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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.

Want to Drill an Oil Well?

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

Although geologic studies suggest that several areas in Arizona may have oil and gas potential (Figure 1), few exploratory wells have been drilled. Arizona, the sixth largest state in the Nation based on area, encompasses about 114,000 square miles. On average, only one deep well has been drilled per every 100 square miles.

The process of exploring for oil, natural gas, carbon dioxide (CO_2), or helium in Arizona includes several steps: evaluating the geologic setting and determining were to drill, obtaining a lease, planning the drilling program. obtaining a permit to drill, drilling the well, and completing the well. I've described these steps and the reasons for them below.

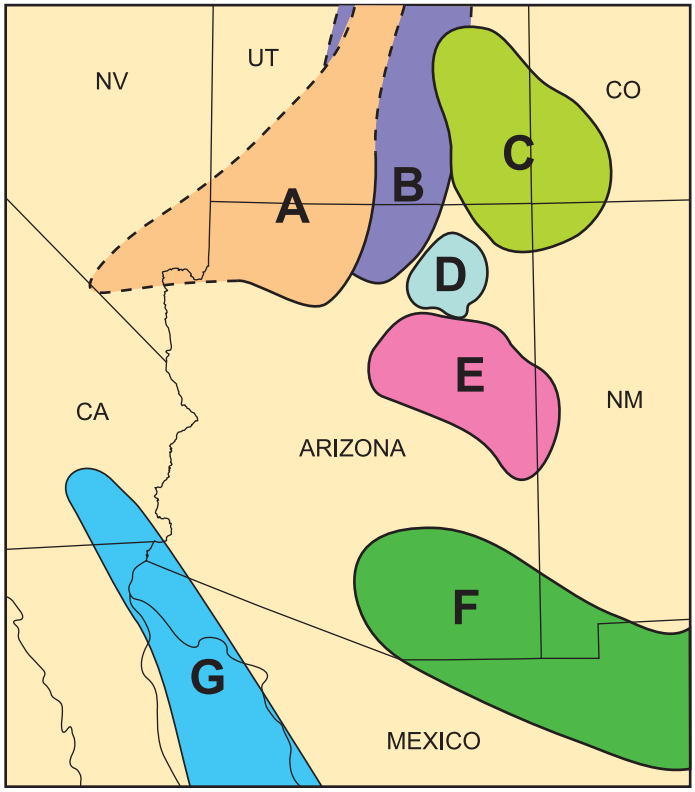

Figure 1. Areas with the best potential for future oil and gas discoveries. **A**-Cordilleran shelf. **B**-Chuar basin. **C**-Paradox basin. **D**-Black Mesa basin. **E**–Holbrook basin. **F**–Pedregosa and Bisbee basins (overlap). **G**–Salton trough.

Geologic setting. A good understanding of geology is essential in any successful exploration program. Oil and natural gas originate in organic-rich rock layers (source rocks) and accumulate in permeable rock layers (reservoir rocks). Traps form where the reservoir rocks are folded into anticlines or grade laterally into non-permeable layers or unconformities. Helium and CO_2 accumulate in similar traps. Geologists study rock outcrops for evidence of potential source and reservoir rocks. They then map the rocks in the subsurface using seismic data and available well control. Most oil, natural gas, CO_2, and helium are trapped in anticlines and at unconformities. These are the settings geologists look for when determining where to drill.

Oil and gas lease. The first step in drilling a well for oil, natural gas, CO_2, or helium in Arizona is to obtain an oil and gas lease from the mineral owner. The lease grants an operator (a person who controls the day-to-day activities of a well) the right to explore and drill for, extract, remove, and dispose of any oil or gas that may be found on the leased lands. A well cannot be drilled legally unless an operator is a mineral owner or has a valid lease.

The Arizona State Land Department administers oil and gas leasing on State Trust land. The U.S. Bureau of Land

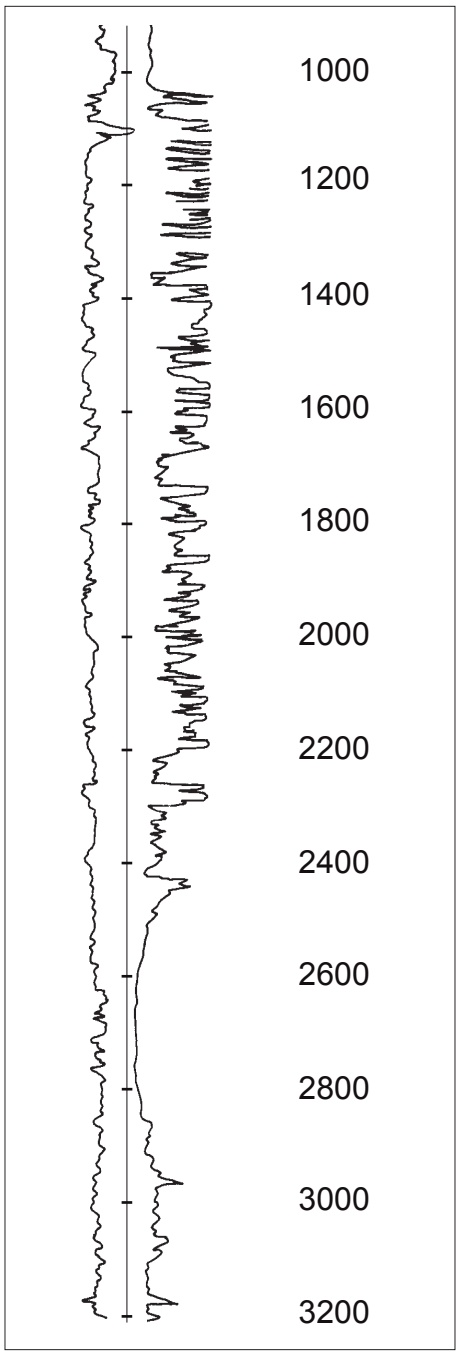

Figure 2. Segment of typical well log. Curve deflections indicate rock properties that can be correlated from well to well. Numbers represent depth in feet below surface .

Management administers leasing on public lands including national forest lands. The Bureau of Indian Affairs, in cooperation with individual Indian nations, administers oil and gas leasing on Indian lands. Exploration companies deal directly with the owners of the mineral rights on private lands to obtain oil and gas leases.

Leasing of State Trust land is noncompetitive (without public auction). Leases have a five-year primary term with an annual rental of $1.00 per acre, and may be extended through a

Figure 3. Pumping unit on producing oil well. Note car for scale.

five-year secondary term with an annual rental of $2.00 per acre. Leasing of public land is competitive. That means the acreage of interest must be nominated by, or receive a pre-sale offer from, an interested party and then be offered for lease at a public auction. These leases have a 10-year primary term with an annual rental of $1.50 per acre for the first five years, and $2.00 per acre for any year thereafter. Lease terms on Indian or fee (privately owned) land are negotiated directly with the Indian tribes or land owners.

Leases are valid as long as annual rental payments are made. If oil and gas are discovered and produced a royalty (normally 12.5 percent) is paid to the mineral owner. The lease is extended for as long as oil or gas are produced.

Drilling permit. After obtaining an oil and gas lease, an operator must next get a permit to drill a well. The Arizona Oil and Gas Conservation Commission (OGCC) regulates oil, gas, helium, CO_2, and geothermal drilling and production in Arizona. The OGCC is attached to the Arizona Geological Survey (AZGS) in Tucson, which provides administrative and staff support. AZGS staff review drilling applications for compliance with rules, issue permits to drill, and perform well-site inspections on behalf of the OGCC.

Basic requirements for drilling, completing, and producing oil and gas wells are explained in the oil, gas, and geothermal resources rules, which are part of the Arizona Administrative Code (A.A.C.) in Title 12 (Natural Resources), Chapter 7 (Oil and Gas Conservation Commission). These rules may be viewed on the Arizona Secretary of State's web page (www.sosaz.com). Paper copies may be purchased from the Secretary of State. The OGCC has authority to approve requests for variance or exception to many of the general statewide rules after notice and hearing. Questions about the OGCC, its rules, or applications to drill may be directed to the Oil and Gas Administrator at the AZGS.

To begin the permitting process it is helpful to first inform the Oil and Gas Administrator about your interest in drilling. This initial contact and informal discussion about the project, its location, and the known geologic and engineering parameters may save time with respect to casing and archaeological requirements. In addition, such a discussion commonly reveals that useful information about a specific site, including the geologic, groundwater, and potential drilling conditions, is available at the AZGS. The AZGS maintains well files and drilling records, rock cuttings and cores, and a geological library. Application forms for a drilling permit are provided on request.

Before drilling, one must submit an application form, an organization report, a surety or cash bond, a drilling prognosis, and an application fee. These requirements are described in A.A.C. R12-7-104 (Application for Permit to Drill). Bonding is described in R12-7-103. The bond required is $10,000 for a well less than 10,000 ft deep and $20,000 for a well 10,000 ft or more in depth. A blanket bond for multiple wells is $25,000. The bond is returned to the operator upon compliance with all drilling, plugging, and restoration provisions of the rules.

The application form includes a survey plat to ensure that the location of the well on a lease conforms with the statewide spacing rules set by the OGCC. Spacing rules prevent waste and potential withdrawal of oil or gas from adjacent leases. Spacing rules also ensure maximum recovery of any subsurface natural resource that may be discovered.

The drilling prognosis is a detailed description of the proposed well. It shows, among other things, the proposed reservoir and total depth, amount of casing, and type and amount of cement to be used when the casing is set. The OGCC requires that casing extend from the surface to the base of all known and reasonably estimated fresh-water aquifers. The casing string must be properly cemented in place to protect groundwater and other natural resources. The amount of surface casing required is based partly on groundwater information obtained from the Arizona Department of Water Resources.

Review of a properly completed application for a permit to drill normally takes five working days or less. An application is approved if it is in accord with all applicable rules and a permit to drill is issued to the operator. A permit to drill is valid for 180 days from the approval date. The OGCC routinely forwards a copy of an

Figure 4a. Drilling for geothermal resources near Alpine, AZ in 1993.

Figure 4b. Same location restored in 1997.

approved application to the county manager of the county in which the well is to be drilled.

A drilling permit is issued with the expectation that an operator will follow all applicable rules and will notify the Oil and Gas Administrator when drilling starts and at least 48 hours before surface casing is placed in the hole and cemented. This notification is needed to allow sufficient time for a representative of the AZGS to travel to the drill site and witness the cement job. By being present the representative can ensure that the surface casing is properly cemented in place to protect groundwater and natural resources from contamination.

Drilling. Once a permit to drill has been issued, an operator can legally drill a well. Drilling for oil and gas in Arizona can be expected to cost between $400,000 and $1,000,000, depending on the depth of the hole and its location. A rig capable of drilling most exploratory holes typically costs $8,000-15,000 per day. The cost just to move a rig to the proposed drill site may be $50,000 or more. Farmington and Artesia, New Mexico, are the closest locations for most oil-field drilling, service, and supply companies. Some companies have had to use drill rigs from as far away as California or Texas when they were not available in New Mexico.

As a well is drilled, fluid ("drilling mud"– mostly water and bentonite clay) is pumped down the inside of the drill pipe and comes back to the surface outside of the pipe. The drilling mud keeps the drill bit cool and brings the rock cuttings produced by the drill bit from the bottom of the hole up to the surface. Most operators hire a specialist called a mud logger to continuously examine the mud and cuttings for any traces of oil and gas as the well is drilled. If a show of oil or gas is detected, an operator may conduct a drill-stem test. This is done by lowering a special tool down the hole on the end of the drill pipe. The tool, which measures the pressure of the rock formation of interest, also recovers a sample of the fluid in the formation. After the hole has been drilled to total depth additional tools are lowered down the hole on a wire-line to measure the natural properties of the subsurface rocks. These properties, including resistivity, natural radioactivity, density, porosity, and permeability, are recorded on long strips of paper (well logs, Figure 2) as the tool is slowly pulled up the hole. An operator may conduct additional open-hole tests depending on what the well logs show.

Completion. If oil or gas are discovered, an operator runs an additional string of casing to the producing reservoir, cements it in place, and completes the well as a producer. A wellhead is installed and connected to either a pipeline, in the case of a gas discovery, or a pumping unit and stock tank in the case of an oil discovery (Figure 3). The mineral owner receives a royalty on all oil or gas that is produced. The mineral owner is obligated to extend the lease for as long as a well produces oil or gas.

The story that an operator found oil but capped the well to wait for higher prices is a myth. It simply costs too much money from the loss of revenue to cap a well and wait for higher prices. It is important for an operator to generate cash flow as soon as possible from a new discovery in order to recover the large expense of an exploration project, which includes costs for geologic studies, leasing the land, and, finally, drilling, testing, and completing the well. The sooner oil or gas is delivered to market, or sold, the sooner these costs are recovered and the operator starts to make a profit. Income from a discovery must also cover the costs of drilling dry holes – those holes that did not find oil or gas.

If a well does not encounter commercial quantities of oil or gas, it must be plugged and abandoned. Zones containing oil and gas are permanently isolated from other zones by cement plugs. These plugs protect groundwater and natural resources from cross contamination between zones. A final cement plug is placed in the top 50 ft of the hole. Finally the rig is removed, a well monument is erected, and the well site is reclaimed (Figure 4a, b). An operator's bond is returned upon compliance with all drilling, plugging, and restoration provisions of the rules.

Subsurface information. Oil and gas statutes require an operator to submit a sample of all drill cuttings and a copy of all logs, tests, and surveys from a well after drilling has been completed. This information is held confidential for one year and may be extended under certain circumstances. A well operator has exclusive use of the data during this time. All drilling and well information is made available for public inspection when the confidential period expires.

The collection of drilling and subsurface geological information is essential for several reasons. The OGCC uses the information to verify compliance with rules, safeguard the public health and welfare, and ensure sound conservation practices. Conservation practices must be based on all available geological and engineering information to optimize recovery and prevent waste of natural resources including oil and gas.

Subsurface geological information enhances the understanding of Arizona's geo-

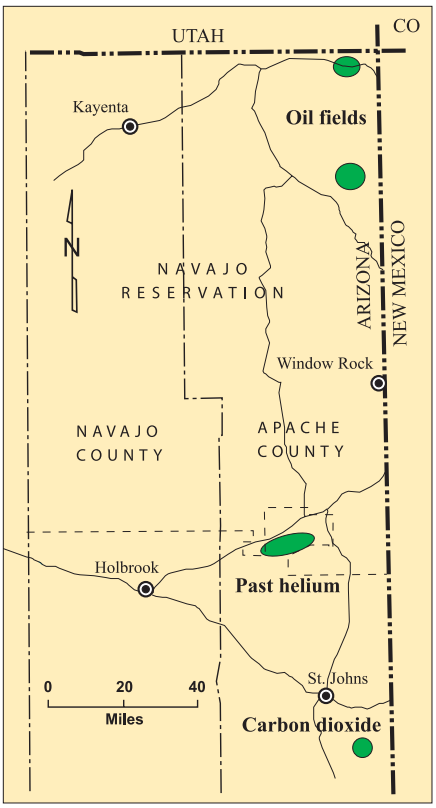

Figure 5. Areas with current and past production of oil, gas, helium, and carbon dioxide.

logic history. The better geologists understand this history, the better they can explore for, develop, and manage Arizona's natural resources. Many companies and individuals, including oil-exploration, groundwater and environmental companies, hydrologists, geologists, and the public, use the well files maintained by the AZGS. Within the last five years geologists at the AZGS used the files to identify areas with promising oil and gas potential, describe known and potential salt deposits, map the extent of valuable salt and potash deposits in the Holbrook Basin, and correlate the subsurface geological units that produce CO_2 in southern Apache County with outcrops in Grand Canyon and the Sedona area. All studies AZGS geologists make are released to the public.

The AZGS maintains a series of 1:500,000-scale county maps that show the location of oil, gas, stratigraphic, geothermal, and selected water wells. These maps, which are available for purchase from the AZGS sales office, aid in the location and retrieval of subsurface information. A statewide map of oil and gas holes is also available. This map includes a report that lists all of the oil and gas well files maintained by the AZGS on behalf of the OGCC.

Economic impact. Drilling a well for oil or gas has a short-term impact on the local economy. A drilling rig operates 24 hours a day using three eight-hour shifts. Each shift employs a crew of four. Other personnel such as welders, geologists, engineers, sales representatives, and supervisors, in addition to crews to run and cement the casing, mud loggers to examine cuttings and collect samples, and mud engineers to monitor and maintain the drilling mud, bring the total personnel associated with the drilling operation to 15 or 20. Although local services and supplies are used whenever possible, most personnel must be brought in from oil-field drilling, service, and supply centers. Drilling crews stay in local motels, buy groceries, and eat in local restaurants. All fuel, water, and non-specialized goods and services needed in the drilling operation are purchased locally.

A discovery of oil or gas may have a substantial long-term impact on the economy. Several people or more will be employed, depending on the size of the discovery. Employees generate personal income, purchase local goods and services, and pay income and sales taxes, some of which support local schools. The state also benefits from severance (ad valorem) taxes paid on all production. Royalties are paid to the mineral owners. These payments could extend over 30 or more years. The total income from taxes, royalties, and purchase of goods and services can easily amount to several hundred million dollars or more over the life of the field, depending on the size of the discovery.

Production in Arizona. Almost 100 wells have produced oil, gas, helium, or CO_2 in Arizona (Figure 5). Currently, 20 oil and eight gas wells produce about 200 barrels of oil and 1 million cubic feet of gas per day from several small fields in northeastern most Arizona. Helium, the first commercially produced gas in the state, was discovered about 40 miles east of Holbrook in 1950. More than 740 million cubic feet were produced from three fields between 1960 and 1976. Natural gas and oil were discovered in 1954 near Red Mesa in northeastern Apache County. Gas from this discovery was not produced until 1959 when the well was connected to a pipeline. Several more fields were subsequently discovered in northeastern Arizona and continue to produce today. The largest is the Dineh-bi-Keyah field, which has produced nearly 18 million barrels of oil since 1967. CO_2 was discovered between St. Johns and Springerville in 1994. Gas from this discovery was first produced in 2002, when one of three wells was connected to a plant that processes liquid CO_2 for use in the beverage industry. Trucks deliver the liquid CO_2 to markets in Arizona. Cumulative production from all wells in Arizona is more than 20.5 million barrels of oil and 38.5 billion cubic feet of gas. Several of the oil and gas fields in northeastern Apache County have been producing for more than 30 years.

Oil and Gas Conservation Commission. The first oil and gas legislation in Arizona was passed in 1927. The act, which provided for the conservation of oil and gas and regulated oil and gas wells, was administered by the State Land Commissioner. These statutes were apparently triggered by the flurry of drilling that occurred in the early 1920s in the Holbrook Basin and Chino Valley.

The Oil and Gas Conservation Act of 1951 provided for the establishment of the OGCC at the session of the legislature next following the discovery and production of oil or gas in the state. Discovery and production occurred in 1959 and the OGCC was established. The act also transferred administrative and enforcement responsibility from the State Land Commissioner to the newly established OGCC. The OGCC was given jurisdiction over geothermal resources in 1972 and enhanced recovery, disposal, and storage wells in 1978. Because of revenue shortfall in 1991, the Legislature eliminated the OGCC (agency) and attached the six-member commission to the AZGS for administrative and staff support.

The OGCC, which holds several regular meetings each year, has six members. The Governor appoints five and the sixth, the State Land Commissioner, is ex officio. Current commissioners are J. Dale Nations, Tucson, chairman; Robert L. Jones, Sun City West, vice chairman; Joseph J. Lane, Phoenix; Michele P. Negley, Phoenix; Robert L. Wagner, Yuma; and Mark Winkleman, State Land Commissioner. The OGCC regulates the drilling, completion, and production of oil and gas wells in Arizona within the framework of four goals that are in the spirit of the conservation legislation that was first passed in 1927. These goals are 1) Conserve natural resources, 2) protect public health and safety, 3) encourage exploration and development, and 4) provide information and assistance.

JUST RELEASED

Geologic map of the Desert Peak 7.5' Quadrangle, southeastern Pinal County, Arizona: Youberg, Ann, Ferguson, C.A., Richard, S.M., Johnson, B.J., Maher, D.J., and Gilbert, W.G., 2002, Arizona Geological Survey Digital Geologic Map 20 (DGM 20), 1 CD-ROM that includes a 1:24,000-scale geologic map. $15.00 plus shipping and handling. *(A paper copy of the geologic map is available for $15.00 plus shipping and handling.)*

Geologic map of the Oro Valley 7.5' Quadrangle, northeastern Pima County, Arizona: Spencer, J.E., and Pearthree, P.A., 2002, Arizona Geological Survey Digital Geologic Map 21 (DGM 21), 1 CD-ROM that includes a 1:24,000-scale geologic map. $15.00 plus shipping and handling. *(A paper copy of the geologic map is available for $15.00 plus shipping and handling.)*

Geologic map of the Chief Butte 7.5' Quadrangle, southeastern Pinal County, Arizona: Spencer, J.E., Richard, S.M., Youberg, Ann, Ferguson, C.A., and Orr, T.R., 2002, Arizona Geological Survey Digital Geologic Map 22 (DGM 22), 1 CD-ROM that includes a 1:24,000-scale geologic map. $15.00 plus shipping and handling. *(A paper copy of the geologic map is available for $15.00 plus shipping and handling.)*

Geologic map of the North of Oracle 7.5' Quadrangle, southeastern Pinal County, Arizona: Orr, T.R., Shipman, T.C., and Spencer, J.E., 2002, Arizona Geological Survey Digital Geologic Map 23 (DGM 23), 1 CD-ROM that includes a 1:24,000-scale geologic map. $15.00 plus shipping and handling. *(A paper copy of the geologic map is available for $15.00 plus shipping and handling.)*

Geologic map of the Sierra Ancha, central Arizona: Skotnicki, S.J., compiler, 2002, Arizona Geological Survey Digital Geologic Map 24 (DGM 24), 1 CD-ROM that includes a 29 p. text and 2 sheets, scale 1:100,000-scale geologic map. $15.00 plus shipping and handling. *(A paper copy of the text and maps are available for $6.00 and $25.00, respectively, plus shipping and handling.)*

Geologic map of the southern Peloncillo Mountains; Skeleton Canyon, Guadalupe Spring, and Guadalupe Canyon 7.5' quadrangles, Cochise County, Arizona and Hidalgo County, New Mexico: Skotnicki, S.J., 2002, Arizona Geological Survey Digital Geologic Map 25 (DGM 25), 1 CD-ROM that includes a 1:24,000-scale geologic map and a 26-page text. $15.00 plus shipping and handling. *(A paper copy of the geologic map and text is available for $21.00 and $5.00, respectively, plus shipping and handling.)*

Geologic map of a portion of the silicified Mescal paleokarst, northern Sierra Ancha, central Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Digital Geologic Map 27 (DGM 27), 1 CD-ROM that includes a 1:50,000-scale geologic map. $10.00 plus shipping and handling. (A paper copy of the geologic map is available for $10.00 plus shipping and handling.)

Preliminary geologic map of the Oak Creek Ranch 7.5' Quadrangle, Gila County, Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Open-File Report 02-08 (OFR 02-08), 1 sheet, scale 1:24,000. *$2.00 plus shipping and handling.*

Preliminary geologic map of the Gentry Mountain 7.5' Quadrangle, Gila County, Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Open-File Report 02-09 (OFR 02-09), 1 sheet, scale 1:24,000. *$2.00 plus shipping and handling.*

Preliminary geologic map of the Parallel Canyon 7.5' Quadrangle, Gila County, Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Open-File Report 02-10 (OFR 02-10), 1 sheet, scale 1:24,000. *$2.00 plus shipping and handling.*

Preliminary geologic map of the Young 7.5' Quadrangle, Gila County, Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Open-File Report 02-11 (OFR 02-11), 1 sheet, scale 1:24,000. *$2.00 plus shipping and handling.*

Preliminary geologic map of the Salt River Peak 7.5' Quadrangle, Gila County, Arizona: Skotnicki, S.J., 2002, Arizona Geological Survey Open-File Report 02-12 (OFR 02-12), 1 sheet, scale 1:24,000. *$2.00 plus shipping and handling.*

Correlation of Pennsylvanian and Permian strata in Coconino County, Arizona: Rauzi, S.L., 2003, Arizona Geological Survey Open-File Report 03-01 (OFR 03-01), 4 sheets, 4 p. *$10.00 plus shipping and handling.*

Structural and stratigraphic relationships of mid-Tertiary strata in the Hackberry Wash-Indian Camp Wash intramontane depression, Tortilla Mountains, Pinal County, Arizona: Dickinson, W.R., 2002, Arizona Geological Survey Contributed Map 02-B (CM 02-B), 13 p., 2 sheets, scale 1:24,000. *$5.00 plus shipping and handling.*

Subsurface geology of the easternmost Phoenix basin, Arizona: Implications for groundwater flow: Reynolds, S.J., and Bartlett, R.D., 2002, Arizona Geological Survey Contributed Report 02-A (CR 02-A), one CD-ROM that includes a 74-page text. $15.00 plus shipping and handling. *(A paper copy of the text is available for $26.00 plus shipping and handling.)*

Geology and hydrology of the Payson-Strawberry-Diamond Rim area, Gila and Coconino counties, central Arizona: Weitzman, Morley, 2002, Arizona Geological Survey Contributed Report 02-B (CR 02-B), 17 p., 1 sheet, scale 1:62,500. *$6.00 plus shipping and handling.*

Arizona Rocks Post Card: Fellows, L.D , 2003, 5 x 7-inches, set of 3. *$1.00 plus shipping and handling.*

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