
# New Mexico EARTH MATTERS

Volume 2, Number 2, Summer 2002


## Notes from the State Geologist

We are celebrating our diamond anniversary in this new fiscal year. Those 75 years of service as the geological survey of New Mexico have led to enormous growth in our understanding of the geology, mineral and energy resource potential, and geohydrologic framework of the state. That time period has also seen an enormous shift in the geoscience needs of the state. In 1927 interest focused mainly on basic geologic mapping and the delineation of hard-rock mining prospects. Today those issues remain important, but so are a broad spectrum of new topics, including ones related to coal and petroleum development, water supply, environmental quality, and geologic hazards (earthquakes, volcanic eruptions, and collapsible and expandable soils). The changes in staffing and research directions of the bureau have paralleled those changes in state and national geoscience concerns. The good news is that we are able to provide valuable counsel to the state and its citizens on the full range of its needs; the bad news is that, with level or declining staffing, we are spread very thin and no longer have a substantial work force concentrated on any one area of interest.

To help with effective dissemination of scientific information on modern geologic issues, we have embarked on a series of outreach activities in which we join with other state, federal, and science-oriented agencies to conduct field conferences for influential decision makers. The first such trip was held in 2001 and dealt with water and watershed management issues (including the impact of forest fires); the second was

*(Continued on page 5)*

## Arsenic in New Mexico's Water

Arsenic is an element with a bad reputation—what's it doing in our drinking water? The amount of arsenic in drinking water in some western states, including New Mexico, is among the highest in the U.S. An element with a surprisingly diverse character and geological occurrence, arsenic can be both beneficial and harmful. In ancient times, when poisoning was a common way of eliminating political contenders, heirs, spouses, etc., the Roman emperor Nero used arsenic to get rid of both Claudius and Britannicus. And who has not heard of the 1940s movie "Arsenic and Old Lace"? However, the "arsenic eaters" of southern Austria discovered that arsenic had a tonic effect and built up a tolerance for it, so that they could ingest each day an amount that would otherwise be fatal. It's possible that arsenic in trace amounts may in fact be an essential element in human nutrition, as are many other elements, such as copper and zinc, that are harmful in larger quantities. Paracelsus, a Swiss physician and alchemist (1493–1541), pointed out that all substances are poisons; the right dose differentiates a remedy from a poison.

*Silicic volcanic rock in the Jemez Mountains of northern New Mexico.*

### The Natural Occurrence of Arsenic in Rocks

Arsenic is a naturally occurring element found in many of the rocks and minerals that make up the earth's crust. The minerals with the highest arsenic content are realgar and orpiment, both arsenic sulfides, which contain 70% and 60% arsenic by weight, respectively. These minerals are rare. More common arsenic-containing minerals include arsenopyrite and pyrite ("fool's gold"). These two minerals can contain as much as 48% and 5% arsenic by weight, respectively. One of the geologic settings in which these minerals occur is areas where precious metals have been deposited, and both minerals are common in New Mexico. Although the arsenic in these minerals is chemically bound into their structure, it can be released if the minerals are chemically altered or broken down.

Most rocks contain much less arsenic than the amounts listed above. The abundance of arsenic is typically highest in organic-rich shale and volcanic rocks, particularly in light-colored, silica-rich volcanic rocks like those in the Jemez Mountains, which can contain as much

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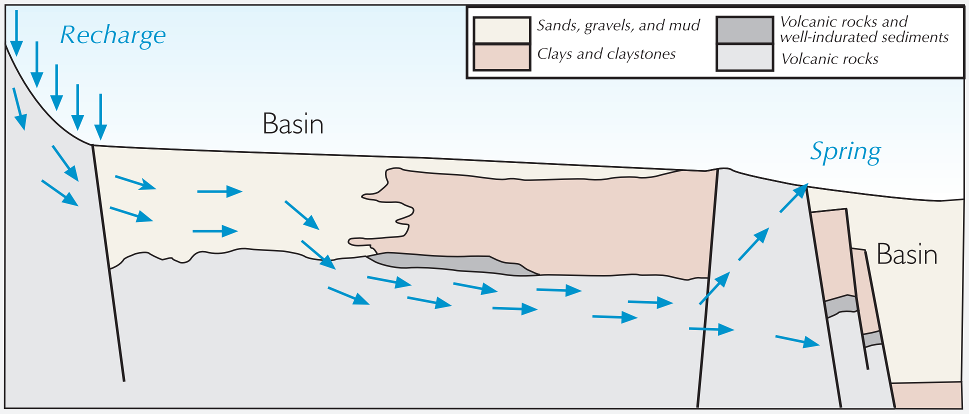



*Idealized cross section of a geologic basin, with arrows showing pathways of water flow. Water falls as rain in the mountains and percolates down into the basin. Water travels preferentially through rocks with interconnected open space, or permeability, such as sandy sediments and fractured volcanic rocks. Water flows around impermeable rocks, such as claystones. As water flows from the mountains into the deep basin, it may become warm, promoting dissolution of arsenic from the rocks through which it flows. This water may be tapped by wells in the basin or may discharge as springs.*

as several hundred parts per million (ppm) of arsenic. Metamorphic and intrusive igneous rocks (common in the Sangre de Cristo Mountains and other parts of northern New Mexico) are very low in arsenic. Limestone and sandy sedimentary rocks, present in much of eastern New Mexico, also contain little arsenic. Sedimentary rocks can be high in arsenic if they are derived from rocks that contained high amounts of arsenic. Some of the sandstones and mudstones that underlie Albuquerque contain high arsenic levels, partly because they are made of particles of silica-rich volcanic rocks from the Jemez Mountains.

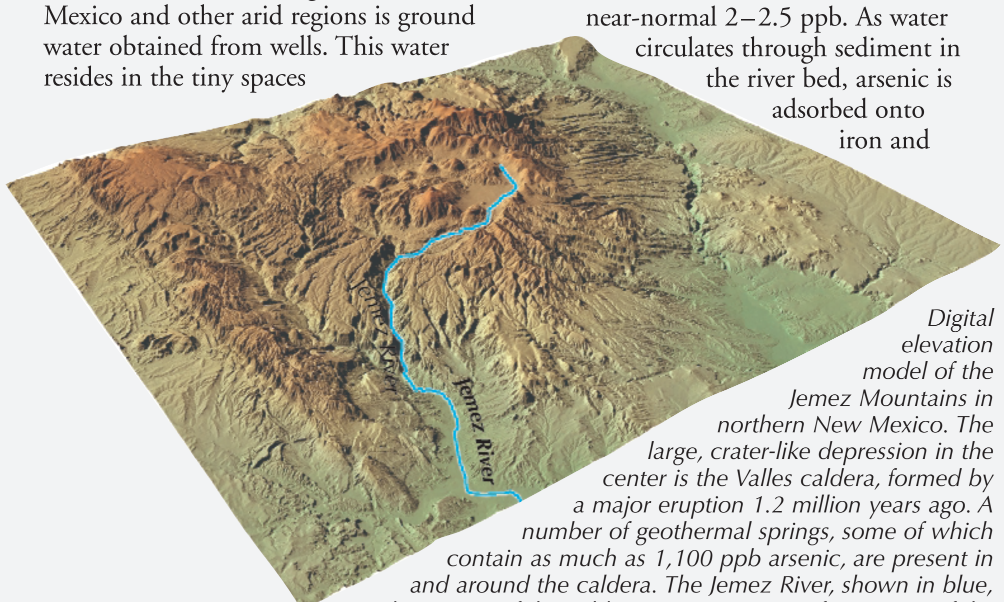
Rocks can undergo geological processes that enrich their original arsenic content. The most common of these processes is hydrothermal alteration, which occurs when hot mineral-laden water moves through a rock, depositing minerals. This process leads to some of the highest concentrations of arsenic in any rocks—as much as 1% by weight. One such geothermal system is the Yellowstone area of Wyoming, characterized by hot water pools and geysers. The hot waters found in the Jemez Mountains of northern New Mexico are also part of an active geothermal system.

## Arsenic in Our Drinking Water

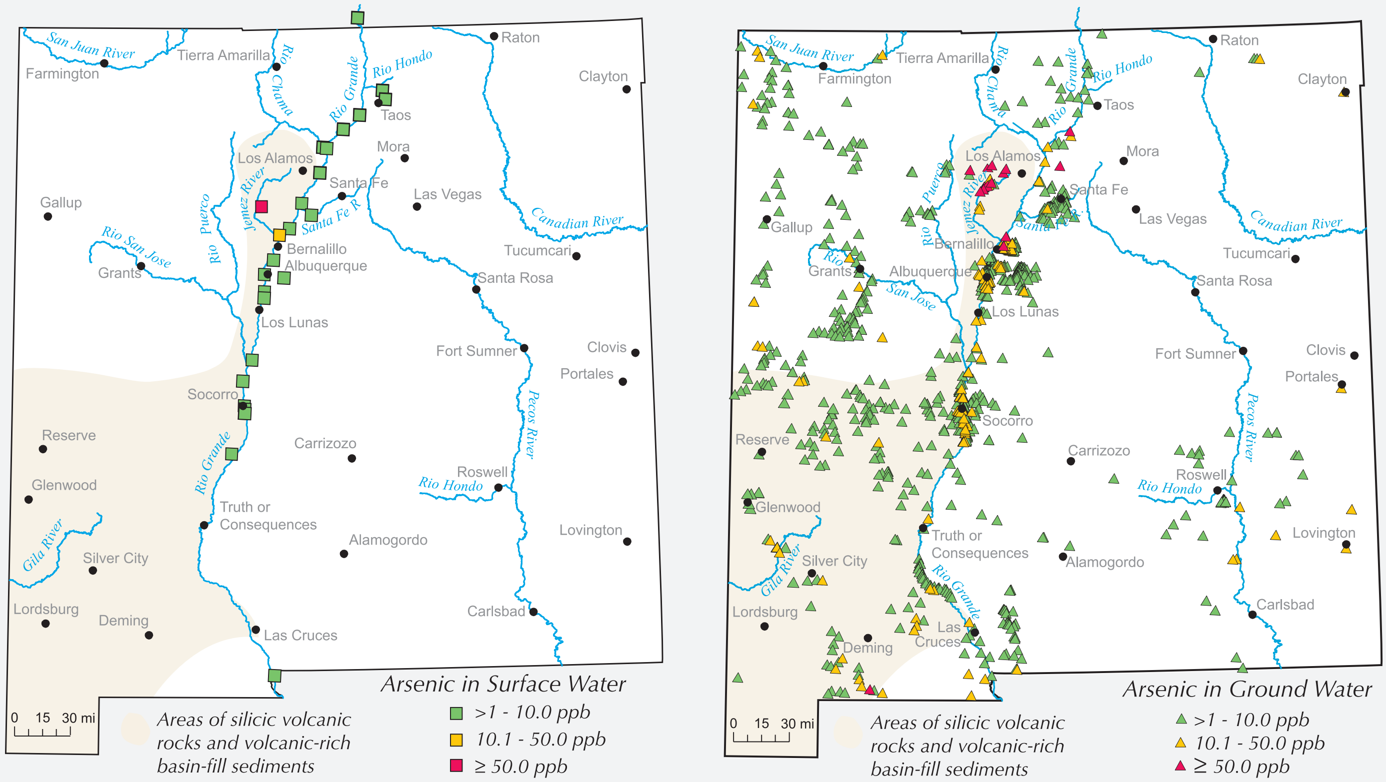
That brings us back to our original question: How does arsenic get into drinking water? Surface and ground waters can—and do—interact with, and leach arsenic from local rocks. This means that the arsenic content of water around active (or fossil) geothermal systems can be quite high. The Jemez River, which contains water draining from geothermal systems in the Jemez Mountains, contains more arsenic than other rivers in northern New Mexico. The arsenic content of water draining from areas of precious metal mineralization—mined or unmined—may also be high because of breakdown of arsenic-bearing minerals in these rocks. When the arsenic content of ground water is high, a geological explanation can often be found. Although this doesn't help remove arsenic from the water, it does allow some prediction of where high levels of arsenic in water may present a problem.

Mountain streams in most of New Mexico have very low arsenic contents—only a few parts per billion (ppb)—but much of the drinking water in New Mexico and other arid regions is ground water obtained from wells. This water resides in the tiny spaces between mineral grains for long periods, where it slowly reacts with and dissolves some of the more soluble minerals and rock fragments. Sand, silt, and clay particles tend to adsorb, or soak up, arsenic onto coatings of iron and manganese oxides as the particles are carried by streams to where, upon deposition, they become part of a ground-water aquifer.

The Rio Grande above Otowi Bridge (near San Felipe Pueblo) carries only about 2 ppb arsenic, but arsenic concentrations increase downstream because of additions of water from other sources. The Jemez River where it joins the Rio Grande near Bernalillo contains 30–80 ppb arsenic, resulting from input from geothermal waters in the Jemez Mountains. The Bernalillo, Rio Rancho, and Albuquerque waste water treatment plants discharge water containing between 7 and 38 ppb arsenic to the Rio Grande. These arsenic levels, some above the newly instituted U.S. Environmental Protection Agency (EPA) limit of 10 ppb, result from the reliance of these communities on ground water from wells in the Albuquerque Basin. By the time the Rio Grande reaches Isleta Pueblo, the arsenic content of its water has increased to about 4 ppb. The Rio Grande then flows past the Mogollon–Datil volcanic field from Bernardo to below Truth or Consequences where it interacts with ground water carrying as much as 47 ppb arsenic, increasing the arsenic content of the Rio Grande to more than 5 ppb. Interestingly, from below Caballo Dam to El Paso the average arsenic content in the Rio Grande decreases to a near-normal 2–2.5 ppb. As water circulates through sediment in the river bed, arsenic is adsorbed onto iron and




*Digital elevation model of the Jemez Mountains in northern New Mexico. The large, crater-like depression in the center is the Valles caldera, formed by a major eruption 1.2 million years ago. A number of geothermal springs, some of which contain as much as 1,100 ppb arsenic, are present in and around the caldera. The Jemez River, shown in blue, drains part of the caldera, receiving water from some of the high-arsenic geothermal springs, and flows into the Rio Grande.*




*Arsenic in surface water (left) and ground water (right) in New Mexico. Units in parts per billion.*

manganese oxides that coat sediment particles, reducing the arsenic content of water in this stretch of the river.

## Health Hazards Associated with Arsenic

High concentrations of arsenic in drinking water are a major health problem in many parts of the world, particularly in developing countries. Major health hazards associated with arsenic are skin, lung, and bladder cancers and cardiovascular disease, but they also include hypertension, diabetes, and anemia. Many countries have extremely high upper limits of arsenic in ground water: Ghana, 200 ppb; Mexico, 400 ppb; Chile, 800 ppb; Bengal and Bangladesh, 2,000 ppb; Taiwan and Argentina, 3,800 ppb; and Thailand, 5,000 ppb. Most of this ground water was used for drinking before the arsenic content was known, and thousands of people were poisoned as a result. In some areas, people still drink water containing these levels of arsenic. In Taiwan, Bangladesh, India, and Chile, where arsenic poisoning is well documented, health problems such as those outlined above have resulted from long-term consumption of water containing more than 400 ppb arsenic. Deleterious health effects have not been reported for consumption of arsenic in drinking water below about 150 ppb, but the lack of detailed studies leaves some uncertainty about exactly how much arsenic is too much.

Arsenic in drinking water was first regulated in 1900 as a result of arsenic poisoning of several thousand beer drinkers in Manchester, England. Brewers and pub owners had been adding chemicals like arsenic and strychnine to jazz up their beer. Arsenic ingestion may have been as high as 1,000 – 5,000 ppb (1–5 ppm) per day for weeks or months. Upon investigation, the highest safe level was found to be about 250 ppb. Application of a five-fold safety margin led to adoption of a drinking-water standard of 50 ppb by the World Health Organization.

The U.S. Public Health Service adopted a 50 ppb standard in 1942. With the passage of the Safe Drinking Water Act in 1975, the Environmental Protection Agency (EPA) adopted the 50 ppb level as an interim regulation, stating that illness was not associated with exposure to arsenic below 50 ppb. The revised Safe Drinking Water Act of 1986 required the EPA to set an arsenic standard by 1989. The agency failed to meet that deadline and was sued in 1989 by the Bull Run Coalition, a citizen group in Oregon concerned about high arsenic levels in snowmelt from Mount Hood (a volcano with associated geothermal activity).

Although arsenic in ground water in the United States can occur at levels as high as 1,200 ppb, waters with such high levels of arsenic have not been used as a source of drinking water. In the western United States, including New Mexico, the concern is whether long-term consumption of water with relatively low arsenic concentrations—50 ppb or below—could cause health problems—in particular, several types of cancer. There are communities in the western U.S. where drinking-water sources contain higher levels of arsenic. Fallon, Nevada (100 ppb) and San Ysidro, New Mexico (200 ppb), where arsenic is removed with household reverse osmosis systems, are two such communities.

## The New Arsenic Standard

Arsenic came more prominently to the public eye on January 22, 2001, when, after 15 years of controversy, the EPA lowered the arsenic-in-drinking-water standard to 10 ppb. A subcommittee of the National Research Council in 2001 agreed with the EPA that the maximum contaminant level should be lowered from 50 ppb, and that the EPA risk estimates were calculated appropriately. The new standard is being appealed by the New Mexico Environment Department, the City of Albuquerque, the Nebraska

*Cliffs of volcanic rock in the Jemez Mountains, which formed during the 1.2 million-year-old eruption of the Valles caldera.*

attorney general, a consortium of southwestern cities, and other groups.

Objections to the stringent new standard are both scientific and economic. The new standard was derived from studies conducted among residents of Taiwan and Chile who for years drank water containing high levels of arsenic (above 400 ppb) and had a high incidence of bladder and lung cancer. There is a 1 in 10 incidence of arsenic-related cancer death for adults that drink water containing 500 ppb arsenic for their entire lives. A straight line projection from these high levels to the lower levels of arsenic typical of the United States resulted in the establishment of the new arsenic standard of 10 ppb. However, the health effects of arsenic at lower levels are uncertain and hypothetical. Arsenic levels in drinking water in the United States are relatively low (the maximum contaminant level has been 50 ppb since 1942), and arsenic-related health problems have not been documented in this country. But only one large-scale study has been done in the U.S. (in Utah), and more studies need to be conducted.

The enormous cost of complying with the new standard is another major objection. In New Mexico, the start-up costs alone would be \$370–\$400 million. Critics say lowering arsenic in drinking water to 10 ppb may force small municipalities out of business and is a poor use of resources that could be better applied to other health problems. New Mexico would bear a particularly high economic burden because of the relatively large amount of municipal water in the state, particularly in small systems, that would not meet the 10 ppb arsenic-in-water standard. In the nation as a whole, 5.5% of municipalities would have to treat their water, whereas in New Mexico, this number is close to 20%. Furthermore, 93% of these municipalities in New Mexico serve less than 15,000 people and are the most poorly equipped to accept this financial burden. Under the new standard, rural drinking water bills for individuals in New Mexico could increase by \$50–90 per month. Finally, costly municipal water could promote the use of personal wells, which are typically less carefully regulated than public water supplies. There is a proposal before the U.S. Congress that would provide money to help communities in New Mexico and other states meet the stricter arsenic standards, a proposal that would head off the financial crisis for some communities, particularly those with public water systems serving 15,000 or fewer residents.

What does this mean for the average New Mexican? Many people feel the jury is still out on the long-term effects of the levels of arsenic in drinking water typical of the United States. Given that there are uncertainties regarding the effects of low levels of arsenic on human health, the economic consequences of the lowered arsenic standard seem, to many people, particularly severe. One might argue that those funds could be better spent addressing more critical health problems currently facing the U.S. population. It's a complex problem and a difficult decision, but it can be resolved only through careful examination of current—and future—data.

—Nelia W. Dunbar,
Charles E. Chapin,
and Lynn A. Brandvold
New Mexico Bureau of Geology
and Minereal Resources

*Each issue of Earth Matters features an invited article on a subject of interest to New Mexicans. These articles represent the authors' informed opinion on important geoscience issues in New Mexico. The New Mexico Bureau of Geology and Mineral Resources is a non-regulatory agency.*

*—Ed.*

## MEASURING ARSENIC IN WATER

In rocks and minerals, the concentration of arsenic is reported as parts per million (ppm). The crustal abundance of arsenic is estimated at 1.5 ppm, where one ppm equals one millionth of a gram of arsenic in a gram of rock. Volcanic rocks commonly contain 1.5–3.0 ppm arsenic but can contain as much as 100 ppm (or more) in mineralized areas. In relatively clean surface waters, such as the Rio Grande and its tributaries in northern New Mexico, arsenic concentrations are typically a thousand times lower than in rocks, or about 1.5 parts per billion (ppb). In water, therefore, arsenic is commonly reported as parts per billion (ppb) or as micrograms per liter (µg/L). The two units of measure are equal. When arsenic concentration is high, it may be reported as milligrams per liter (mg/L). One mg/L = 1 ppm = 1,000 µg/L = 1,000 ppb. The bottom line: You probably don't want to drink water whose arsenic concentration is reported as more than 0.050 mg/L, or 50 ppb.

Analysis for trace amounts of arsenic in water used to be a difficult and time-consuming process, involving concentration and isolation by distillation followed by addition of color forming reagents and measurement of the color intensity. The detection limit for arsenic using this old analytical technique was 50 ppb. The more recent development of analytical instruments—graphite furnace atomic absorption, hydride-generation atomic absorption, and inductively coupled plasma-mass spectrometry—now allow rapid and accurate analyses in the very low ppb range. Depending on the type of sample and the accuracy needed, an analysis for arsenic now takes under 60 minutes and costs about \$7.50. This ability to detect arsenic in trace amounts has contributed to the push to lower the arsenic standard in drinking water from 50 ppb to 10 ppb.

## For More Information on Arsenic

*Arsenic in Groundwater, United States Geological Survey*
http://webserver.cr.usgs.gov/trace/arsenic/

*Arsenic Health Effects Research Program, University of California, Berkeley*
http://ist-socrates.berkeley.edu/~asrg/

*Chronic Arsenic Poisoning, History, Study and Remediation, Harvard University*
http://phys4.harvard.edu/%7Ewilson/arsenic_project_main.html

*Arsenic in Drinking Water Site, EPA*
http://www.epa.gov/safewater/ars/ars10.html

*Arsenic Fact Sheet, World Health Organization*
http://www.who.int/inf-fs/en/fact210.html

*Arsenic in Drinking Water: 2001 Update, National Research Council book*
http://www.nap.edu/catalog/10194.html

## Bureau News

### Bureau Staff Receive Awards

Ron Broadhead, principal senior petroleum geologist and associate director at the New Mexico Bureau of Geology and Mineral Resources, was this year's recipient of the Monroe G. Cheney Science Award for singular contributions to the science of petroleum geology. The award, presented by the Southwest Section of the American Association of Petroleum Geologists, was presented in June 2002 at this year's section meeting in Ruidoso, New Mexico.

Peggy Johnson, hydrogeologist at the bureau, is the 2002 winner of the John C. Frye Memorial Award in Environmental Geology, for *Water, Watersheds, and Land Use in New Mexico*, the 2001 Decision-Makers Field Guide. The award is given annually to recognize the outstanding paper in environmental geology published by a state survey or by the Geological Society of America during the preceding three years. The award, given in cooperation with the Association of American State Geologists (AASG), will be presented in October at this year's annual meeting of the Geological Society of America, in Denver, Colorado.

### Our Newest Hire

Hydrologist Lewis Land joined us this summer as our newest hire. Lewis will be stationed in Carlsbad, New Mexico, where he will be our liaison to the National Cave and Karst Research Institute. Lewis will also be conducting geohydrologic studies in the Pecos River drainage.

### Rockin' Around New Mexico

The sixth annual Rockin' Around New Mexico, a summer geology workshop for teachers, was held July 8-10 in Farmington. This workshop, in support of earth science education in New Mexico, has become one of the bureau's most popular outreach programs. It is sponsored by a consortium of state agencies and private industry. For information on next year's workshop, call Susie Welch at (505) 835-5112.

## Notes from the State Geologist *(Continued from page 1)*

just completed in May of this year and concerned the future of conventional and unconventional energy in New Mexico. Although the field excursions can only accommodate a small number of attendees, we have used the occasions to produce high-quality, multi-authored, color guidebooks. These are written for a non-technical audience and provide a balanced and comprehensive look at geologic and hydrologic issues. They are available through our publications office and are reasonably priced so we hope you will avail yourself of the insights they contain. We will also be celebrating our anniversary with the issuance of a new 1:500,000-scale geologic map of the state, the first since 1965. It will be available by early 2003 and represents well the ongoing progress we are making in understanding the geologic framework of New Mexico.

—Peter Scholle
Director and State Geologist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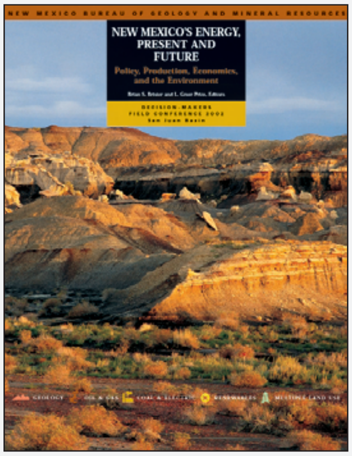
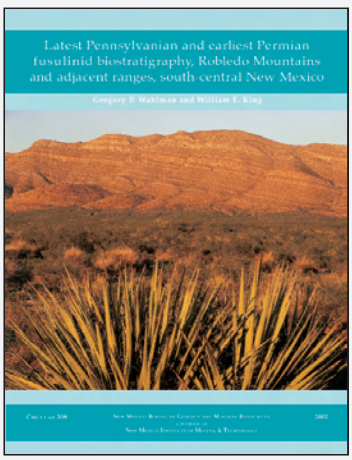
Cover photo of Ship Rock, New Mexico by
**Paul G. Logsdon**

# New Publications




**New Mexico's Energy, Present and Future: Policy, Production, Economics, and the Environment,**
edited by Brian S. Brister and L. Greer Price
Decision-Makers Field Guide 2002, San Juan Basin, 160 pp.
$15.00

*New Mexico, with some of the most significant energy reserves in the lower 48 states, is a major player in this country's conventional energy production. The state also has enormous potential for developing significant renewable/alternative energy resources, including solar and wind. This anthology of 30 articles is a timely look at how energy works in New Mexico today, with an eye toward the promises and challenges that lie ahead. Produced in conjunction with the second annual Decision-Makers Field Conference in May 2002, this volume is an important contribution to the literature on energy in New Mexico.*




**Latest Pennsylvanian and earliest Permian fusulinid biostratigraphy, Robledo Mountains and adjacent ranges, south-central New Mexico,**
by Gregory P. Wahlman and William E. King
Circular 208, 32 pp.
$10.00

*The Robledo Mountains of south-central New Mexico, and the Doña Ana and San Andres Mountains to the east, contain one of the most continuous marine carbonate sections through the Pennsylvanian–Permian boundary in the southwestern United States. The authors describe this unique stratigraphic section in some detail, with an emphasis on fusulinid remains, including descriptions of new species not previously reported from this area. Based on their detailed work in the field and the laboratory, the authors correlate these rocks with rocks of similar age in other parts of the United States, and propose the Robledo Mountains section as a new reference for the Pennsylvanian–Permian boundary in southwestern North America.*


**Minerals of New Mexico 24" X 36" poster** - $5.00 plus $2.50 shipping and handling (posters are rolled and mailed in a cardboard tube).

*The nineteen spectacular mineral specimens featured on this poster offer a glimpse of some of the most beautiful minerals in New Mexico. Photographed by renowned photographer Jeff Scovil, specimens are from the collection of the Mineral Museum on the campus of New Mexico Tech in Socorro. This poster was produced by the New Mexico Bureau of Geology and Mineral Resources in cooperation with the Mining and Minerals Division of New Mexico's Energy, Minerals and Natural Resources Department.*

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