New Mexico EARTH MATTERS

Winter 2004

Coalbed Methane in New Mexico

New Mexico is one of only eleven states in the U.S. that produce more energy than they consume—what is generally termed a net energy producer. Most of that energy has traditionally come from oil and natural gas reserves in the San Juan Basin in the northwest and the Permian Basin in the southeast, and from coal energy exported as electricity. In recent years coalbed methane (CBM) has played an important role in that mix: One-third of the natural gas currently produced in New Mexico is CBM. With significant coal resources in the state, both in developed and underdeveloped frontier areas, CBM is likely to play an increasingly important role in the energy resources—and economy—of New Mexico.

Fossil fuels continue to dominate the niches where they are most effectively used: electricity generation (coal), transportation (oil), and clean, efficient fuel for heating and cooking (natural gas), at least (in the case of natural gas) for those consumers within reach of the nation's extensive pipeline infrastructure. Recent U.S. demand for electricity has outstripped the flexibility and capacity of conventional generation from coal and nuclear energy systems. Increasingly, natural gas is the fuel of choice for bridging that gap, and for some good reasons: Natural gas electric generating plants are less costly to build and operate, they can be brought on line more quickly, they consume less water, and their environmental impact in terms of surface disturbance and air emissions (including carbon dioxide) is smaller.

Two symbols of prosperity in northwestern New Mexico: In the foreground a pumpjack lifts water from the Fruitland coal to facilitate coalbed methane production. The irrigated field in the background is part of the Navajo Agricultural Products Industry (NAPI), the Navajo Nation's farming and agricultural enterprise. Photo © Adriel Heisey.

Natural gas has been an important product in New Mexico for many years. In the early days of New Mexico's oil fields, it was an undesirable and practically worthless byproduct of oil production and was often flared. It is most economically transported using pipelines, the construction of which is dependent upon "downstream" demand, and such pipelines simply didn't exist in New Mexico at that time. The first commercial use of natural gas in New Mexico came in 1921 when gas was piped one mile from a gas well to Aztec, New Mexico. Over the following decades the nation's pipeline infrastructure grew, so that by 1951 natural gas could be exported from New Mexico's San Juan Basin to California.

Decades of exploration, gas field development, price and infrastructure deregulation, and industry stabilization have led to a better balance of supply and demand, and to prices that more closely represent the cost of finding and extracting this natural resource. Gas prices since the mid-1990s have steadily risen with increased demand, particularly for generating electric power. According to the Gas Technology Institute in 2001, annual consumption of natural gas in the U.S. is expected to increase 53 percent over the next fifteen years. As conventional gas fields are depleted, our domestic supply is shifting toward unconventional sources of natural gas, including CBM.

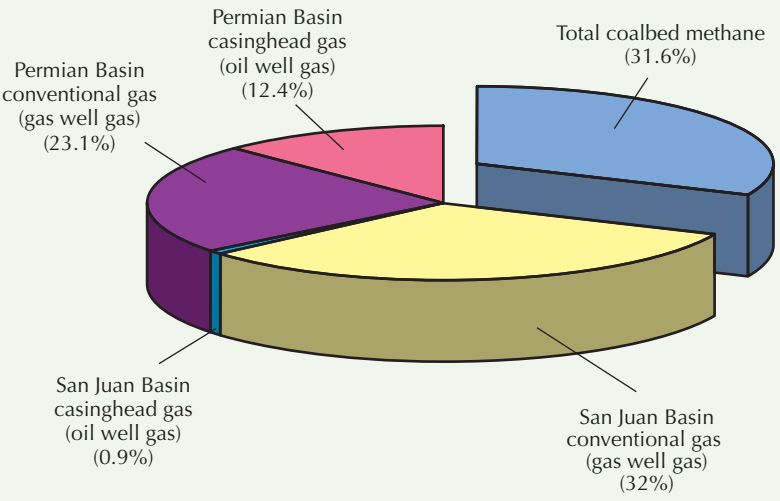
Coalbed Methane Explained

Methane (CH_4) is the simplest and most abundant of several hydrocarbon components of natural gas produced from the world's oil and gas fields. CBM is natural gas, mostly methane, produced from coal. Coal is formed when organic peat deposits are subjected to natural heat and pressure associated with burial over long

periods of time. This process of thermal maturation of organic material generates methane as a byproduct. Methane can also be generated from coal through digestion of organic matter by bacteria.

Once created, methane is bound in the coal matrix. The methane can be released by dewatering: pumping out water that naturally exists in fractures in the coal. The goal of dewatering is to deplete the water from the coal aquifer over the entire coal field – and keep it depleted – through continual pumping. As dewatering progresses, the natural pressure in the coal decreases, and the bonds that hold methane in the coal matrix weaken to allow the gas to flow freely. Methane has long been a hazard in underground coal mines that also dewater coal. Methane must be vented from mines to avoid deadly explosions. In the 1980s commercial attempts to pump water and extract methane from coal beds using oilfield techniques proved successful. By the 1990s large-scale efforts to produce this extensive resource were underway in a number of coal fields across the U.S. One benefit of CBM operations is that a mining hazard has been reduced, and mining of the coal resource remains an option.

CBM is most economically produced from coal beds at depths of less than 4,000 feet due to limits on well cost. A large diameter hole is drilled, and steel pipe is cemented into the well to seal off shallow ground water aquifers. Drilling resumes, and a smaller hole is deepened to below the coal beds. More pipe is cemented into the hole and, then holes are made in the pipe to access the coal bed. The well is usually stimulated to improve production by artificially fracturing the coal around the well, achieved by pumping large volumes of fresh water, gel (like gelatin), and clean sand proppant. As the coal fractures, the sand "props" the fractures open so that water and methane can flow toward the well. Pumpjacks, familiar sights in the oil patch, are used to lift water to the surface. The produced water is injected into an approved subsurface water disposal aquifer or, if fresh, the water can be discharged into surface streams. The methane is piped from the well to market. CBM produced at the wellhead sometimes contains traces of undesirable components such as carbon dioxide (CO_2), which are removed by gas processing plants. The gas also requires compression to allow it to flow through high pressure interstate pipelines. The result is a relatively clean and simple energy source that, upon combustion, generates energy and CO_2 exhaust.



Types of natural gas produced in New Mexico.

Of this total, CBM contributed 531 Bcf or 32 percent. The market value of that volume of CBM (at $5 per mcf) would be $2.657 billion. New Mexico is currently ranked first in CBM production and reserves in the U.S. It is currently produced in San Juan, Rio Arriba, and Colfax Counties, where it is an important contributor to the economy. As CBM production has grown in importance over time in terms of volume, so has its contribution to the state's coffers.

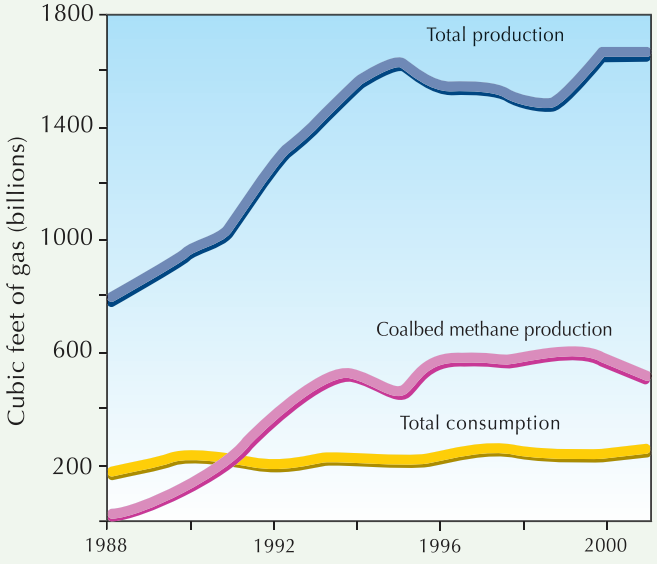
Economic Importance

The oil and gas industry is a major contributor to New Mexico in terms of General Fund contributions, royalties, severance tax proceeds, and earnings on Permanent Funds generated by the industry, which totaled $1.7 billion in 2001. Add in the benefits of employment and related economic activity, and it is clear that much of our wealth and economic health is derived from our oil and gas natural resources.

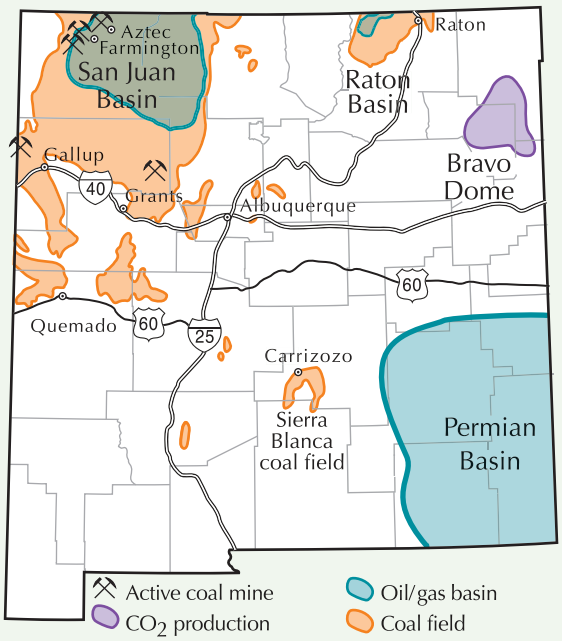
Natural gas is measured in units of cubic feet, generally reported in thousands (mcf) or billions (Bcf) of cubic feet. One mcf of pipeline-quality methane gas produced and sold from New Mexico currently has an average price tag of about $5. In 2001 New Mexico oil and gas operators produced 1,677 Bcf of combustible natural gas.

New Mexico's Coalbed Methane-producing Basins

CBM is currently being produced in two geologic basins in New Mexico. The thick and relatively shallow Fruitland Formation (Cretaceous) coals in the San Juan Basin in northwestern New Mexico near Farmington have yielded an enormous amount of natural gas over the past decade. Almost one-half of San Juan Basin natural gas production is from the Fruitland Formation CBM play at depths generally less than 4,000 feet. The Fruitland coal development, now considered to be a mature play, is an important model for burgeoning CBM development efforts worldwide. Fruitland Formation CBM wells average billions of cubic feet



Production and consumption of natural gas in New Mexico, in billion cubic feet of gas.



Major oil and natural gas production and coal resources in New Mexico.

of methane over their estimated 20+ year lives. The play is undergoing a resurgence of activity as more wells are drilled to effectively produce the resource.

The Raton Basin, east of the Sangre de Cristo Mountains and west of Raton, became New Mexico's newest natural gas-producing region in 1999, when a pipeline was completed to transport natural gas to an interstate pipeline at Trinidad, Colorado. A flurry of drilling since then has developed less than half of the prospective area, much of which lies within the boundaries of the extensive Vermejo Park Ranch. Raton Basin coal beds in the Vermejo and Raton Formations (Cretaceous to Paleocene) are thin by comparison with San Juan Basin Fruitland Formation coal beds. Vermejo and Raton Formation wells will likely average several hundred million cubic feet of methane each from depths generally less than 2,000 feet. The play is in an early dewatering stage; time will tell as to the eventual volume and life of individual wells or the number of wells ultimately required to most effectively produce the resource.

Frontier Coalbed Methane Possibilities

New Mexico currently ranks third in the U.S. lower 48 states in recoverable coal reserves from existing mines. Coal resources underlie 20 percent (15 million acres) of the state's total area, but most of the prospective area is in northern New Mexico in the San Juan and Raton Basins. Several lesser coal fields outside of these basins could become CBM-producing basins if they meet several important criteria. Viable CBM production requires coals with sufficient methane content, sufficient thickness (for dewatering efficiency, one thick coal is better than an equivalent thickness of multiple thin coals), relatively shallow depth (which keeps drilling costs low), access to infrastructure in terms of roads and a pipeline, and access to the land itself so that drilling and production activity can occur.

A natural future CBM play is Menefee Formation (Cretaceous) coals in the San Juan Basin, extending south toward Grants and Gallup. The Gas Technology Institute estimates a Menefee Formation CBM reserve of 34 trillion cubic feet. The Menefee Formation has been mined economically for four decades at the McKinley mine near Gallup and for twenty years at the Lee Ranch mine near Grants. The coals vary widely in thickness and number of seams, and thus effort must be placed in locating areas where the coal is thick and contains sufficient methane. Developing this resource in the producing part of the San Juan Basin makes sense because of the existing infrastructure. In fact, many wells there have been recompleted to include Menefee Formation conventional production. Unfortunately, the coals tend to be thicker south of the San Juan Basin infrastructure. In that area "checkerboard" land ownership (where it can be difficult to get all parties to agree to allow access) potentially can hamper development efforts. Nonetheless, there are currently several exploration operations underway in this play, including a 6-million-acre area in the southern San Juan Basin.

Another coal field in New Mexico being considered for CBM potential is the Cretaceous coals that exist in a swath between Interstate 40 and Highway 60 in west-central New Mexico. There has been some interest in developing these coals, as demonstrated by leasing activity in the area between Gallup and Quemado. There are a number of challenges to developing in this region: relatively thin coal beds overall, lack of infrastructure, and complex land ownership issues. Similar coals also exist in the northwestern Sierra Blanca coal field near Carrizozo. Here, the methane content of the coal is unknown. The area was leased for coal mining in the past, but operations never expanded beyond an initial exploration phase that established the presence and depth of the coals and delineated a general area of possible interest. There are a number of lesser occurrences of coal in New Mexico, but many of these are limited in size, have thin coal beds, low methane resource potential, and thus little likelihood for economic CBM development.

Related Research

CBM is clearly important to New Mexico's present and future economy, and research is ongoing to improve our knowledge of the resource. The New Mexico Bureau of Geology and Mineral Resources is involved in applied research on the location and quality of coal, natural gas, and water resources related to CBM. The November 2003 issue of *New Mexico Geology*, a bureau publication, reviews the geology of the growing Raton Basin CBM play. The bureau, in conjunction with the New Mexico Tech petroleum engineering department, is presently conducting a study for the Carson National Forest to assess CBM potential of federal land in that basin.

One cooperative study focuses on the large quantities of brackish water produced in CBM operations in the Raton and San Juan Basins. Sampling and analysis of this produced water by the bureau's analytical chemistry laboratory suggest that much of this water could be reused rather than disposed. Treated water might be used as an alternative for irrigation or industrial-use water, easing the increasing demands on the state's fresh water supply.

The Future

When it comes to society's use of energy, we strike a difficult balance between environmental versus capital costs while

meeting ever-growing energy needs. Over time we are evolving toward a methane economy that can be cleaner and more efficient than other fossil fuel alternatives. In fact, natural gas may be the gateway product for future fuel cell technology, which is cleaner yet. In the long term, we may need to import natural gas from overseas to meet demand. However, to fuel our immediate needs in the coming decades, the U.S. will continue to supply much of its own natural gas, increasingly from unconventional resources like CBM. New Mexico is in a unique position to benefit economically in the near term with its abundant supply of natural gas that includes both the prolific existing and potential new CBM fields.

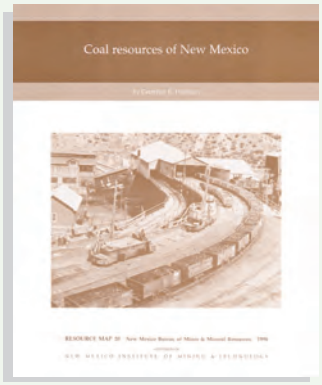
—Brian S. Brister
New Mexico Bureau of Geology
and Mineral Resources

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

—Ed.

For More Information

In 1996 the New Mexico Bureau of Geology and Mineral Resources published Coal Resources of New Mexico by Gretchen K. Hoffman, Resource Map 20. This full-color map of New Mexico (1:1,000,000) clearly highlights the state's coal resources. It is accompanied by a 22-page booklet that contains more detailed descriptions of the major coal-bearing sequences and coal fields in the state. It is available from the bureau for $7.50 (plus $2.50 shipping & handling) by calling our Publication Sales Office at (505) 835-5410.



Bureau News

The first **New Mexico Earth Science Achievement Awards** were presented on January 30, 2004, to Representative Joe Stell of Carlsbad, for outstanding contributions advancing the role of earth science in areas of public service and public policy in New Mexico, and to Dr. John W. Shomaker of Albuquerque, for outstanding contributions advancing the role of earth science in areas of applied science and education in New Mexico. This annual award is co-sponsored by the bureau and New Mexico's Energy, Minerals and Natural Resources Department in Santa Fe. It will be presented annually to honor individuals who have made outstanding contributions to advancing or facilitating the role of geoscience in areas of education, research, public service, and public policy in New Mexico. Nominations for next year's award are solicited from at large and can be made at any time; names should be submitted directly to Peter Scholle at the bureau.

The U.S. Department of Labor's Mine Safety and Health Administration has awarded New Mexico a $50,000 grant to assist with the development of an electronic inventory of maps for abandoned underground mines in New Mexico, as part of the **Underground Mine Mapping Initiative**. This project is designed to increase the protection of the public and mine workers from the hazards of abandoned underground mines. The bureau will work with the Energy, Minerals and Natural Resources Department and the New Mexico Bureau of Mine Inspection.

Peggy Johnson has been promoted to senior hydrogeologist with the bureau. Peggy has been on the bureau staff since 1996 and has been involved in a number of important bureau initiatives, including the 2001 and 2003 Decision-Makers Field Conferences.

Virginia McLemore, senior economic geologist, received both an appreciation award and the Presidential Certificate of Merit from the American Institute of Professional Geologists in 2003. These awards were granted in recognition of her dedication above and beyond the call of duty and for motivational efforts leading to the revitalization of the New Mexico section.

The bureau received $275,275 for this, its 12th year of participation in the **STATEMAP** program. The program, funded by the U.S. Geological Survey, is designed to rapidly produce and distribute state-of-the-art, detailed geologic quadrangle maps of population centers along the Rio Grande watershed. The bureau continues to be the most successful state survey in the country competing for STATEMAP funds, having received a total of $2,075,382 from the USGS over the past ten years, the top total in the nation. The program is a matching-funds program; the bureau provides a 50 percent match to all awards.

Stephen Hook has been hired on a temporary basis as a petroleum geologist with the bureau, filling the vacancy left by Bill Raatz. Bill resigned at the end of 2003 to accept a position with Oxy Permian in Houston. Steve is a former bureau employee who moved to Socorro following his retirement from ChevronTexaco in 2002.

Peter Scholle, state geologist and director of the New Mexico Bureau of Geology and Mineral Resources, has been elected treasurer of the American Geological Institute (AGI) for a two-year period beginning in 2004. AGI is a nonprofit federation of 42 geoscientific and professional associations, representing more than 100,000 earth scientists. The organization plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources and interaction with the environment.

We note with regret the passing last fall of **Jacques R. Renault** and **Clay T. Smith**. Dr. Renault was emeritus senior geologist at New Mexico Bureau of Geology and Mineral Resources. He joined the bureau in 1965 as a petrologist and managed the X-ray facilities until his retirement in 1995. Dr. Smith was professor emeritus in the Department of Earth and Environmental Science at New Mexico Tech. He had worked in the department from 1947 until his retirement in 1987 and worked cooperatively with bureau staff for many years. We will miss both Jacques and Clay for their professional contributions and their willingness to share their expertise with others.

Staff Profile

Ronald F. Broadhead

Principal Senior Petroleum Geologist

Ron Broadhead has worked on petroleum geologic issues at the bureau for the past 23 years, and currently heads the bureau's petroleum section. Ron's interest in petroleum exploration, as applied to both frontier basins and producing basins, goes back to his years as an undergraduate at New Mexico Tech and as a graduate student working on shale gas at the University of Cincinnati. After completing his advanced degree, Ron went to work for Cities Service Company, working in the Arkoma Basin, central Oklahoma, Texas panhandle, southwestern Kansas, and along the Ouachita thrust belt.

This interest lured Ron back to New Mexico Tech in 1981, when he accepted a position with (what was then) the New Mexico Bureau of Mines and Mineral Resources. Here he focused on New Mexico's underexplored basins, and on underexplored trends in producing basins. Today he continues to focus on questions as basic as "How much oil and gas remain to be produced in New Mexico?" Ron recently saw the fulfillment of 20 years of research and published studies on the structure, stratigraphy, and petroleum source rocks of the Tucumcari Basin. Within the past two years several independent energy companies have begun exploration and drilling for natural gas in the Tucumcari area. These smaller, independent companies are the backbone of exploration and production across the country. In New Mexico they conduct almost all of the exploration within the state and are responsible for over 50 percent of production.

Ron's ongoing research covers a broad range of topics. With his colleagues at the Texas Bureau of Economic Geology, Ron is collaborating on a two-year project (funded by the Department of Energy) to construct a digital portfolio of major oil reservoirs in the Permian Basin.

With financial support from the New Mexico Land Office, Ron is studying the distribution of helium-rich gases across the state. Helium becomes a very valuable commodity after it is separated from associated gases. The State Land Office is also funding research to document the geology of the Chupadera Mesa area of eastern Socorro and western Lincoln Counties and to relate that geology to oil, natural gas, and helium potential. This region has attracted significant exploratory interest in recent years.

With New Mexico Tech's Petroleum Recovery Research Center, Ron has helped to develop the DOE-funded online prospecting tool known as the Fuzzy Logic Expert System Risk Reduction project. The project allows construction of 3-dimensional structure, paleostructure, and stratigraphic maps from online well and production data that are being collected in the Permian Basin. The project uses sophisticated logic programming to get the computer to replicate the thought processes of experienced petroleum geologists.

From 2002 to 2003 Ron served as a member of the New Mexico Tech team that traveled across the U.S. hosting workshops for representatives from industry, research organizations, and government agencies. The workshops examined future research needs for the exploration and production of natural gas from unconventional sources, and created a blueprint document for future onshore gas exploration.

Like many bureau employees, Ron is involved in teaching, as well. Each spring for the past 23 years Ron has taught a class on subsurface and petroleum geology. Besides subsurface strata and structure, the students analyze well cuttings and log data from productive reservoirs.

After more than 20 years of service to the bureau and the people of New Mexico, Ron is known and respected throughout the exploration community for his wealth of expertise and willingness to unselfishly share that knowledge. In 2002 the Southwest Section of the American Association of Petroleum Geologists named Ron as the recipient of the Monroe G. Cheney Science Award "for singular contributions and service toward the understanding of petroleum geology in the southwest region"—outside recognition of the contributions his colleagues here in New Mexico have long appreciated.

New Mexico Earth Matters

Volume 4, Number 1
Published twice annually by the
New Mexico Bureau of Geology and Mineral Resources

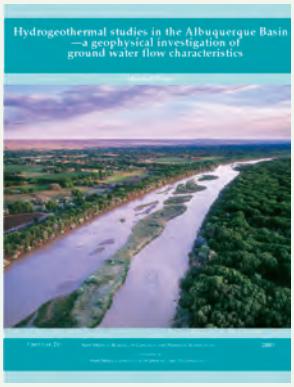
Peter A. Scholle
Director and State Geologist
a division of
New Mexico Institute of Mining and Technology
Daniel H. López
President
801 Leroy Place
Socorro, New Mexico 87801-4796
(505) 835-5420

Albuquerque Office
2808 Central SE Albuquerque
New Mexico 87106
(505) 366-2530

Visit our main Web site
http://geoinfo.nmt.edu

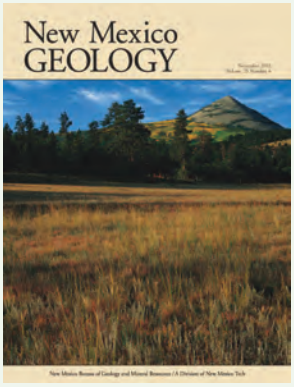
Earth Matters is a free publication. For subscription information please call (505) 835-5410, or e-mail us at pubsofc@gis.nmt.edu

New Publications



Hydrogeothermal studies in the Albuquerque Basin—a geophysical investigation of ground water flow characteristics by Marshall Reiter. Circular 211, 2003, 74 pp. $10.00 plus shipping and handling.

Highly sensitive well logs that measure ground water temperature as a function of depth are an important geophysical tool for discerning ground water flow patterns. This study focuses on temperature data from wells in the Albuquerque Basin, including the Albuquerque metropolitan area. These temperature logs can provide insights that are not otherwise available, including the degree to which faults serve as either conduits for or barriers to ground water flow. Temperature data can also be used to identify (both shallow and deep) zones of ground water movement. The study will be of interest to hydrologists and geohydrologists throughout the Southwest.



New Mexico Geology, a quarterly journal for regional research and service directed to the New Mexico geoscience community. 1-year subscription, $12; 2-year subscription, $22. Single issues $ 3.50 plus shipping and handling.

For 25 years New Mexico Geology has published peer-reviewed research papers, abstracts, books reviews, and more. This newest issue includes an article on the geology of the growing Raton Basin coalbed methane play by Gretchen Hoffman and Brian Brister. The February issue will include Ivan Wong et al.'s earthquake scenario and probabilistic ground-shaking hazard maps for the Albuquerque-Belen-Santa Fe corridor.

Water Resources of the Lower Pecos Region, New Mexico: Science, Policy, and a Look to the Future, edited by Peggy S. Johnson, Lewis A. Land, L. Greer Price, and Frank Titus. Decision-Makers Field Guide 2003, 148 pp. $15 plus shipping and handling.

This anthology of 30 short articles is a timely look at water issues along the lower Pecos River, from Sumner Lake to the Texas state line. Produced in conjunction with the third annual Decision-Makers Field Conference in October 2003, this volume is an authoritative look at the historical framework and a summary of where we are—and where we're going—on the Pecos River in New Mexico. Topics include:

- *Regional geology of the lower Pecos region*
- *An overview of water operations in the Pecos River basin*
- *Regional hydrology of the Roswell artesian basin and the Capitan aquifer*
- *Irrigation districts in southeast New Mexico*
- *Managing forests for increasing water yields*
- *Drought in New Mexico*
- *Salt cedar control and riparian habitat restoration*

For more information about these and other bureau publications: visit our Web site at http://geoinfo.nmt.edu; write or visit our Publications Office on the campus of New Mexico Tech, 801 Leroy Place, Socorro, New Mexico 87801; call (505) 835-5410 or (505) 835-5490; or e-mail us at pubsofc@gis.nmt.edu. Payment (check or money order payable to NMBGMR) must be enclosed with mailed orders. Telephone orders may be paid with VISA, Discover, American Express, or MasterCard.

New Mexico Bureau of Geology and Mineral Resources
New Mexico Tech
Earth Science for the 21st Century

New Mexico Bureau of Geology
and Mineral Resources
801 Leroy Place
Socorro, New Mexico 87801-4796

Return service requested

NONPROFIT ORGANIZATION
U.S. Postage
PAID
PERMIT NO. 1888
ALBUQUERQUE, NM