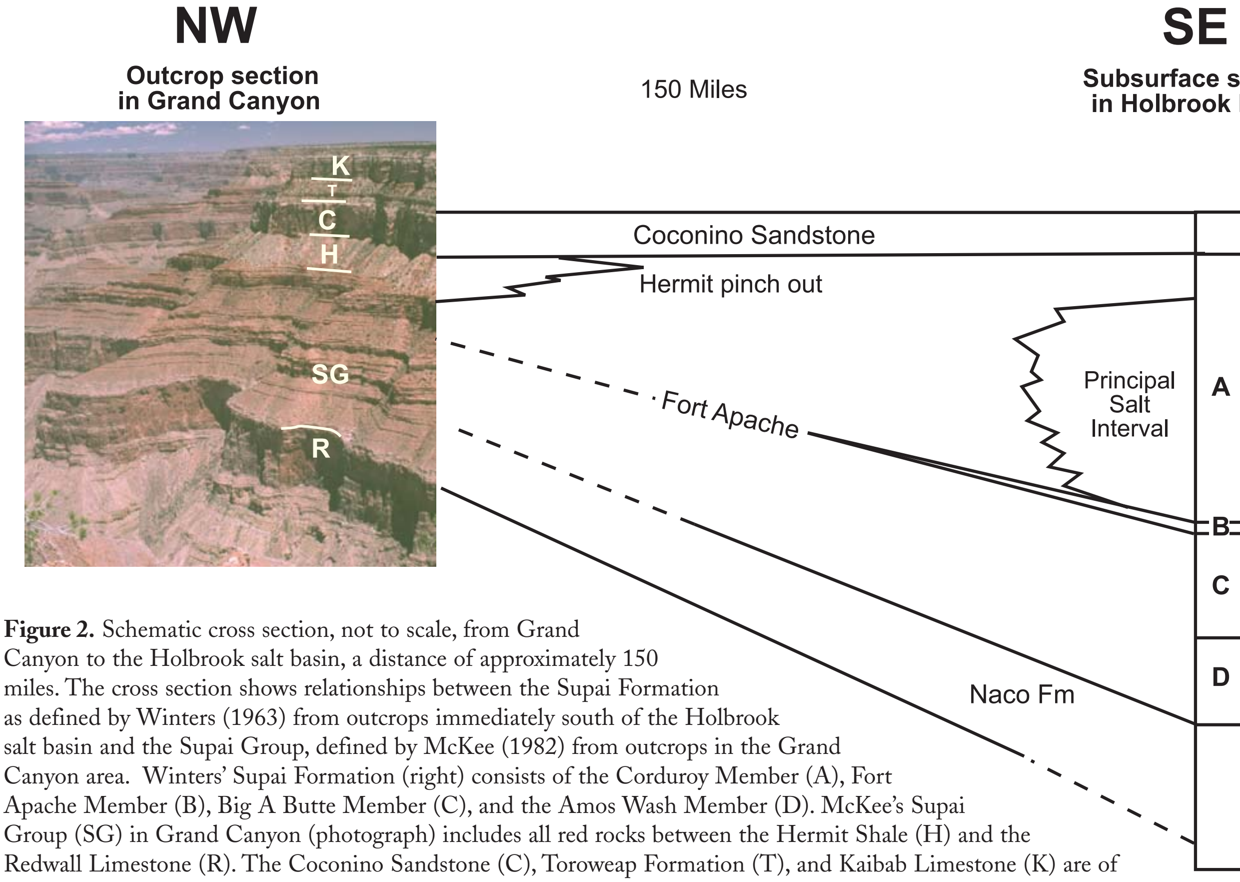

Figure 2. Schematic cross section, not to scale, from Grand Canyon to the Holbrook salt basin, a distance of approximately 150 miles. The cross section shows relationships between the Supai Formation as defined by Winters (1963) from outcrops immediately south of the Holbrook salt basin and the Supai Group, defined by McKee (1982) from outcrops in the Grand Canyon area. Winters' Supai Formation (right) consists of the Corduroy Member (A), Fort Apache Member (B), Big A Butte Member (C), and the Amos Wash Member (D). McKee's Supai Group (SG) in Grand Canyon (photograph) includes all red rocks between the Hermit Shale (H) and the Redwall Limestone (R). The Coconino Sandstone (C), Toroweap Formation (T), and Kaibab Limestone (K) are of Permian age; the Naco Formation is Pennsylvanian; and the Redwall is Mississippian in age.

Holbrook salt basin study, Rauzi (2000) examined logs from 223 wells to plot the thickness and extent of the salt.

In the third study of the series Rauzi (2003) extended subsurface correlations from the Holbrook basin westward into outcrop areas in the Sedona area and Grand Canyon. He concluded that (1) the Fort Apache Member of the Supai Formation in the Holbrook salt basin can be traced into outcrops in the Sedona area, (2) if the Fort Apache Member was present in Grand Canyon, its approximate position would be below the Hermit Shale, and (3) the Hermit Shale, which crops out in Grand Canyon, pinches out toward the east and south.

Rauzi's conclusions (Figure 2) are similar to those made previously by Peirce (1989), but differ from those of Elston and DiPaolo (1979) and Blakey and Knepp (1989).

Resources in the Holbrook salt basin. The Holbrook basin contains halite (common table salt) and potassium-rich deposits in the Supai Formation (early Permian age). The halite deposits cover about 3500 mi^2 of the basin. They reach a maximum aggregate thickness of 655 ft midway between Holbrook and St. Johns, where the cross sections intersect (Figure 3). The top of the salt is less than 1,000 ft below the surface in most of the basin.

Although salt has not been produced commercially, liquified petroleum gas (LPG) has been stored in several caverns dissolved in salt along the Burlington Northern Santa Fe Railroad in the northeastern part of the basin since 1971.

Potassium deposits near the top of the salt unit cover about 600 mi^2 and are up to 38 ft thick. The potash minerals include sylvite, carnallite, and polyhalite. Potash has not been produced commercially, even though exploration drilling in the 1960s and 1970s indicated a potential of as many as 285 million tons of nearly 20 percent average grade K_2O.

Nearly 740 million cubic feet of high-grade helium was produced from wells northeast of Holbrook in the 1960's and 1970's. Gas, mostly nitrogen, in those wells contained 8 to 10 percent helium. The helium was produced from reservoir rocks in the Coconino Sandstone and overlying Shinarump Conglomerate at the Pinta Dome, Navajo Springs, and East Navajo Springs units. Gas containing 2.4 to 4.09 percent helium was under sufficient pressure to blow drill pipe out of one of the potash test holes. The helium processing plant was dismantled in 1976.

CO_2 was discovered near St. Johns in 1994 and production began from one well in July 2002. The CO_2 reservoirs are in the Supai formation.

Shows of oil and gas have been recorded in wells throughout the basin. Oil stains and oil seeping from fractures in a core were observed in a well between Alpine and Nutrioso in the southeastern part of the basin. Oil stains on a core were also reported in a well near Mormon Lake in the western part of the basin. The operator reported an oily scum on residue of the rock that was dissolved in acid.

Resource potential. Potential exists throughout the Holbrook salt basin to produce salt for industrial purposes

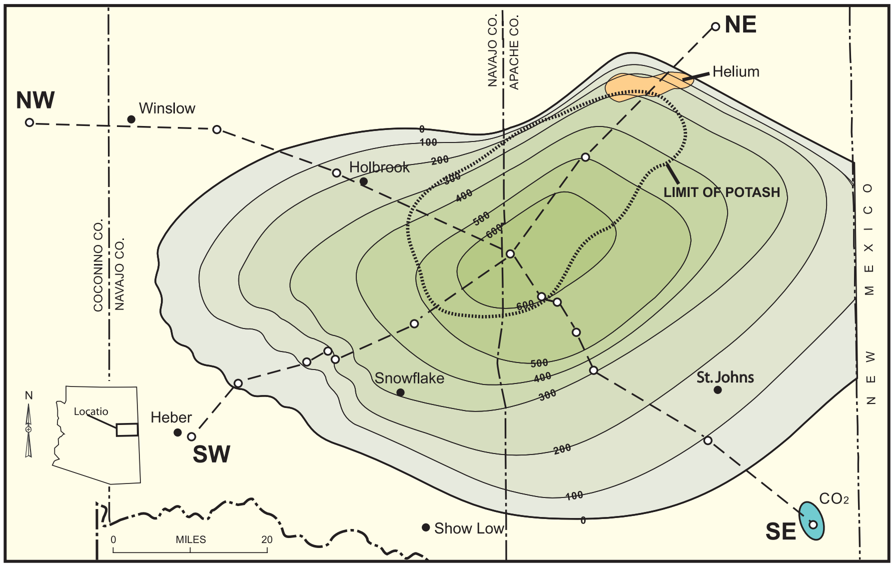

Figure 3. Holbrook salt basin showing the thickness of salt (in feet) and location of cross sections in Open-File Report 00-03.

continued from page 4

such as water treatment systems and deicing highways. Additional storage caverns could be dissolved in salt.

Production of helium near Holbrook and CO_2 near St. Johns demonstrates that reservoir rocks are present and that subsurface conditions are favorable for the generation of these gases.

Oil shows indicate that oil has either been generated in these rocks or has migrated into them. Geologic conditions could include a variety of different kinds of traps for helium, CO_2, and oil and gas. Drilling depths are shallow to moderate, ranging from less than 4,000 to 6,000 ft. On average only about one well has been drilled per 100 square miles in Arizona.

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MAPPING AWARD

The Arizona Geological Survey was awarded $210,665 from the National Geologic Mapping Program, administered by the U.S. Geological Survey, to begin mapping in October. These funds are matched by an equal amount of in-kind work by AZGS staff, making the total value of the project $421,330. Mapping will be done in areas near Wickenburg, Tucson, and Bullhead City. Work will be supervised by AZGS geologists Jon E. Spencer and Philip A. Pearthree.

These areas have high priority for mapping because of population growth and related needs, including identification of aggregate resources, water supply, waste disposal sites, and potential flood-prone areas.

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