New Mexico EARTH MATTERS

Winter 2007

Uranium – Is the Next Boom Beginning?

Why is uranium at the heart of one of the most emotionally charged natural resource debates of our time? And why does New Mexico play a central role in this global issue? The answers are that uranium is the fuel for both nuclear weapons and nuclear power plants, and New Mexico has extensive known uranium reserves. New Mexico could play an important role in U.S. nuclear energy independence.

Uranium is useful because it is radioactive, meaning it is unstable; uranium atoms decay over time, giving off energy in the process. Uranium mining has provided major economic benefits for surrounding communities in New Mexico, but it has left a legacy of environmental and health problems. A greater understanding of the state's history of uranium mining, and of how uranium is extracted from the ground and processed, is critical if we are to make informed decisions regarding the future of uranium mining in New Mexico.

Uranium in New Mexico

Pure elemental uranium is a silvery white metal. It combines easily with oxygen and other elements or compounds to form uranium minerals such as uraninite (or pitchblende), coffinite, and carnotite. The richest deposits in New Mexico are found in the world-class Grants uranium district between Gallup and Laguna in the San Juan Basin of northwestern New Mexico. These ores are located mainly in sandstones in the Westwater Canyon and Brushy Basin Members, and in the Jackpile Sandstone of the Jurassic Morrison Formation. Similar deposits are found in the Salt Wash Member of the Morrison Formation in the smaller Shiprock mining district. Most of these host rocks were laid down about 150 million years ago in ancient stream channels, areas between streams, and small lakes or playas.

Uranium in situ leach well field. Workers are checking flow-rate controllers for leachate injection wells, visible in the background. Mining sites like these are typically short-lived (less than a year).

Uranium typically is leached from volcanic rocks and other surrounding units and is concentrated by fluids migrating through permeable sandstone units. Precipitation of uranium minerals is associated with a subsurface transition from oxidizing to reducing conditions, forming narrow, elongate or tabular ore deposits. These formations have yielded about 97 percent of all New Mexico uranium production to date.

New Mexico's uranium production began in 1948. Over the next three decades the Grants mineral belt produced more uranium than any other district in the world, accounting for over one-third of all production in the U.S. More than 174,000 tons of uranium oxide (U_3O_8) were produced in New Mexico from more than 200 mines in 18 counties before production ceased in 2002. At the height of the uranium boom in the late 1970s–early 1980s, more New Mexicans were employed in uranium mining and milling than all other types of mining combined. Annual production between 1977 and 1982 averaged over $370 million, more than any other commodity. Several mills were built in the Grants area to separate ore from waste rock and concentrate or process uranium. All have now been closed.

The Boom and Bust Mining Cycle

Many mining commodities follow boom and bust cycles: Unit values rise, spurring increased production causing oversupply, which then results in a decrease in prices that curtails production. Uranium is no exception. The first uranium boom in the 1950s was a result of the demand by the U.S. government for materials for nuclear weapons research and production. For more than 20 years fixed-price contracts kept the market strong. When the federal Atomic Energy Commission's procurement program ended in 1970, uranium was bought and sold on the open market, and prices fell. By then nuclear power plants fueled with enriched uranium were being built across the globe, and prices again increased. New Mexico's production hit an all-time high of over 8,500 tons in 1978. Prices paid for New Mexico production peaked at almost $40

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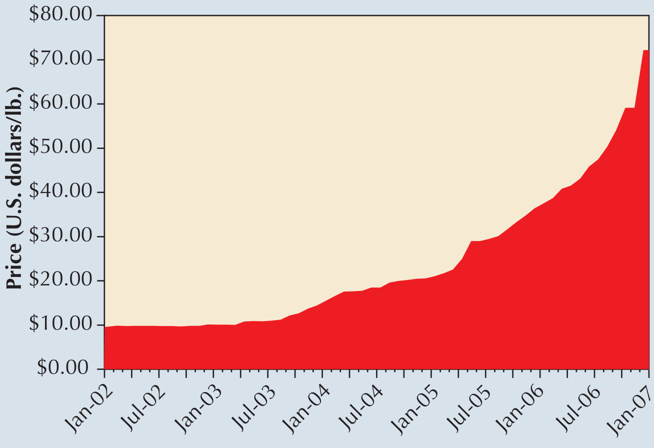


In the past five years prices for uranium ore (U_3O_8) have skyrocketed from $10 per pound to over $70 per pound. Shown are spot prices © UxC (www.uxc.com); reproduced with permission.

per pound in the early 1980s, but oversupply caused prices to plummet to under $10 by 1989, and they stayed there for the next dozen years. The oversupply was compounded by the end of the Cold War, when uranium from weapons stockpiles was released and sold. Today's annual global production of about 110 million pounds now falls short of demand, and stockpiles are shrinking. In addition to the 435 active nuclear power plants world-wide (the U.S. has 103), many countries are planning new ones, with China and India alone expecting to build 43 new plants in the next 15 years.

Unlike electrical generation stations that burn fossil fuels, nuclear power plants generate no greenhouse gases. Nuclear power is touted by some as the fuel of the future, or at least part of a mix of future energy sources, if we are to meet anticipated electricity demands and attempt to curb climate change. Thus, it should come as no surprise that prices are skyrocketing in anticipation of a future supply shortfall. Spot market prices were at $72 per pound as of January 2007, having risen six-fold in the last three years.

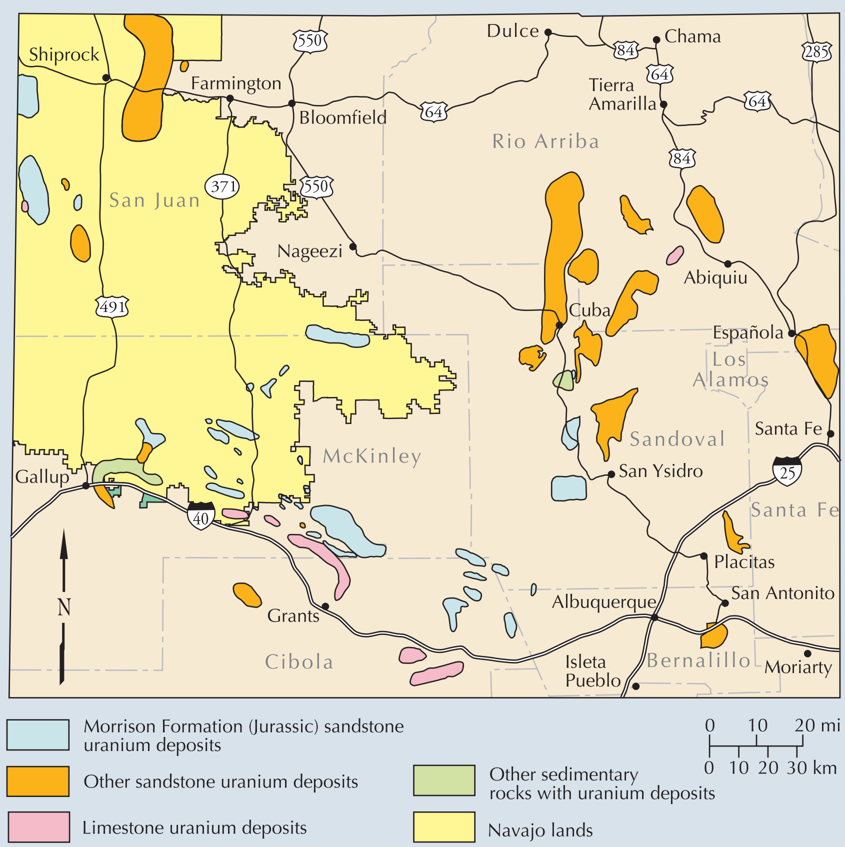
High prices provide strong incentive for mining companies to explore and develop new mines and re-open old ones. The federal Energy Information Administration (EIA) indicates that New Mexico still has reserves of at least 341 million pounds of uranium oxide that are minable at $50 per pound or less. This amounts to 38 percent of U.S. reserves, second only to Wyoming. The neighboring states of Colorado, Arizona, Utah, and Texas also have significant reserves that are being examined for increased production.

In Situ Leach Extraction

Uranium extraction during previous cycles was conducted mainly using conventional mining methods (open-pit or underground shaft-and-tunnel techniques). Much of the proposed new round of uranium mining will use newer, in situ leach (ISL) technology. Instead of digging pits, shafts, and tunnels to bring ore to the surface, ISL involves drilling a series of injection and recovery wells into a uranium orebody. Water is pumped up from the orebody, an oxidant (such as hydrogen peroxide) is added to the water, and the water is injected back into the orebody. The oxidizing fluid dissolves uranium minerals, and the uranium-laden waters are brought to the surface in recovery wells. Those waters are passed through ion-exchange resin pellets that remove the uranium, much like a water filter under a kitchen sink. The pellets are then hauled to a central processing facility where the uranium is stripped off the pellets and concentrated into a low-grade form of uranium oxide called yellowcake. The stripped pellets are then sent back to the mining site, and the process is repeated.

Generally a central processing plant is semi-permanent. The well field at any given mining site, however, typically is used only for a period of up to a year before that site is tapped out. Each well-field mining site normally undergoes several years of continued pumping and reverse osmosis to remediate the water back to original conditions or other mandated standards. Mining sites are also ringed with monitoring wells to detect any leakage of contaminated waters. The key to safe ISL operations involves removing more water than is injected (commonly about 5 percent more). That creates a cone of depression around the site and draws regional ground water into the site rather than allowing it to move outward. The excess water and removed contaminants are disposed of by injection into deep strata that already contain waters unsuited for human use.

The uranium ISL technique is a proven one that has been used for nearly 25 years in south Texas. If new mining is permitted

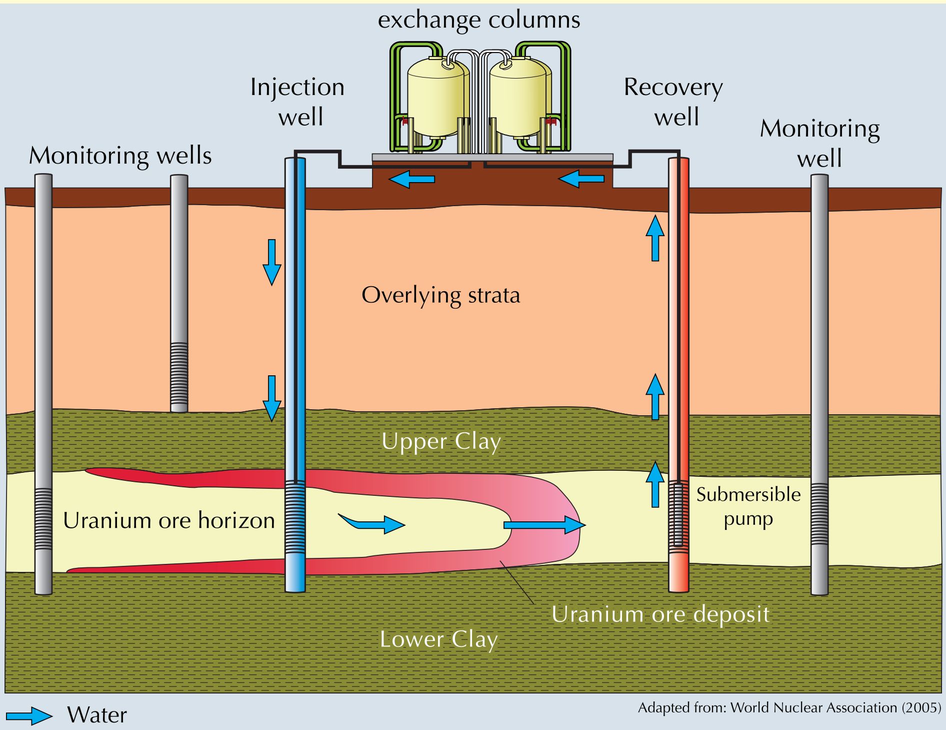


Geologic occurrences of uranium in northwest New Mexico. Most of New Mexico's uranium reserves, and virtually all past production, are in this region.

Informing the Debate

One way to acquire the additional scientific data required to make informed decisions down the line is to create a partnership composed of the major research institutions in the state. Currently the three state research universities and the two national laboratories in New Mexico are working toward such a partnership. This would create a program to collect unbiased data to inform the inevitable debate regarding renewed uranium mining in New Mexico. Program components we hope will include:

- Outreach and education, to conduct meetings around the state to inform the public and the regulatory community about modern methods of uranium mining, to discuss safety issues, and to solicit suggestions for program improvement.
- Baseline data studies of soils, surface and ground water, air quality, and current radiation levels in human populations to gather information on natural and other contaminants. New and existing geochemical data will be used to model ways to minimize potential environmental impacts.
- Hydrologic studies, aquifer mapping, and modeling to characterize major aquifers and potential deep waste injection zones, in order to predict potential solution mining impacts, and to facilitate the development of environmentally sound extraction operations.
- New technologies to more effectively remove uranium and other hazardous materials in waters in the potential mining areas. Evaluate potential to use cleaned produced waters to supplement existing conventional water supplies.
- An online database of existing uranium and uranium mining data from federal and state agencies and mining companies should be developed and made available.
- Modern resource assessment and characterization of known and potential uranium deposits.



A modern uranium in situ leach operation. The process involves drilling a series of injection and recovery wells into a uranium orebody. Uranium-laden waters are brought to the surface and passed through resin pellets that remove the uranium. The pellets are then hauled to a processing facility where the uranium is stripped. The remediated water is returned to the subsurface. Monitoring wells detect any leakage of contaminated waters.

in New Mexico, it will be the technique of choice in many areas with suitable ores. However, the presence of abundant organic matter, relatively impermeable host rocks, excessive depth, and other factors make ISL unsuited for some deposits.

Will the Past Be Prologue to the Future?

Will New Mexico participate in the next boom? The interest is there. Strathmore Resources, Neutron Energy Inc., Western Energy Development Corp., and Urex Energy Corp. all submitted exploration permit applications to the state Mining and Minerals Division in 2006. Hydro Resources Inc. is currently permitting two sites for uranium in situ leach extraction. All of these activities are in the Grants–Gallup area.

Past mining has been linked to health problems in miners and nearby residents. As a result, fear of sickness and contaminated land and water supplies has created enormous resistance to allowing new mining in New Mexico. Central to opposition is the Navajo Nation. The Navajo tribal council passed a resolution in 2005 banning all future uranium mining, even though some of the largest remaining ore reserves are located on or near Navajo and other Native American tribal lands. Most old uranium mines were abandoned and many remain unreclaimed, and high levels of uranium, heavy metals, and other radioactive elements are present in some areas.

Will future uranium extraction create problems similar to those associated with past activities? ISL mining of uranium, like all mining techniques, has potential environmental impacts. Surface contamination due to leakage of produced waters, contamination of potable ground water aquifers, and release of other potentially toxic metals (including vanadium, zinc, selenium, molybdenum, and others) into ground waters can occur where ISL operations are not conducted carefully. Predicting where mining solutions migrate underground is difficult. Further compounding the problem, many uranium deposits are located in aquifers tapped for human and livestock use. But prior knowledge of the geologic and hydrologic complexities of the site, coupled with strong and effective monitoring, can go a long way toward preventing such problems. These are not trivial requirements and are part of the reason why extensive background information should be collected before mining. In addition, traditional mining methods will probably have to be used for deposits not amenable to ISL, and such operations carry risks of human radiation exposure, surface contamination of mining and milling sites, leakage from tailings ponds, etc.

Uranium Environmental and Health Permit Requirements

Not all permits and requirements applicable to uranium exploration, extraction, and processing facilities are included. For additional information contact the New Mexico Mining and Minerals Division at 505-476-3400.

AGENCY	REQUIREMENTS
FEDERAL AGENCIES	
Nuclear Regulatory Commission	License for mills, processing plants, in situ leach extraction; addresses safety, environmental protection and reclamation
Forest Service/Bureau of Land Management	Approvals for exploration and mining activities on federal land require reclamation, financial assurance
Mine Safety and Health Administration	Requirements for health and safety of workers at mines and on-site mills
STATE AGENCIES	
Environment Department	
Ground Water Quality	Discharge permits require monitoring, prevention of contamination, reclamation, remediation
Underground Injection Control	Requirements to ensure water quality standards are met
Surface Water Quality	Requirements to meet surface water quality standards
Hazardous Waste	Permits for transportation, treatment, storage, and disposal of hazardous waste
Radiation Control	Licenses for processing and handling of radioactive material not covered by federal Nuclear Regulatory Commission
Occupational Health and Safety	Requirements for workers safety at off-site mills and processing plants
Mining and Minerals Division	Permits for exploration, surface and underground mines include reclamation, financial assurance; excludes in situ leach operations
State Land Office	Lease provisions address operations and reclamation on state-owned lands

There are now laws and regulations in place that address past and potential future problems, laws that were not in place during earlier mining. All old mill sites, which were the most contaminated, have been reclaimed under the federal 1978 Uranium Mill Tailings Radiation Control Act and the 1980 Comprehensive Environmental Response, Compensation, and Liability Act, better known as Superfund. Some health problems are being addressed, and many of the old mines have been cleaned up through various federal, state, tribal, and corporate reclamation programs. But significant problems remain, and with them, a legacy of fear, anger, and frustration.

Mining companies eager to renew exploration and extraction say that the problems of the past will not be repeated because of the new requirements and better technology. Detractors point out that many past mining operations that obtained all the proper permits still suffered contamination because protections were not adequate or toxic solutions and materials were not controlled as anticipated. For example, a fully permitted earthen tailings dam at a uranium mill at Church Rock near Grants ruptured in 1979, spilling almost 100 million gallons of radioactive fluids into the Rio Puerco of western New Mexico/eastern Arizona, creating the largest accidental release of radioactive material in U.S. history. Evidence of the spill was detected 50 miles downstream, and the federal Environmental Protection Agency is still working on ground water decontamination. Although environmental protections have been strengthened since then, dam construction was considered state of the art at the time.

The Road Forward

New Mexico's known uranium reserves have a value of about $20 billion at current prices, based on conservative estimates of the Energy Information Administration. Renewed uranium mining in New Mexico could generate substantial income for the state and jobs for its citizens, both very important factors in a state ranked forty-fifth in per capita income in 2005. But with widespread public opposition to the idea of renewed uranium mining, how do we reconcile these opposing perspectives?

Clearly, the answer is not simple, but it should be based on rational discussion. We can and should proceed with renewed uranium mining only if it can be done with full assurance that such resource extraction will not be accompanied by environmental degradation, ground water contamination, and associated adverse health effects. Careful mining practices can minimize or eliminate such hazards, and mining need not be permitted where the state deems the process too hazardous. To understand if we can, in fact, conduct uranium mining in this state without compromising health and environmental safety requires more information than we currently have. Additional scientific background data must be collected in order to make informed decisions (sidebar on page 3).

Many federal and state requirements are currently in place to prevent a recurrence of previous problems. However, they are dispersed across many laws, regulations, and policies that are complex and difficult to understand. It is unclear whether there are significant gaps in this regulatory patchwork. Since no large-scale in situ operations have been conducted in New Mexico to date, we do not know how productive proposed large-scale operations will be, or what environmental effects could occur. Coverage by New Mexico statutes is usually more comprehensive than that offered by federal counterparts, and New Mexico must decide whether areas addressed only by federal requirements are adequately covered, or whether we believe additional protections are warranted.

Retroactive programs to reclaim mines and treat health problems have a limited history of success; it is much better to avoid the problems through preventive measures. Comprehensive, effective regulation must be in place before new operations begin. All the existing regulations should be carefully evaluated together for effectiveness, efficiency, and gaps. An action plan should be developed and implemented to address issues that are identified.

We can learn from the past and approach the new round of mining with sufficient scientific data and a regulatory framework that ensures the health and safety of the state's citizens while still allowing the extraction of a valuable and much needed resource. With good baseline data the state can effectively mandate cleanup standards and maintain or even improve water quality in mining areas.

— Douglas Bland and Peter A. Scholle

Doug Bland is special projects manager and Peter Scholle is director and state geologist at the New Mexico Bureau of Geology and Mineral Resources in Socorro.

Bureau News

On January 26 the **2007 New Mexico Earth Science Achievement Awards** were presented to Representative Mimi Stewart, for outstanding contributions advancing the role of earth science in areas of public service and public policy in New Mexico, and to Dr. Frank Titus, 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, a division of New Mexico Tech in Socorro, and the Energy, Minerals and Natural Resources Department in Santa Fe, were initiated in 2003 to honor those often-unrecognized champions of earth science issues vital to the future of New Mexico. Selections were made following a statewide nomination process. This year's presentations were made by Joanna Prukop, cabinet secretary of the New Mexico Energy, Minerals and Natural Resources Department, and Dr. Peter Scholle, state geologist and director of the New Mexico Bureau of Geology and Mineral Resources. Nominations for next year's awards are welcome from the general public and may be made directly to Peter Scholle at the New Mexico Bureau of Geology and Mineral Resources.

The bureau is now involved in Phase II of an ongoing project with **Molycorp Inc.** Initiated in 2002, the project is aimed at an understanding of how weathering will affect the long-term stability of the rock pile slopes at the Molycorp molybdenum mine on the Red River, near Questa, New Mexico. Phase II of the project will concentrate on in situ shear testing, as well as the completion of work initiated in Phase I. Funded by Molycorp, the project is administered by the University of Utah and involves researchers from the University of Utah, University of British Columbia, and New Mexico Tech. The Phase II contract has brought $1.3 million to the bureau; total funding to the bureau for this project is now in the neighborhood of $3.5 million. Three graduate theses were completed in Phase I of the project; more than seven additional graduate theses will be completed over the next two years. Phase II is scheduled for completion in December 2008.

The bureau is currently engaged in a regional **hydrogeologic study in the southern Sacramento Mountains**. Funded by the Otero County Soil and Water Conservation District with funds allocated by the state legislature, the study was prompted by concern over declining ground water levels and spring discharges in the area. The project began in the fall of 2005 and will continue through 2011, with approximately $1,000,000 in funding. The goals of the study are to use geologic and hydrologic data to characterize the local and regional aquifer systems, define limits of the aquifers, and identify geologic controls on recharge and movement of ground water. These data will also help evaluate the impacts of severe drought and increasing vegetation density on local and regional water budgets.

In August 2006 the **National Conference of State Legislatures** presented a Notable Documents Award to the bureau for *The High Plains of Northeastern New Mexico: A Guide to Geology and Culture* by William Muehlberger, Sally Muehlberger, and L. Greer Price (Scenic Trip 19, published in 2005). The award is given for outstanding publications in the service of government, "…innovative in providing substantive information on contemporary issues of interest to legislatures." This book is the newest of the volumes in our Scenic Trip series, which since 1953 has provided popular regional guides to the geologic and cultural features of New Mexico.

If you order publications by phone or have the occasion to stop by for information, you will note that we've hired a **new manager for the Publication Sales Office**/Geologic Information Center at the New Mexico Bureau of Geology and Mineral Resources. Rasima Bakhtiyarova joined us in December 2006. Rasima is a native of Azerbaijan but came to us most recently from Auburn University in Alabama.

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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
geoinfo.nmt.edu

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Jane C. Love

Layout
Thomas Kaus

Graphics
Thomas Kaus
Leo Gabaldon
Mark Mansell

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(505) 835-5490, or e-mail us at
pubsofc@gis.nmt.edu

Cover photo of Ship Rock, New Mexico
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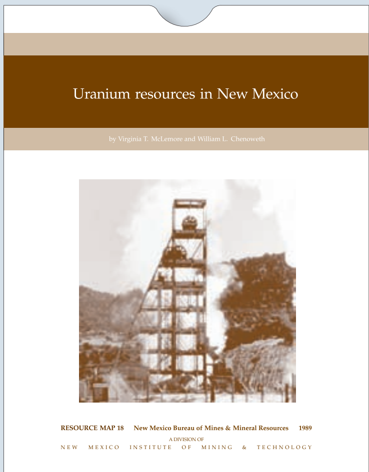
Publications

For More Information on Uranium in New Mexico

The New Mexico Bureau of Geology and Mineral Resources has issued a number of important publications over the years on uranium resources in New Mexico. Most are available for purchase through the Publications Sales Office, a few are available as free downloads from the bureau Web site at geoinfo.nmt.edu. Among the more popular publications are:



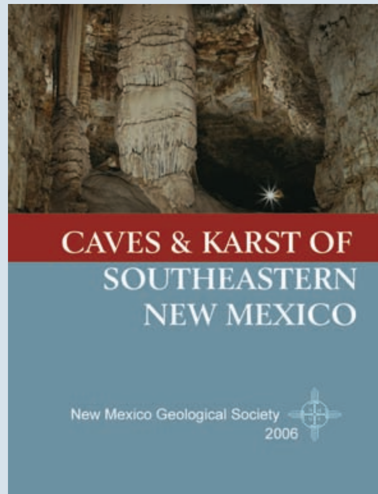
Resource Map 18—Uranium resources in New Mexico, by V. T. McLemore and W. L. Chenoweth, 1989, 36 pp. text, 1 sheet, scale 1:1,000,000. $7.50

Memoir 15—Geology and technology of the Grants uranium region, prepared by the Society of Economic Geologists, compiled by V. C. Kelley, general chairman, Uranium Field Conference, 1963, reprinted 1978, 277 pp. $10.00

Memoir 38—Geology and mineral technology of the Grants uranium region 1979, compiled by C. A. Rautman, 1980, 400 pp. $15.00

Open-file report 353—Uranium mines and deposits in the Grants district, Cibola and McKinley Counties, New Mexico, by V. T. McLemore and W. L. Chenoweth, 1992, 22 pp., 2 tables, 1 fig., 7 sheets. Can be downloaded at no charge at ftp://geoinfo.nmt.edu/Open-files

Open-file report 461—Database of uranium mines, prospects, occurrences and mills in New Mexico, by V. T. McLemore, K. Donahue, C. B. Krueger, A. Rowe, L. Ulbricht, M. L. Jackson, M. R. Breese, G. Jones, and M. Wilks, 2002. Can be downloaded at no charge at ftp://geoinfo.nmt.edu/Open-files



Guidebook 57—Caves and karst of southeastern New Mexico, edited by Lewis Land, Virgil W. Lueth, William Raatz, Penelope Boston, and David W. Love, 2006, Guidebook 57 of the New Mexico Geological Society, 344 pages. Soft cover: $50.00

This guidebook, published in September 2006 by the New Mexico Geological Society, was compiled to accompany the 57th annual fall field conference to southeastern New Mexico. This is one of the most significant regions in the world for those who are interested in the study of caves and karst. In addition to detailed road logs throughout the field trip area, the book includes articles on stratigraphy, speleogenesis, geophysics, cave features, hydrology, Quaternary geology, paleontology, and economic geology, as well as a geologic overview of the Guadalupe Mountains area of west Texas and New Mexico. The book includes 16 pages of color plates.

For more information about these and other bureau publications: Visit our Web site at geoinfo.nmt.edu; write or visit our Publications Sales Office on the campus of New Mexico Tech, 801 Leroy Place, Socorro, New Mexico 87801; call (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. Additional charges for shipping and gross receipts tax (New Mexico residents) are not reflected.

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