
# New Mexico EARTH MATTERS

Volume 3, Number 1, Winter 2003


## Caves and Karst in New Mexico

The caves of New Mexico are among the most outstanding, beautiful, and geologically significant in the world. In the south-central part of the state near the town of Capitan are Fort Stanton Cave and Torgac Cave. In the southeastern part of the state, southwest of the town of Carlsbad, are Carlsbad Cavern, visitor attraction for millions, and Lechuguilla Cave, the deepest cave in the United States and fifth longest cave in the world. Also in the Carlsbad area is Parks Ranch Cave, the longest gypsum cave in the United States. These caves and the landscapes in which they occur are important geologic resources of New Mexico. In the past twenty years or so, they have played an important part in geologists' growing understanding of how caves form.

### What is Karst?

Karst is the term geologists use to describe a topography characterized by caves, sinkholes, and underground drainage. What distinguishes a karst landscape from other landscapes is the dominance of solution features in soluble sedimentary rocks such as limestone and gypsum. Traditionally, karst has been thought of as a near-surface phenomenon, where weak carbonic acid, formed from the solution of carbon dioxide in surface and ground waters, is responsible for the solution features. Recently the concept of karst has expanded to encompass solution features (including caves) that result from the deep-seated dissolution of reservoir or ore porosity, with sulfuric acid the primary mechanism of dissolution. This mechanism, it turns out, is responsible for some of the most spectacular caves of New Mexico.

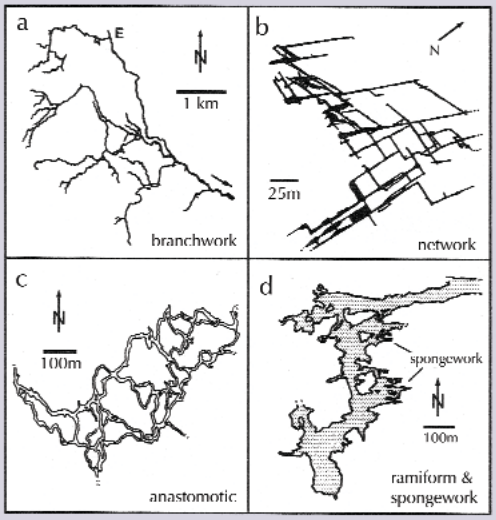
*Gypsum chandeliers in the Chandelier Ballroom, Lechuguilla Cave. Photo by Peter and Ann Bosted.*

### Types of Karst

Worldwide, geologists recognize three main types of karst. Carbonic acid karst is the most common type of karst and accounts for over 90 percent of all karst terrain on Earth. Typical of carbonic acid karst is the recharge of water at the surface through sinkholes and caves, and the discharge of that water to springs in nearby river valleys. Carbonic acid is responsible for the dissolution of these near-surface caves, derived from carbon dioxide in the atmosphere and soil zone above the cave. Branchwork, network, and anastomosing (a network of branching and rejoining) passage patterns are characteristic of carbonic acid karst, branchwork caves being by far the most common type. Well-known carbonic acid caves include Mammoth Cave in Kentucky, Jewel and Wind Caves in South Dakota, Kartchner Caverns in Arizona, and Fort Stanton Cave in New Mexico.

Thirty years ago cave researchers noted with interest the fact that many of the spectacular caves of New Mexico and Texas bore little resemblance to the better-known caves of Kentucky and Virginia. Other similar caves had been noted since the 1930s. The patterns created by the cave passages themselves were remarkably different and bore little relation to the known hydrologic features of the area. Thus began the unraveling of one of the more interesting stories in the growth of our knowledge of speleogenesis and the origin of sulfuric acid caves.

These caves–and similar caves in other parts of the world–came to be known as sulfuric acid karst. In caves associated with sulfuric acid karst, there is no apparent relationship to recharge through the overlying surface. Instead, cave passages form where there is a deep-seated source of hydrogen sulfide, usually derived from oil and gas reservoirs. When hydrogen sulfide in solution mixes with oxygenated water at or near the water table, it forms sulfuric acid, and it is this acid that dissolves away the limestone to form cave passages. This sulfuric acid is far more aggressive than weak carbonic acid and is therefore a potent mechanism for dissolving large cave passages such as Carlsbad Cavern's Big Room, more than six football fields long.




*Common patterns of solutional caves. From Palmer (1991).*

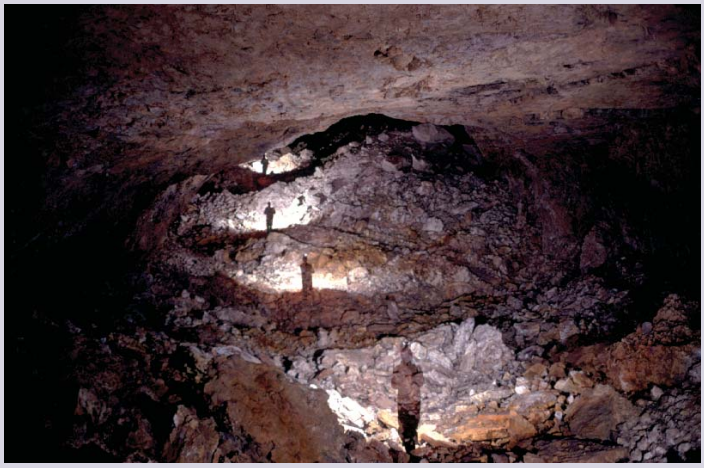
Sulfuric acid caves commonly consist of interconnected solution cavities of varied size in a seemingly random three-dimensional pattern, like pores in a sponge. These "spongework" caves commonly contain large passages that end abruptly away from the source of hydrogen sulfide. Examples of this type of karst include Carlsbad Cavern and Lechuguilla Cave in New Mexico, and the Cueva de Villa Luz in Tabasco, Mexico. The Cueva de Villa Luz is an active sulfuric acid cave: measured hydrogen sulfide values in the cave air reach 152 parts per million (which means that researchers working underground must wear gas masks), and the pH of drip water can reach almost zero. (By comparison, drinking water typically has a pH of 7–8; lemon juice has a pH of between 2 and 3.

Gypsum, native sulfur, and certain other diagnostic minerals associated with sulfuric acid karst (including the clay minerals endellite and alunite, and uranium minerals such as tyuyamunite) form as by-products of this sulfuric acid reaction. Gypsum can be found in Carlsbad and Lechuguilla Caves in massive blocks up to 30 feet high. Detailed chemical analyses of these minerals offer some clue as to their origin. The gypsum, native sulfur, and alunite characteristically have low (negative) sulfur isotope values (-10‰ to -25‰), indicating that the ultimate source of sulfur was microbial reactions related to oil and gas. Microorganisms deep beneath the surface fed on pools of petroleum under the Carlsbad region, producing hydrogen sulfide with negative sulfur isotope values. Ultimately this isotopically negative sulfur ended up in the cave gypsum, native sulfur, and alunite.

Finally, there is a third type of karst, evaporite karst, which is also represented in the caves of New Mexico. The dissolution of highly soluble sedimentary rocks (like gypsum, anhydrite, and halite) is involved in the genesis of evaporite karst, without the benefit of any kind of acid. There are two types of evaporite karst: surface (or uncovered) karst, and interstratal (or covered) karst. Surface evaporite karst develops in the vadose zone (the unsaturated zone above the water table) within evaporite rock and is exposed at the surface. Ground water recharge is usually through sinkholes, and water can move very rapidly to sites of discharge. Typical surface landforms are sinkholes, sinking streams, caves, blind valleys, and domes and breccia pipes (cylindrical collapse features associated with solution) exposed at the surface. Surface evaporite karst typically forms either network mazes or sinuous single conduits. Prime examples of this type of karst include Optimistcheskaya Cave in the Ukraine and, here in New Mexico, Parks Ranch Cave.

A second kind of evaporite karst, interstratal evaporite karst, is characterized by little or no surface expression of karst. In this instance solution processes in evaporite rock usually take place beneath a layer or layers of non-karstic rock. Dissolution at depth can occur either in the vadose zone (the unsaturated zone above the water table) or the phreatic zone (the saturated zone beneath the water table), and karst valleys form when the overburden collapses into these deep-seated caves. Nash Draw, in the area of the WIPP site, is an example of a karst valley related to the dissolution of evaporite rock. Breccia pipes, which form at depth by dissolution processes but typically do not reach the surface, are examples of interstratal karst. The breccia pipes encountered in the subsurface at the Culberson sulfur mine south of Carlsbad are interstratal karst features.

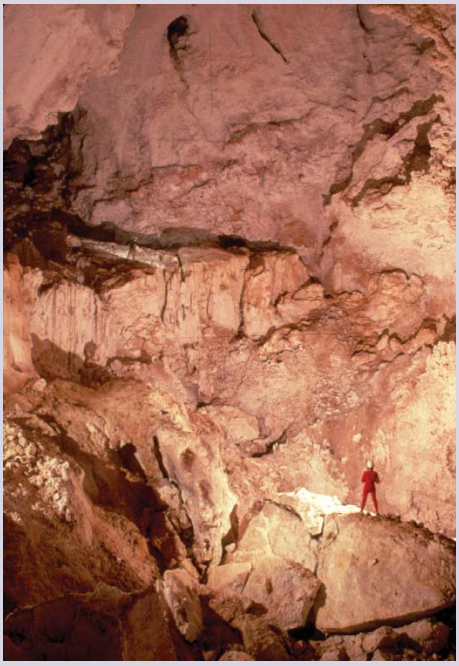
Interstratal evaporite karst can be an insidious type of karst because one does not usually know if it is there, or how it may be involved in the transport of ground water. Interstratal karst channels can completely bypass matrix porosity (the small, interconnected pores through which ground water generally moves) and can carry contaminants at high velocities to sites of discharge, thus increasing the potential for contamination of surface water resources at discharge sites. One of the remaining concerns for some at the Waste Isolation Pilot Plant (WIPP) site has been our incomplete knowledge regarding the extent of interstratal karst processes at or near the site.



*The "ghosts" of Fort Stanton Cave, near Fort Stanton, New Mexico. Fort Stanton contains long, linear passageways typical of carbonic acid speleogenesis. Photo by Alan Hill.*

## Caves Are Fragile and Protected Places

Many of New Mexico's caves are on public land, administered by the National Park Service, U.S. Forest Service, or Bureau of Land Management, and can be entered only with permission. The same invariably goes for caves on private property. In either case, caving is best done in the company of experienced cavers who are familiar with the particular hazards and conservation issues involved. Anyone entering a cave—in New Mexico or elsewhere—would do well to remember the creed of the National Speleological Society: Take nothing but pictures, leave nothing but footprints, kill nothing but time.



*Thirty-foot-high gypsum blocks in the Prickley Ice Cube Room, Lechuguilla Cave, New Mexico. Notice the people for scale. Photo by Peter and Ann Bosted.*

## Karst Areas of New Mexico

Although caves are scattered throughout New Mexico, they are concentrated in two outstanding karst areas in the state. One is near Capitan, in the northern Sacramento Mountains, the other near Carlsbad, in the Guadalupe Mountains-Delaware Basin area of southeastern New Mexico. Northeast of Capitan is Torgac Cave, which is developed in the San Andres Limestone and contains gypsum "claw" stalactites. Fort Stanton Cave east of Capitan, which is also formed in the San Andres Limestone, contains "velvet"-covered calcite and "starburst" gypsum, among other notable speleothems. Both of these caves are carbonic acid caves. They are located on lands managed by the Bureau of Land Management.

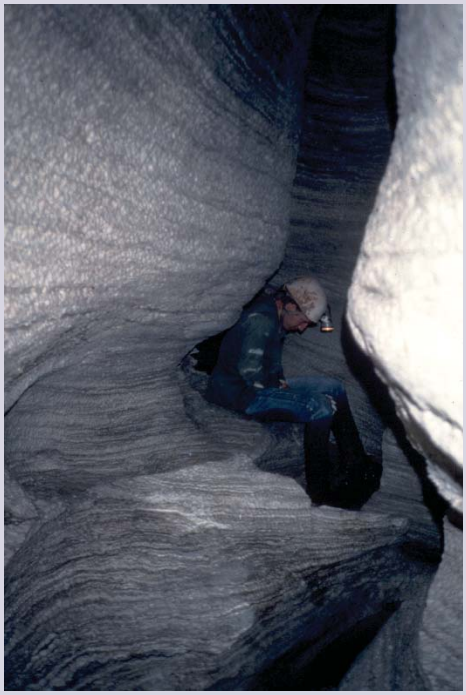
The Guadalupe Mountains of New Mexico provide one of the premier cave areas in the world. The world-famous Carlsbad Cavern and Lechuguilla Cave (as well as over a hundred other caves) are developed in the Capitan Formation, a reef limestone of Permian age. All of the caves in the Guadalupes are sulfuric acid caves, where petroleum in the adjacent Delaware Basin has supplied the hydrogen sulfide for sulfuric acid speleogenesis. Carlsbad Cavern is now 30.9 miles long and 1,037 feet deep at its lowest point, the Lake of the Clouds. Lechuguilla Cave is over 109 miles long and 1,567 feet deep, making it the deepest cave in the continental United States. Lechuguilla Cave contains a variety of speleothems of astonishing beauty, including the incredible gypsum chandeliers of the Chandelier Ballroom.

## The Importance of Karst

Aside from their obvious value as areas of geologic interest and potential research, karst landscapes are important from a ground water perspective. Many cities and towns in the United States draw their water from karst aquifers; an understanding of the working of these underground aquifers is extremely important in terms of evaluating the potential for environmental impacts both on and below the surface. Ground water contaminants are transported much more easily and quickly through karst aquifers than through other types of rock, such as sandstone. Karst aquifers also do not provide the filtration that other kinds of rock do.

Another concern has to do with the collapse of subsurface karst features, with disastrous results to overlying structures. Also, withdrawing too much water from a karst aquifer can cause collapse of surface rock and dwellings. These two problems are less prevalent in New Mexico than in other areas of the United States (such as Kentucky and Florida) because most of the caves here no longer carry large amounts of ground water. Nonetheless, it's an environmental issue of some concern in New Mexico. Some years ago a portion of Interstate 40 near Santa Rosa collapsed in the eastern part of the state due to the collapse of underlying karst features.

*Massive sulfur under gypsum, Ghost Town, Lechuguilla Cave, New Mexico. Photo by Bob Buecher.*



*Cave passage in Parks Ranch Cave, New Mexico. The bedrock is gypsum of the Castile Formation. Photo by Carol Belski.*

Carbonate (i.e., limestone) reservoirs of cavernous size can host large volumes of oil and gas. This is the case for some of the reservoirs (such as the Dollarhide field) on the east side of the Delaware Basin in southeastern New Mexico and west Texas. Many of the oil-producing rock units in New Mexico are producing from areas of paleokarst. In an evaporite rock system, hydrogen sulfide oxidized to sulfuric acid can create holes (porosity) in limestone that can then fill with oil. This porosity need not represent an ancient karst land surface or dissolution in the shallow-phreatic or vadose zones; it can form entirely in the deep subsurface. Such karstic reservoirs are prime targets for petroleum exploration.

Mississippi Valley-type ore deposits, of economic importance to a number of states, are also usually associated with karst. As is the case in some petroleum reservoirs, karst processes create the porosity that Mississippi Valley-type ores fill. These Mississippi Valley ore deposits, particularly those in Missouri and Illinois, are the primary source of lead and zinc in the United States. Similar deposits in the western United States are important sources of copper and rare minerals such as arsenic, vanadium, and uranium.

New Mexico has a wealth of cave resources for the general public, cavers, and speleologists to enjoy, explore, and study. Carlsbad Cavern, the most important tourist attraction in the state, has been a national park since 1923, with over half a million visitors each year. New Mexico is also home to the new National Cave and Karst Research Institute (based in Carlsbad), established by Congress in October of 1998. Finally, a wide range of interdisciplinary research efforts are underway in caves across the United States, the reason being that caves provide a unique environment and rare opportunity for many kinds of research in many disciplines. New Mexico, home to some of the most spectacular and significant of these rare and fragile places, is wise to place a premium on the value of this resource, today and in the years to come.

Carol A. Hill
Adjunct Professor
University of New Mexico

## Suggested Reading

DuChene, H. R., and Hill, C. A. (eds.), 2000, The caves of the Guadalupe Mountains symposium: Journal of Cave and Karst Studies, v. 62, no. 2, 107 pp.

Ford, D. C., and Williams, P. W., 1989, Karst geomorphology and hydrology: London, Unwin Hyman, 601 pp.

Hill, C. A., and Forti, P., 1997, Cave minerals of the world (second edition): Huntsville, AL, National Speleological Society, 463 pp.

Hose, L. D., and Pisarowicz, J. A., 1999, Cueva de Villa Luz, Tabasco, Mexico: reconnaissance study of an active sulfur spring cave and ecosystem: Journal of Cave and Karst Studies, v. 61, no. 1, pp. 13-21.

Palmer, A. N., 1991, Origin and morphology of limestone caves: Geological Society of America, Bulletin, v. 103, pp. 1-21.

White, W. B., 1988, Geomorphology and hydrology of karst terrains: New York, Oxford University Press, 464 pp.

# Bureau News

## Bureau Sponsors New Award

The first New Mexico Earth Science Achievement Award, sponsored by the New Mexico Bureau of Geology and Mineral Resources, will be awarded in 2004, to honor individuals who have made significant contributions to advancing or facilitating the role of geoscience in the arenas of education, research, public service, and public policy in New Mexico. The recipient will be selected by a committee chaired by the state geologist and including three members of the bureau's executive committee and the past president of the New Mexico Geological Society.

The bureau is currently soliciting nominations for this award. The deadline for nominations for this first year is December 15, 2003. The committee will review nominations in January 2004 and make a recommendation in February. Awards will be presented at the New Mexico State Capitol in Santa Fe during the legislative session, in conjunction with Natural Resources Day. Awards can be made to two nominees per year, in the categories of Research/Education and Public Service/Public Policy. Anyone may nominate someone for this award, but current employees of the New Mexico Bureau of Geology and Mineral Resources are not eligible for nomination.

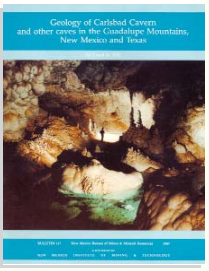
For more information concerning the New Mexico Earth Science Achievement Award, including more specific guidelines for nomination, please call the director of the New Mexico Bureau of Geology and Mineral Resources, Peter Scholle, at (505) 835-5302.

## New Hydrologist

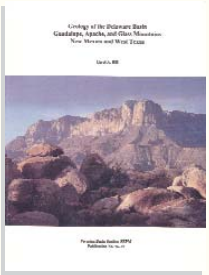
In January 2003 hydrologist John Sigda joined the staff of the New Mexico Bureau of Geology and Mineral Resources. John has been working on a Ph.D. at New Mexico Tech, which will be completed in the next few months. He recently summarized some of that work in a talk on campus titled "Conduits to Catchments: Deformation Band Faults in the Vadose Zone." John will be splitting his time between our Albuquerque office and the main office in Socorro.

## For More Information

The New Mexico Bureau of Geology and Mineral Resources carries a number of publications of interest relevant to caves, including:




**Geology of Carlsbad Cavern and other caves in the Guadalupe Mountains, New Mexico and Texas** by Carol A. Hill. Bulletin 117, 1987, 150 pp. $18.00



**Geology of the Delaware Basin, Guadalupe, Apache, and Glass Mountains, New Mexico and West Texas** by Carol A. Hill, Permian Basin Section-SEPM Publication No. 96-39, 1996, 480 pp.

Both are available for purchase through our Publications Office by calling (505) 835-5410.

### The Mysterious Life of Caves

In October 2002 the public television program NOVA featured scientists from New Mexico in a program titled The Mysterious Life of Caves, including Carlsbad Cavern and Lechuguilla Cave in New Mexico. This one-hour program is available on video for $19.95 from WGBH in Boston. Visit their Web site at www.wgbh.org/ for more information.

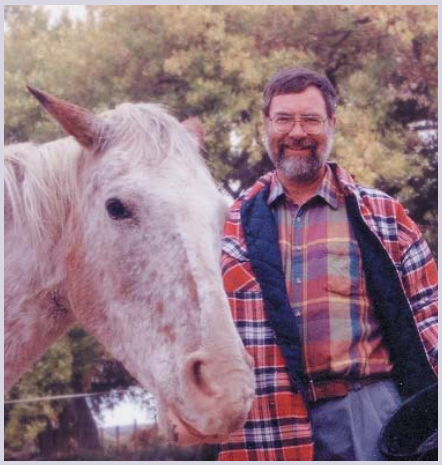
### The National Cave and Karst Research Institute

In October 1998 Congress created the National Cave and Karst Research Institute to be located in Carlsbad, New Mexico. In December 2002 the institute hired its first director, Louise Hose. The mission of the institute is to further the science of speleology by facilitating research, enhancing public education, and promoting environmentally sound cave and karst management. The institute works in partnership with the U.S. Geological Survey, the National Park Service, and other federal and state agencies. New Mexico Tech has been a partner in this endeavor since its inception. For more information on the National Cave and Karst Institute, visit their Web site at www.aqd.nps.gov/nckri/

## Staff Profile

David W. Love
*Principal Senior Environmental Geologist*

Dave Love came to the bureau as an environmental geologist in 1980, upon finishing his doctorate at the University of New Mexico (where he worked on the Quaternary geology of Chaco Canyon). For many years he worked in close collaboration with John Hawley (who retired in 1998). Over the course of his twenty-plus years at the bureau he has worked on a broad range of projects related to geologic hazards and environmental geology, including stream development, water quality, and soils. In 1982, less than two years after his arrival, Dave met Jane Calvert, who'd come to the bureau in 1981 as an assistant editor. Later that year they were married.



Among his many endeavors at the moment, Dave currently is working on Plio-Pleistocene stratigraphy of the Isleta area (in collaboration with Nelia Dunbar and Bill McIntosh) and on basin fill stratigraphy of the Albuquerque Basin (with Sean Connell). In 2001, with co-investigators Richard Chamberlin, Bruce Allen, and Bill Haneberg, Dave installed a series of three tiltmeters on the margins of the Socorro magma body and began looking at minute changes in ground tilt. The area above the magma body (an area of 1300 square miles) is responsible for 40 percent of the state's earthquakes and is known to be rising at a rate of 2 to 4 mm per year. Supported in part by New Mexico's Department of Public Safety, this group has now gathered over a year's worth of data.

Like many of our staff, Dave works in close collaboration not only with other bureau staff but with other state and federal agencies, including the National Park Service, Bureau of Land Management, Department of Public Safety, and the U. S. Geological Survey. He has also worked closely with the Pueblo of Isleta. He is actively involved in outreach, including regular participation in *Rockin' Around New Mexico*, the bureau's annual field conference and workshop for teachers throughout the state. He contributed to the first two Decision-Makers Field Conferences (in 2001 and 2002) and works regularly with the Southwest Institute on their annual field excursions. Dave has published widely, is working on several popular publications (including a new Scenic Trip), and has taught a number of courses (including environmental geology, sedimentology, and oceanography) over the years.

In 1999 Dave co-authored a paper on the natural conditions that contribute to the transport and trapping of non-aqueous-phase liquids, such as spills from gasoline storage tanks. This research led to Dave (and two colleagues) receiving U.S. and Canadian patents on a spill containment and recovery system.

Dave has been an active member of the New Mexico Geological Society since his arrival at the bureau, and a regular contributor to their publications. In 1991 he received their Honorary Lifetime Member Award. Over the years his other awards have included the Western States Seismic Policy Council's Award (with Susie Welch) in 2001 for Excellence in Outreach to Schools, the Association of Engineering Geologists Publication Award in 1999, and, in March 2001, the Interior Department's Unit Award for Excellence of Service for his work with the Chaco Center.

In 2002, after more than twenty years of service, in recognition of his experience and dedication, Dave was promoted to Principal Senior Environmental Geologist. He continues to earn the respect of his peers, displaying a dedication to the science of geology, a broad knowledge of the geologic framework of our state, a willingness to collaborate with others, and ongoing service to the people of New Mexico.


# New Mexico EARTH MATTERS

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*

Board of Regents
Ex Officio
**Bill Richardson**
*Governor of New Mexico*
**Ann Murphy Daily**
*President*
1999–2004, Santa Fe
**Jerry A. Armijo**
2003–2009, Socorro
**Richard N. Carpenter**
2003–2009, Sante Fe
**Sidney M. Gutierrez**
2001–2007, Albuquerque
**Isaiah K. Storey**
2003–2005, Socorro

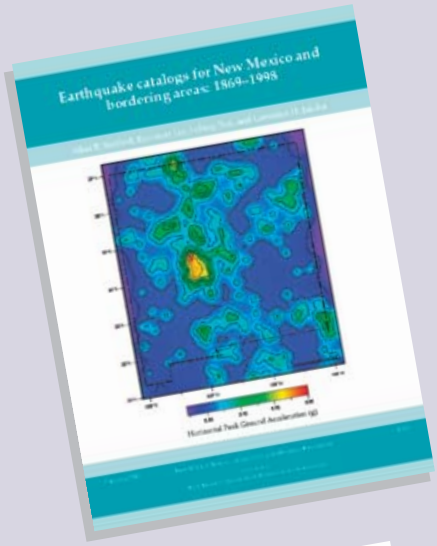
Editors
**L. Greer Price**
**Jane C. Love**

Layout
**Thomas Kaus**

Graphics
**Kathryn Glesener**

*Earth Matters* is a free publication. For subscription information please call (505) 835-5420, or e-mail us at pubsofc@gis.nmt.edu

# New Publications





**Earthquake catalogs for New Mexico and bordering areas: 1869-1998** by Allan R. Sanford, Kuo-wan Lin, I-ching Tsai, and Lawrence H. Jaksha. Circular 210, 104 pp. $10.00

*Records of earthquakes for a specific area over a given period of time are significant sources of data for researchers of earthquake activity. Such records allow researchers to evaluate seismic hazards and make more accurate predictions concerning the likely location—and magnitude—of future earthquakes. The catalogs presented here represent more than 40 years of research, provide an accurate historical record of earthquakes in New Mexico, and document a number of trends. Data from the catalogs can also be downloaded at http://geoinfo.nmt.edu/publications/earthcat*

**A Report from the New Mexico Bureau of Geology and Mineral Resources,** 2000-2001.

*In 2002 the bureau published a biennial report, covering calendar years 2000-2001. This 24-page, full color booklet offers a broad overview of our activities, including a statement of our mission, financials, and a look at ongoing projects. If you would like a copy, please give the folks in our Publication Sales Office a call at (505) 835-5410 and we will send you one. Single copies are available free upon request.*

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 Pl, Socorro, NM 87801
- Call (505) 835-5420
- E-mail us at pubsofc@gis.nmt.edu

Payment by check or money order payable to NMBGMR must be enclosed with mailed orders. Telephone orders may be paid with VISA, Discover, or MasterCard.

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