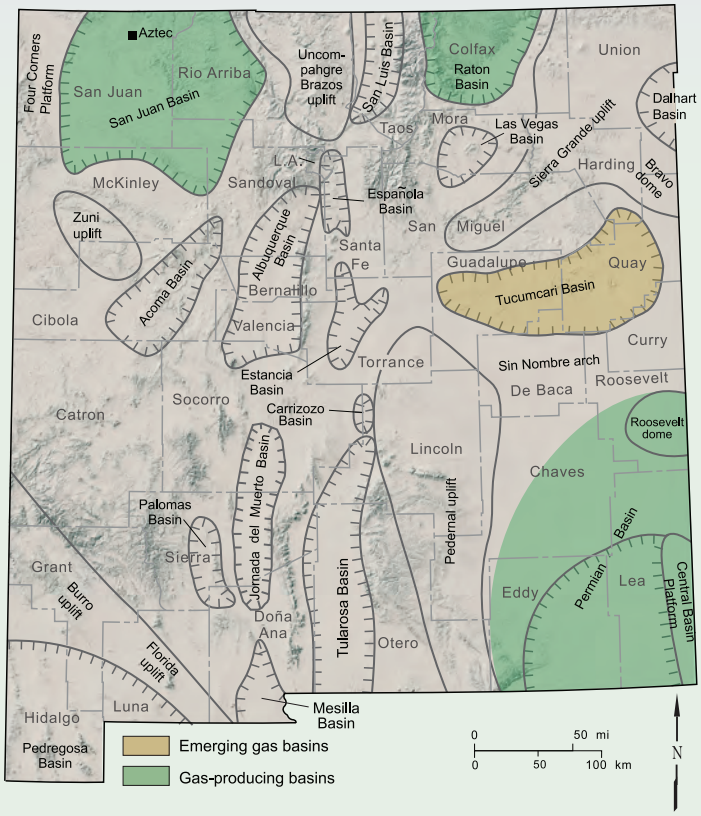
New Mexico EARTH MATTERS

WINTER 2012

New Mexico's Natural Gas Resources

New Mexico is an energy-producing state, which means that we produce more energy than we consume, and we export a significant amount of energy (in the form of oil, gas, and electricity) to surrounding states. This is a result primarily of New Mexico's rich natural resources, particularly oil and gas. Natural gas is likely to play an important role in our statewide energy mix down the line, thanks both to new discoveries in frontier gas provinces as well as expanding technologies for the development of existing resources. Furthermore, power companies are now investing in gas-generated power plants, which are seen as cleaner than the traditional coal-burning plants. Finally, for companies looking to invest in wind and solar, natural gas offers the promise of backup, allowing those industries to provide continuous power to the grid.



Basins and uplifts in New Mexico.

Natural gas production in New Mexico dates from 1921 with the discovery of the Aztec field of the San Juan Basin in the northwestern corner of the state. Natural gas was discovered while drilling for oil in the Upper Cretaceous Farmington Sandstone at a depth of 890 feet. In the 1920s there was little demand for natural gas in northwestern New Mexico or anywhere in the American Southwest, so the gas was piped to the nearby community of Aztec where it was used for home heating and cooking.

Oil was discovered in the San Juan Basin in 1922 and in the Permian Basin in 1924. Massive exploration, drilling, and development programs followed, and soon many large oil reservoirs were discovered, mostly in the Permian Basin and to a much lesser extent in the San Juan Basin. Crude oil was refined principally into motor fuel and other products such as heating oil and lubricants. Most of the oil fields in New Mexico produced substantial volumes of natural gas along with the oil. As no widespread markets existed for natural gas in those early days, much of the gas was flared (burned) at the wellhead. Exploration for and development of natural gas resources remained limited until years later, when the San Juan Basin was revealed to be a major natural gas province.

Conventional Gas

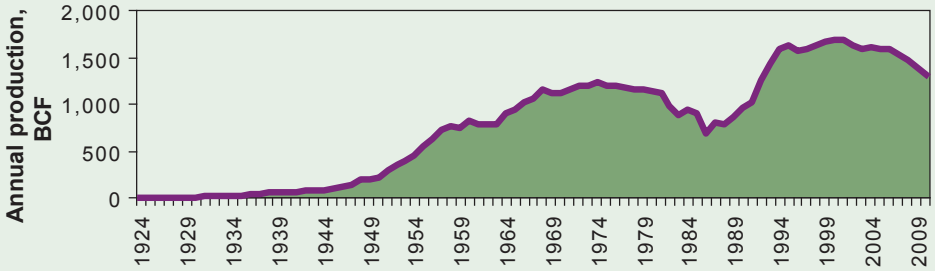
After World War II the demand for natural gas as an energy source soared. Exploratory vertical drilling in the 1950s and 1960s in the San Juan Basin resulted in new discoveries of major natural gas reservoirs. Some of these were conventional reservoirs, as the gas was produced from discrete accumulations in permeable rock. However, many were widespread, less permeable ("tight gas"), blanket-type accumulations in Upper Cretaceous sandstones. This new gas not only filled the needs of New Mexicans, it was exported through interstate pipelines to California. Production boomed. Reservoirs filled with natural gas were now sought after rather than avoided. Additional drilling provided data that helped to define the extent and nature of natural gas reservoirs both in the San Juan and Permian Basins. Even as conventional gas has declined, discovery of substantial new and previously unrecognized gas reservoirs continues to this day.

Coalbed Methane

Underground coal miners have long known that coal beds are associated with natural gas that, if not properly vented, will result in large and often tragic explosions within the coal mines. In the 1980s it was found that coalbed methane (the term used for natural gas in coals) could be produced economically from the Upper Cretaceous Fruitland Formation of the San Juan Basin. The Fruitland coals were quickly

and systematically developed through the drilling of exploration and production wells. The volume of natural gas produced from the Fruitland coals quickly equaled the production of natural gas from all other conventional/tight gas reservoirs in the San Juan Basin as well as all of those in the Permian Basin. Peak coalbed methane production was reached in 1999 when 612 billion cubic feet (BCF) was produced; production has subsequently fallen by 33 percent to 407 BCF as developed reservoirs have started to deplete. Peak natural gas production in New Mexico was reached in 2001 when 1.68 trillion cubic feet (TCF) was produced; production has since fallen by 22 percent to 1.3 TCF during 2010, largely as a result of depletion of coal reservoirs in the San Juan Basin but also with depletion of known, conventional gas reservoirs in both the San Juan and Permian Basins.

In 1999 coalbed methane production began from the Upper Cretaceous and lower Tertiary Raton and Vermejo Formations in the Raton Basin of north-central New Mexico, after more than a decade of exploration and evaluation. The coals are thinner, more lenticular, and in general less thermally mature than those in the San Juan Basin, and they cover only a fraction of the area that the Fruitland coals cover. Nevertheless, 26 BCF of coalbed methane was produced annually from 2006 through 2010 from the Raton Basin, supplying 2 percent of New Mexico's total gas production and bringing substantial economic activity to the Raton area.



Annual historical gas production in New Mexico from 1924 to 2010, in billion cubic feet (BCF). The increase in production in the 1990s was due to the discovery and production of coalbed methane in the San Juan Basin. Compiled with data obtained from U.S. Bureau of Mines, U.S. Department of Energy, and New Mexico Oil Conservation Division.

Hydraulic Fracturing

The growth of natural gas production in New Mexico has been possible by routine use of artificial fracturing ("fracking") of oil and gas reservoirs. The tight gas sandstone reservoirs in the San Juan Basin have too little permeability to give up gas to the borehole without fracking. By increasing reservoir permeability, the process increases flow rates and the total volume of gas that will eventually be produced by the well. Since 1950 the reservoirs in most of the oil and gas wells drilled in New Mexico have been fracked with a technique that involves pumping water and sand down the borehole under pressure until the strength of the reservoir rock is exceeded. Fractures start to form, slowly radiating out from the well bore at depths where the well's steel casing has been selectively perforated. Because almost the entire well bore is protected by heavy steel casing that has been cemented in place, fractures can develop only along reservoir intervals where the steel casing has been perforated or in selected intervals where the well remains uncased. Before 1950 wells were fracked by lowering a cylinder of nitroglycerin into the well bore and setting off an explosion at the depth of the reservoir. This was not only less controllable and less effective than the hydraulic method, it was very dangerous. Development of the tight gas sandstone reservoirs of the San Juan Basin, once considered unconventional, is now routine, and these reservoirs currently yield about one-third of the state's gas through 30,000 wells.

Hydraulic fracturing is not without its controversies. The potential for the contamination of ground water from fracking is a major concern in parts of the country, particularly the eastern and southeastern U.S. At the end of 2011, the Environmental Protection Agency issued a preliminary report that linked hydraulic fracturing in Wyoming with ground water contamination. Most of the natural gas reservoirs in New Mexico are thousands of feet below the shallow aquifers. Nonetheless, it is an issue that will be of ongoing concern to New Mexicans.

The Oil Conservation Division (OCD) of the New Mexico Energy, Minerals and Natural Resources Department regulates drilling and production of natural gas throughout New Mexico. In November 2011 the Oil Conservation Commission held a rulemaking hearing pertaining to hydraulic fracturing fluids. The rule was not officially adopted by the commission. However, during the commission's deliberation it was determined that an operator would need to file a disclosure form with OCD within 45 days of the completion of the well. Texas and Colorado have since passed more stringent requirements regarding disclosure of the composition of hydraulic fracturing fluids. On federal lands, drilling and production are regulated by the Bureau of Land Management.

Shale Gas

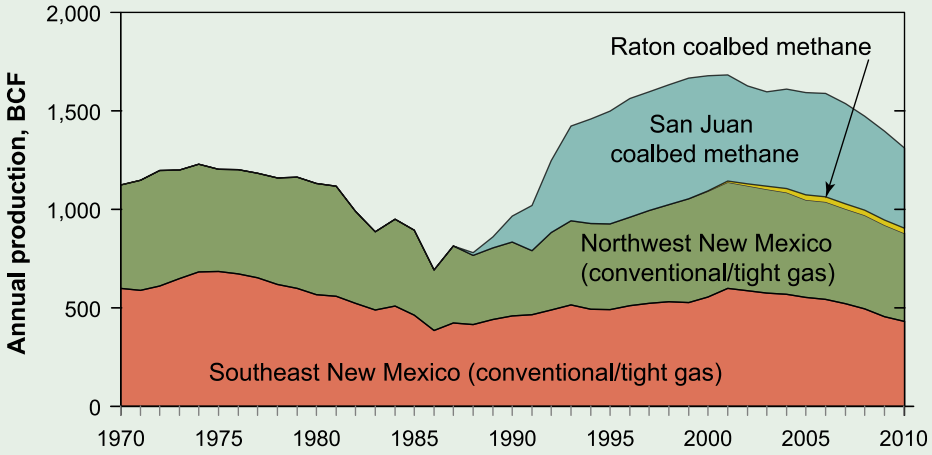
U.S. gas production has increased in recent years through the identification and development of shale gas reservoirs. A decade ago, shale gas accounted for only about 2 percent of all U.S. gas production. In 2011 shale reservoirs contributed 14 percent of U.S. gas production, and they are expected to contribute 46 percent of all gas production in 25 years.

The first commercial gas production in the world was shale gas obtained in 1821 from wells penetrating shales near Fredonia, New York. Production was at low volumes because of the very low permeability of shale reservoirs. Although production soon spread throughout many parts of the Appalachian and Michigan Basins, these early shale gas wells provided only low volumes of production. With the advent of deeper drilling techniques in the late 1800s, shale gas was eclipsed by the higher volumes of production obtained from conventional reservoirs in sandstone and carbonate rocks.

About 10 years ago, two advances in well drilling and completion technology rendered shale gas competitive: the development of economically viable methods to drill wells horizontally through reservoirs, and the development of techniques for multistage fracking of shale reservoirs penetrated by these horizontal wells. Horizontal drilling permits the well to come in contact with a much larger volume of the reservoir than is possible with traditional vertical wells. Multistage hydraulic fracking increases the permeability of the shale in proximity to the well. Together, these two advances increase flow rates and ultimate recovery of shale gas.

Economic Benefits of Natural Gas Production in New Mexico

Natural gas production is a perennial mainstay of New Mexico's economy through the jobs it provides and the revenues it generates for state government and education. The oil and natural gas industry provides more than 13,000 direct jobs with average annual salaries of more than $64,000. Natural gas contributed $480 million in tax revenues during 2010 in the form of the School Tax, Severance Taxes, Conservation Tax, and ad valorem production taxes. Natural gas royalties to the state include $107 million received from production on state trust lands, and 48 percent (or $167 million) of the federal royalty received from natural gas production on federal lands in New Mexico. Another $48 million in royalties was received from hydrocarbon liquids (for example propane) that were extracted from produced natural gas at gas processing plants. In all, income obtained from both oil and natural gas production contributes approximately 30 percent of the state's general fund revenues and has contributed 95 percent of the Land Grant Permanent Fund, which distributed $566 million to public schools and universities in the state during fiscal year 2009.



Annual gas production in New Mexico from 1970 to 2010, subdivided by gas type. Compiled from data obtained from New Mexico Oil Conservation Division.

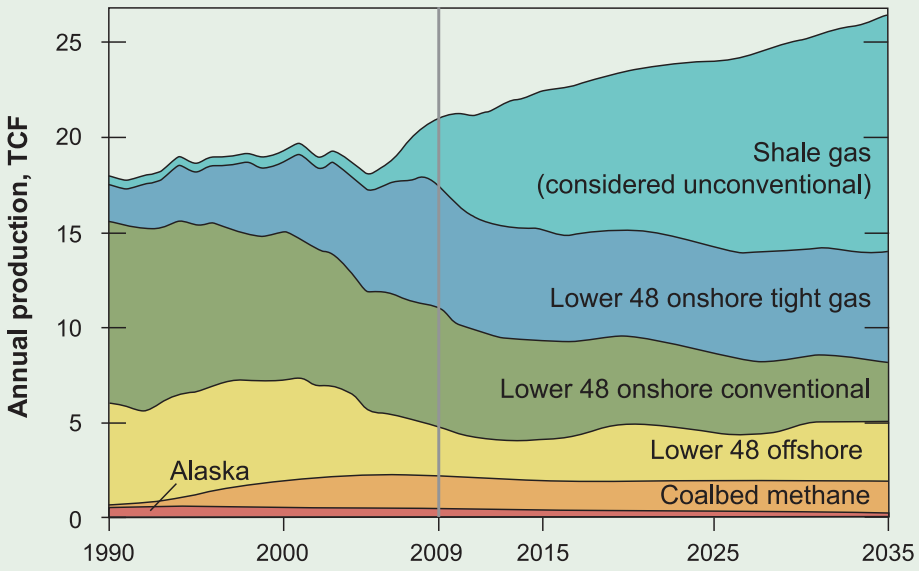
These new technologies are now so well understood and so often used that shale gas reservoirs are now generally considered conventional reservoirs rather than exotic and unconventional. Today, approximately one-half of the wells drilled in New Mexico are horizontal wells, and almost all of the wells are hydraulically fractured.

Thus far there has been minimal shale gas exploration and production in New Mexico. Most development of shale gas has been confined to selected wells in the Upper Cretaceous Lewis Shale in the San Juan Basin. Existing vertical wells that produce conventional gas from deeper sandstone reservoirs in the Cretaceous section have been recompleted in the Lewis Shale in order to supplement declining production from the deeper reservoirs. However, the Lewis Shale has not become a major gas producer, and operators in the area have mostly pursued more conventional targets instead.

Other, largely unevaluated, opportunities for shale gas abound in New Mexico. In the San Juan Basin, the Upper Cretaceous Mancos and Niobrara shales, as much as 1,400 feet thick, have definite shale gas possibilities in the deeper, more mature parts of the basin. In the Raton Basin, the Pierre and Niobrara shales have characteristics favorable for shale gas production and have been tested recently by three vertical exploratory wells that are part of a long-term evaluation effort. In the Permian Basin of southeastern New Mexico, several shales have possibilities: the Devonian-age Woodford Shale, the Mississippian-age Barnett Shale, the Pennsylvanian-age Morrow and Atoka shales, and the Permian-age Wolfcamp shales. Although these shales have not been adequately evaluated, all have general geologic properties that suggest the presence of shale gas. In southwestern New Mexico, the Devonian Percha Shale has some intriguing possibilities. Although it is unlikely that all of these shales will yield major gas production, it is almost certain that one or more of them will eventually contribute to natural gas production in New Mexico.

The Future of Natural Gas Production in New Mexico

Approximately one-half of natural gas production is obtained from wells drilled within the last five years. In the U.S. as a whole, production has increased over the last several years and is expected to continue to increase over the next three decades. The future of natural gas production is likely to include major new reserves of conventional gas as well as shale gas. New sources of conventional gas will continue to be discovered in the Permian and San Juan Basins. However, the hitherto unproductive and largely untested frontier basins in the state offer some of the most exciting possibilities for future production that will



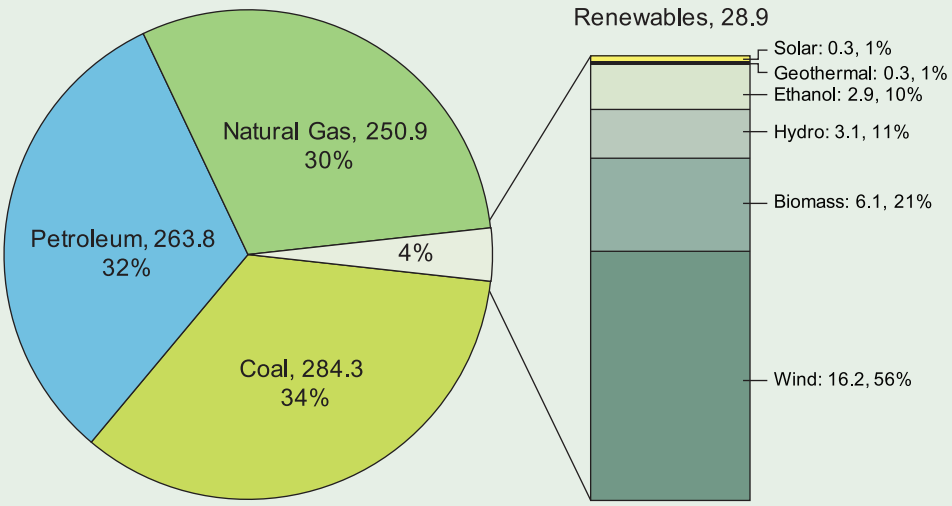
Recent and projected U.S. gas production by gas type. From DOE/EIA Annual Energy Outlook (2011).

be necessary to replace declining production from currently active gas reservoirs. Among these is the Tucumcari Basin of east-central New Mexico. Recent exploratory drilling that followed publication of a series of reports by the New Mexico Bureau of Geology and Mineral Resources has led to the discovery of natural gas. Full exploration and development of natural gas and associated liquids such as propane will take several decades.

There has been much interest lately in the possibility of natural gas providing backup for developing sources of alternative and renewable energy, such as wind and solar, which by themselves can provide only an intermittent source of power. The increased construction of wind farms on the plains of eastern New Mexico will require an additional source of energy to maintain a steady source of power to the grid. The growth of natural gas production in the Tucumcari Basin could provide that backup, enabling the successful development of these alternative sources of energy.

With construction of new natural gas-fired plants over the next 25 years, natural gas is projected to account for 60 percent of the growth in U.S. electrical generation. Natural gas is favored over other forms of generation because of low cost of construction, safety, reliability, and clean output with relatively low CO_2 emissions. There is also a growing interest in the use of natural gas as a motor transport fuel. New resources of shale gas and gas produced from new areas will help fulfill the growing demand for natural gas and will help offset declining production from older fields.

—Ron Broadhead and L. Greer Price



Total primary energy consumption in New Mexico in 2008 in trillion BTU. Wind energy provided more than half of the total renewable energy due to the significant growth of wind farms in the state since 2003. The percentage of energy from natural gas is likely to increase in the coming years. These figures include energy used for exported electricity. From New Mexico Energy, Minerals and Natural Resources Department Annual Report, 2010.

Ron Broadhead is a principal senior petroleum geologist with the New Mexico Bureau of Geology and Mineral Resources in Socorro, where he has worked for more than 30 years. Most recently he has been involved in oil and gas resource assessments of the Tucumcari Basin, the Permian Basin, and Colfax and Mora Counties.

L. Greer Price is currently interim director of the New Mexico Bureau of Geology and Mineral Resources, where he has worked for 11 years. He has been Chief Editor since 2001 and Deputy Director since 2007. Much of his time has been devoted to the publishing program and other outreach efforts.

Helium: An Increasingly Important Byproduct

Helium occurs in minute quantities in almost all natural gases, but only rarely in concentrations high enough (> 0.3 percent) to be of interest as a commodity that can be economically extracted. In New Mexico, helium has been produced since 1943 from several small accumulations in the Shiprock area of northwestern New Mexico. Originally the helium was used as a lifting gas for blimps during World War II. The known accumulations near Shiprock are now largely depleted.

The extremely low density of helium, which renders it useful as a lifting gas in balloons and blimps, is not its only useful property. It is chemically inert so it won't react with other substances, catch fire, or explode. Helium also has the lowest boiling point of any substance (-269° C = -452° F = 4 degrees above absolute zero!) so that when it is compressed under extreme pressure to a liquid it becomes colder than any other substance. These properties give helium several unique uses. It is used to cool the powerful magnets in magnetic resonance imaging (MRI) instruments that are so integral to modern medicine. It is also essential to the mass production of computer chips and fiber optic cables. Without adequate supplies of helium, much of today's advanced technology would not be widely available.

Our country's supply of helium is principally obtained from natural gas accumulations in the strata of southwestern Kansas and the Oklahoma and Texas panhandles. Currently domestic production only meets 62 percent of U.S helium sales. Natural gas production from our main helium sources has fallen as the known and developed reservoirs have become increasingly depleted. In the meantime our demand for helium has increased as new technologies that require helium have become widely available in our society.

Although large helium accumulations have been discovered in Algeria and Russia, these supplies seem destined for overseas markets only. Helium needed for U.S. industries will have to be produced from the U.S., and New Mexico may play a significant role in future production. Exploration for additional helium accumulations has been underway in the Shiprock area in recent years. In addition, some of the newly discovered natural gas accumulations in the Tucumcari Basin contain enhanced concentrations of helium and may end up being produced for their helium contents as well as for fuel.

Bureau News

Earth Science Achievement Awards

The 2012 New Mexico Earth Science Achievement Awards will be presented on February 13 in Santa Fe. This year's winners are William C. Olson, for outstanding contributions advancing the role of earth science in areas of public service and public policy in New Mexico, and G. Emlen Hall, for outstanding contributions advancing the role of earth science in areas of applied science and education in New Mexico. These awards, co-sponsored by the New Mexico Bureau of Geology and Mineral Resources and the Energy, Minerals and Natural Resources Department (EMNRD) in Santa Fe, were initiated in 2003 to honor those often unrecognized champions of earth science issues vital to New Mexico. Selections were made following a statewide nomination process. The presentation will occur at noon in the rotunda of the state capitol building on Monday, February 13, during the legislative session, in conjunction with Earth Science Day. The public is invited to attend the ceremony.

The John P. Taylor Lifetime Achievement Award

The John P. Taylor Lifetime Achievement Award was awarded this fall to Dr. Paul Bauer, Associate Director at the New Mexico Bureau of Geology and Mineral Resources. The award honors the memory of John P. Taylor, a wildlife refuge biologist whose energy, perseverance, and foresight regarding land and water management activities earned him national recognition and respect. The award is given by the New Mexico Riparian Council, an organization dedicated to the continued survival, maintenance, and enhancement of riparian systems in New Mexico for further benefit and enjoyment of present and future generations. The award was made to Paul in recognition of his contribution of significant time and energy to the restoration and protection of riparian ecosystems, as well as his contribution toward research and environmental education. Paul managed the STATEMAP Program from 1993 to 2004 and served as program coordinator for the bureau's decision-makers field conferences. He has been involved in legislative outreach efforts on water and rivers of New Mexico and has worked cooperatively with agencies throughout the state, in addition to his own research.

USGS Grant

The New Mexico Bureau of Geology and Mineral Resources was recently awarded a grant to research rare earth element potential in the Caballo and Burro Mountains of southern New Mexico. Specifically the project will examine occurrences associated with Cambrian-Ordovician magmatism. The proposal was submitted by Virginia McLemore and Nelia Dunbar and will include student support as well as funds for field and lab work. The grant for $60,000 was funded through the USGS Mineral Resources External Research Program.

National Outdoor Book Award

One of the bureau's newest publications, *The Rio Grande: A River Guide to the Geology and Landscapes of Northern New Mexico*, was recently honored with an award from the National Outdoor Book Association. Written by Paul Bauer and published in August 2011, the book won top honors in the Outdoor Adventure Guidebook category. The National Outdoor Book Awards is the outdoor world's largest and most prestigious book award program. It is a non-profit, educational program sponsored by the National Outdoor Book Awards Foundation, Association of Outdoor Recreation and Education, and Idaho State University. The purpose of the awards is to recognize and encourage outstanding writing and publishing. The book has been a popular seller since its appearance and is available through our publication sales office.

Rockin' Around New Mexico 2012

This summer our annual teacher's workshop, Rockin' Around New Mexico, will return to the Jemez Mountains, to visit some of the places that were inaccessible last summer due to the fires burning at the time. Topics will include the geology of local seismic, volcanic, and geothermal features relating to the Valles caldera, and seismic hazards in New Mexico. This year's 3-day workshop is scheduled for July 9–12. Classroom teachers in grades 1–12 are encouraged to attend. Teachers who are interested in attending should contact Susie Welch at (575) 835-5112 or via e-mail at susie@nmt.edu

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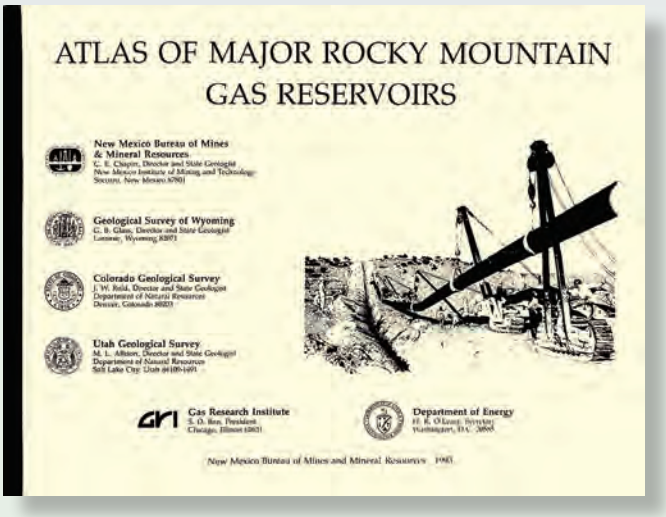

Atlas of Major Rocky Mountain Gas Reservoirs, a co-publication of the New Mexico Bureau of Geology and Mineral Resources, the Gas Research Institute, and the U.S. Department of Energy, 1993, Over 200 pp, 17" x 22", ten large (24" x 36") colored map sheets, and CD ROM. $99.50 including domestic shipping (gross receipts tax applies for New Mexico transactions). ISBN# 9781883905002.

This oversized atlas (and accompanying database) synthesizes information on sixty-six major gas plays in Colorado, New Mexico, Utah, and Wyoming. Each is described and illustrated with maps, logs, and cross sections. The atlas includes descriptions and geologic engineering data for 861 reservoirs that, as of December 1990, each had produced more than 5 billion cubic feet of gas. Prepared in cooperation with the geological surveys of Colorado, Utah, and Wyoming.

Minerals of New Mexico poster, recently reprinted, 24" x 36", $5.00 plus $4.50 shipping and handling including tax.
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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