New Mexico EARTH MATTERS

Summer 2006

Geothermal Energy in New Mexico

Snapdragons at Burgett Geothermal Greenhouses near Cotton City.

Geothermal energy is the heat energy that is generated and stored in the earth. This heat represents one of the largest energy resources available to mankind. Geothermal energy can be used to produce electricity economically, or the heat may be applied in a direct-use fashion (such as greenhouse heating) for any process that requires large amounts of hot water or low-grade steam less than 300° F. When used in a sustainable manner, geothermal energy is a renewable energy resource. Geothermal energy has a smaller land and environmental footprint than all currently used conventional and renewable energy technologies. Practically no carbon dioxide emissions result from geothermal energy use. Because geothermal energy produces continuous or base load power, electricity production in the United States from geothermal energy was greater than the power produced by wind and solar energy combined over the last ten years. When geothermal energy is applied in a direct-use fashion, substantial energy savings accrue to the user when compared to natural gas. Given the large geothermal resource base in New Mexico and the huge array of potential applications, the environmental and economic benefits to the state could be enormous.

Geothermal Resources

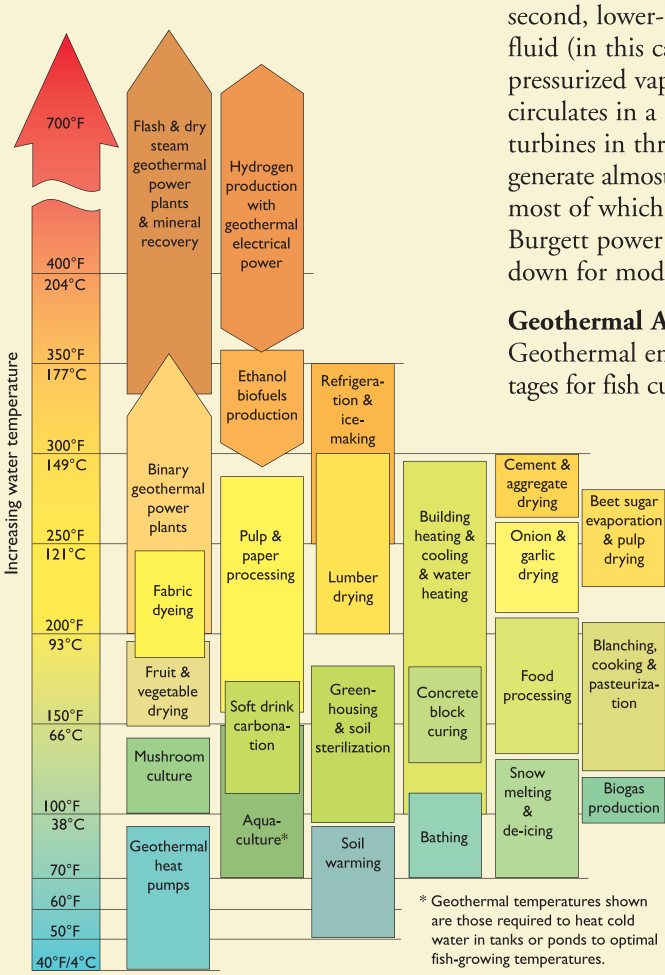
Accessible geothermal resources represent the heat that is stored in the conventionally drillable upper part of the earth's crust. This heat is continually augmented by radioactive decay of natural uranium, thorium, and potassium in the earth's crust, and by heat that is conducted into the crust from the hotter core and mantle below. In other words, the crust acts as a low-grade nuclear reactor, with added heat from the earth's interior. In regions with young and active volcanoes, locally intense heat may be introduced into the crust by magma that rises upward from partially melted regions of the mantle through weaknesses in the crust.

The most economic geothermal resources result from geologic processes that allow convection to concentrate deep-seated heat at economically drillable depths. All current geothermal users in New Mexico use convective resources that naturally circulate water through deep-seated bedrock, sweeping up the heat and transporting it upward into shallow reservoirs. Fault zones can help concentrate and redirect the hot water flow upward. Where these systems intersect the surface, hot springs are found. Heat from active or young volcanoes is not necessarily required for this type of geothermal resource. The subsurface shape of a typical convective geothermal reservoir may resemble a small isolated summer cumulonimbus cloud or thunderhead. The lateral outflow plume of geothermal convection is analogous to the anvil or stretched top of the thunderhead, whereas the upflow zone resembles the rising cauliflower-like bulk of the thunderhead. The most permeable portions of the upflow zone and the shallow lateral discharge are most easily and economically exploited.

Some of the largest geothermal resources in New Mexico are associated with deep and confined (artesian) aquifers or conductive geothermal reservoirs. Temperatures in conductive resources result from the increase in temperature with depth. Most of the western half of New Mexico has high temperature gradients that typically range from 1.6° F to 2.5° F per 100 feet in depth (as opposed to 1.1° F to 1.4° F per 100 feet in depth typically found elsewhere). Because deep wells are required to tap these resources, they have higher upfront costs. However, where large heating loads are required, the overall economics have advantages over fossil fuels.

Classification of Uses and Resources

A common geothermal resource classification uses temperature. High-temperature resources are greater than 350° F and are suitable for large-scale electrical generation for sales on the transmission grid. Intermediate-temperature resources are between 190° and 350° F and are increasingly used for smaller-scale power generation for sales over the grid or for on-site power. Low-temperature resources are less than 190° F and at least 15° to 30° F above the local mean annual surface temperature. Low-temperature resources are the most common in New Mexico. They can be used in a variety of direct-use geothermal heating applications, including greenhouses, aquaculture (fish farms), space and district heating, and many industrial uses such as cooking, curing, or drying that require large amounts of low-grade heat. High- and intermediate-temperature geothermal resources may also be used in direct-use applications by "cascading" residual heat from power production to lower-temperature applications, enhancing the overall efficiency and economics of use.



Temperature ranges of applications ideally suited to geothermal energy (modified from Geothermal Energy Uses, courtesy of the Geothermal Education Office, 2005).

Current Geothermal Use in New Mexico

Electric Power

Geothermal electricity has been produced at the 30-acre Burgett Geothermal Greenhouse in the Animas Valley near Cotton City. The facility extracts energy in a cascaded fashion, whereby 230° F water from geothermal wells is first fed into the power plant heat exchangers at a rate of 1,200 gallons per minute; the 185° F outflow from the power plant is used to heat greenhouses. Electricity is produced with binary-cycle power technology that employs heat exchangers to allow the geothermal water to boil a second, lower-boiling-point working fluid (in this case isopentane). The pressurized vapor of the working fluid circulates in a closed loop to drive turbines in three modular units and to generate almost 1 megawatt of electricity, most of which is used on location. The Burgett power plant is currently shut down for modifications.

Geothermal Aquaculture

Geothermal energy offers several advantages for fish culture. Many species have accelerated growth rates in warm water. Geothermal water can be used as a growth medium, adding to the agriculture receipts in the state without consumptive use of valuable fresh water. The AmeriCulture Tilapia Farm at Cotton City raises tilapia, a tasty warm water fish that is becoming increasingly popular. The AmeriCulture Tilapia Farm is heated with a 400-foot-deep geothermal well, at much lower costs than it could be heated with fossil fuels. From eggs produced on site, AmeriCulture grows and markets tilapia fry to growers and researchers nationwide and sells adult tilapia to restaurants across the Southwest. In addition, AmeriCulture has contracted Barber-Nichols, Inc. of Denver, Colorado, to design a binary-cycle power plant to provide electricity for the fish farm water pumps and refrigeration. Funding is provided through a cost-share grant with the U.S. Department of Energy.

Tilapia fry from eggs produced on site at AmeriCulture, Inc. near Animas, New Mexico.

Geothermal Space and District Heating

The aridity and high elevation of parts of New Mexico create significant heating loads on cold winter nights. Where shallow geothermal resources co-exist with large heating demands, geothermal space and district heating have cost advantages over fossil fuels. A district geothermal heating system on the New Mexico State University campus in Las Cruces was in operation from 1982 until 2004. It used as much as 260 gallons per minute of 147° F water, pumped from a depth of 744 to 971 feet with a campus geothermal well. Geothermal water was passed through a heat exchanger to heat fresh water that was fed into hot water loops on campus as needed. The cooled geothermal water was injected back into the reservoir margin beneath the campus golf course. Geothermal water was used to heat dorms, academic buildings, and athletic facilities on the eastern third of the campus. The system also provided hot water for showers in the dorms and athletic facilities. At present, the

Site	County	Installed heating capacity, million Btu/hour	Annual energy use, billion Btu/year	Annual energy savings	Use
NMSU/SWTDI	Doña Ana	0.5	1.4	$14,000	aquaculture
Masson Radium Springs Farm	Doña Ana	30.0	79.0	$790,000	16-acre greenhouse
Radium Hot Springs	Doña Ana	0.3	0.8	$8,000	spa
Faywood Hot Springs	Grant	0.9	2.3	$23,000	spa
Gila Hot Springs	Grant	2.1	5.4	$54,000	district heating
Burgett Geothermal Greenhouse	Hidalgo	70.1	184.2	$1,800,000	30-acre greenhouse
AmeriCulture Tilapia Farm	Hidalgo	9.0	23.7	$240,000	aquaculture
Ojo Caliente	Rio Arriba	0.6	1.6	$16,000	spa
Jemez Springs Bath House	Sandoval	0.9	2.3	$23,000	spa
Giggling Star, Jemez Springs	Sandoval	0.6	1.6	$16,000	spa
Charles Motel, T or C	Sierra	0.4	1.0	$10,000	spa
Fire Water Lodge, T or C	Sierra	0.4	1.0	$10,000	spa
Geronimo Springs Museum, T or C	Sierra	0.1	0.3	$3,000	space heating
Hay-Yo-Kay Hot Springs, T or C	Sierra	0.4	1.0	$10,000	spa
Marshall Hot Springs, T or C	Sierra	0.4	1.0	$10,000	spa
River Bend Hot Springs, T or C	Sierra	0.4	1.0	$10,000	spa
Sierra Grande Lodge, T or C	Sierra	0.4	1.0	$10,000	spa
Artesian Bath House, T or C	Sierra	0.4	1.0	$10,000	spa
TOTALS		**117.9**	**309.6**	**$3,057,000**	

Estimated annual energy use and savings for geothermal applications in New Mexico. Figures assume an annual 30 percent use of installed geothermal direct-use heating capacity.

geothermal injection well requires replacement, and the system needs upgrades after 22 years of service.

At Gila Hot Springs, a 300-foot-deep flowing well provides 165° F water for geothermal heating of a trailer court, rental cabins, store, and several homes. The New Mexico Institute of Mining and Technology at Socorro is currently assessing the feasibility of installing a campus geothermal district heating system in conjunction with a cost-share grant from the U.S. Department of Energy.

Geothermal Greenhouses

The best-known use of geothermal energy in New Mexico is for greenhouses. Geothermal greenhouses account for nearly half of the greenhouse acreage in the state. New Mexico leads the nation in geothermal greenhouse acreage. The success and growth in the geothermal greenhouse industry in New Mexico can be attributed to several factors, including abundant sunshine and low humidity, inexpensive land, co-existence of geothermal resources with fresh water, a good agricultural labor force, and favorable shallow geothermal resources. Current geothermal greenhouses use wells less than 1,000 feet deep, with resource temperatures ranging from 143° to 230° F.

Geothermal Heat Pumps

Ground-coupled heat pumps allow space heating and cooling through the use of heat exchange loops that are buried horizontally in the ground or installed vertically in wells. In winter, heat is extracted from the earth and concentrated by the heat pump for indoor heating. In summer, indoor heat is removed and placed in the ground. Several large geothermal heat pump installations heat and cool public schools in New Mexico.

Economic Impact

The geothermal heating cost for New Mexico geothermal greenhouses is currently less than $1.50 per million Btu, compared to more than $11 per million Btu for natural gas with boiler losses. This represents a savings of more than $2.5 million for the state's two large geothermal greenhouses. Geothermal greenhouse sales are estimated at $27 million and rank among the top ten in agriculture sector gross receipts in the state.

The Burgett Geothermal Greenhouse (30 acres) near Cotton City is probably the largest business in Hidalgo County. The Masson Radium Springs Farm geothermal greenhouse (16 acres) is the largest employer in northern Doña Ana

Cacti at Southwest Technology Development Institute's geothermal greenhouse, New Mexico State University.

Heat exchangers, pumps, and tank at Masson Radium Springs Farm geothermal greenhouses. Heat exchangers are used to transfer heat from geothermal water to a closed-loop fresh water heating system.

County. Geothermal spas at Ojo Caliente, Jemez Springs, Faywood Hot Springs, Gila Hot Springs, and the many spas in Truth or Consequences attract important tourism dollars to New Mexico.

Future Potential

Geothermal development resembles oil and gas in leasing, royalties, and drilling. Exploration and evaluation of geothermal resources borrow methodologies used in oil and gas, ground water, and mineral exploration. Geothermal energy is environmentally friendly. In most cases, spent geothermal fluids are injected back into the reservoir. With the use of heat exchangers, harmful scaling and corrosion is eliminated and fluids can be isolated from both the natural environment and surface geothermal equipment.

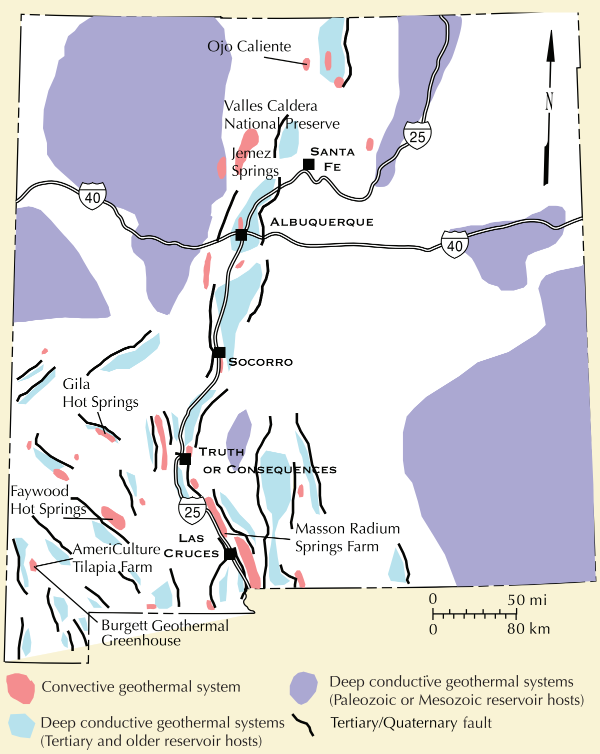
One impediment to geothermal growth is the initial capital costs associated with resource exploration, testing, and well drilling. However, geothermal energy has the advantage of low operations and maintenance costs, without the volatility associated with fuel costs. Most of the surface equipment used by geothermal operations is "off the shelf" and has well-known engineering characteristics and costs. This is especially true with direct-use installations.

The Valles caldera in the Jemez Mountains has proven geothermal reserves capable of generating as much as 20 megawatts or more of power. This resource has a probable magmatic heat source. Environmentally sensitive development of the Valles geothermal resource could provide royalty income to sustain and operate the Valles Caldera National Preserve and provide cost-stable power to the surrounding pueblos.

Small-scale geothermal electric power at less than 20 megawatts is likely in the next few years at several sites in New Mexico. Some of the generation is likely to be done in conjunction with cascaded direct use in a combined heat and power mode.

With the passage of the Energy Policy Act of 2005, formerly unfair federal royalty rules for direct-use geothermal energy are being modified to allow for an equitable fee structure that should encourage additional growth. In recent years, the U.S. Department of Energy has sponsored an outreach program, *Geopowering the West*, to educate the public and to encourage the development of all forms of geothermal energy. The Web site for the *Geopowering the West* is found at www.eere.energy.gov/geothermal/gpw/

Geothermal energy is a potentially powerful vehicle for rural economic development in New Mexico. Future uses of geothermal energy may include chile and onion drying, cheese and milk processing, and process heat for biofuels refining. Small-scale electrical power generation is very likely to expand in the cascaded mode with direct-use development. Because deep-seated saline water and oil field brines may be hot, geothermal desalinization and power generation may augment enhanced recovery of oil and gas and help sustain both our valuable water supply and our petroleum industry. For instance, oil field water flood operations could extract the heat of deep-seated oil field brines to generate geothermal binary-cycle power before reservoir injection for enhanced oil recovery. The power would be used for pump jacks and other oil field electricity requirements or placed on the transmission grid. The heat may also have use in multistage vacuum distillation of brines to produce desalinated water. The accessible geothermal resource base in New Mexico is vast, and the options for economic use are growing.



Geothermal resources in New Mexico.

—James C. Witcher
Witcher and Associates
Las Cruces, New Mexico

Jim Witcher is a geologist with nearly three decades of experience with geothermal exploration and development.

For More Information

The following Web sites offer a wealth of information on geothermal energy resources and development.

U.S. Department of Energy
www.energy.gov
Geothermal Education Office
www.geothermal.marin.org
Geothermal Energy Association
www.geo-energy.org
Geothermal Resources Council
www.geothermal.org
National Renewable Energy Laboratory
www.nrel.gov

All photos by Rob Williamson, courtesy of National Renewable Energy Laboratory. Adult tilapia inset on page 2 courtesy of Damon Seawright of AmeriCulture Tilapia Farm.

Staff Profile

Marshall Reiter

Principal Senior Geophysicist

Marshall Reiter grew up in Pittsburgh, Pennsylvania, and graduated from the University of Pittsburgh with a B.S. degree in physics. An interest in geophysics was sparked by Robert Stoneley, a visiting professor from Cambridge, and Marshall continued his education in geophysics at the University of Utah and Virginia Polytechnic Institute. His Ph.D. research on heat flow in southwestern Virginia caught the attention of Allan Sanford, professor of geophysics at the New Mexico Institute of Mining and Technology, and Marshall was offered a teaching position in January 1970. During his years in the department, Marshall and his students' geothermal studies identified the Rio Grande rift as a ribbon of high heat flow from central Colorado to El Paso.

Marshall moved from the college division of New Mexico Tech to the New Mexico Bureau of Geology and Mineral Resources in April 1975, although he continued to direct graduate students' research. From the late 1970s through the early 1980s he and the students collected heat-flow measurements in deep hydrocarbon wells to establish the regional heat-flow gradient below ground water flow. Their work suggested a lower crust-upper mantle heat source beneath the San Juan Mountains in southwestern Colorado, an interpretation that is consistent with recently published seismic investigations.

Geothermal studies continue to be Marshall's main research interest as well as rock and earthquake mechanics. Tracking the thermal history of the San Juan Basin led Marshall and his students back to new hydrogeothermal investigations in the Socorro area. In his current research Marshall uses terrestrial heat flow measurements in the pursuit of regional hydrologic information. Geophysicists have long recognized that the conductive geothermal gradient within the earth can be disturbed by ground water flow, thus skewing the measurements of terrestrial heat flow. Conversely, they realized that temperature logs not only provide heat-flow data but can also reveal characteristics of the hydrologic regime. Marshall and his colleagues at New Mexico Tech have been able to: (1) estimate rates of both horizontal and vertical (up and down) ground water flow, (2) locate geologic features that control ground water flow patterns, and (3) estimate regional recharge. Marshall has studied and interpreted heat-flow data and their possible correlation to hydrologic data throughout New Mexico: from the San Juan Basin and southeastern boundary of the Colorado Plateau to the Albuquerque Basin and along the Rio Grande rift in the Socorro area, Jornada del Muerto, Roswell Basin, and Pecos River valley.

During the past few years Marshall has begun applying his geothermal studies in the Albuquerque Basin to climate change. In the Southwest, heat transfer in the vadose zone, the unsaturated zone above the water table, is typically dominated by conduction. Monitoring temperatures in the vadose zone may enable one to observe changing trends in ground surface temperature possibly related to changes in climate. Loss of natural vegetation and paving during urbanization seem to result in ground surface heating at one study site in the Albuquerque Basin.

Measurements of subsurface temperature gradients and heat flow can also serve to determine the depth and temperature at the base of the crustal layer where most continental earthquakes occur. Marshall is currently comparing the subsurface temperature gradients along the San Andreas fault in California with those along the Coyote fault near Socorro, New Mexico.

In his 36+ years at New Mexico Tech, Marshall has published more than 60 papers in professional journals and serial publications. Marshall and his wife, Bonnie, have two sons and a daughter, and one grandson. Bonnie taught at Socorro Middle School for 12 years as a reading specialist. Since retiring from teaching, Bonnie often accompanies Marshall on field trips to help with the measurements.

New Mexico
EARTH
MATTERS

Volume 6, Number 2
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
geoinfo.nmt.edu

Editors
L. Greer Price
Jane C. Love
Layout
Thomas Kaus
Graphics
Thomas Kaus
Leo Gabaldon
Kathryn Glesener

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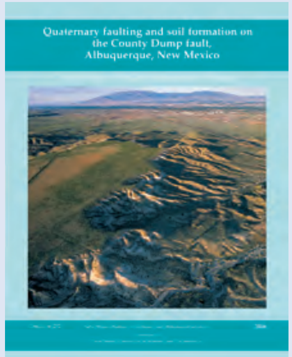
Cover photo of Ship Rock, New Mexico

New Publications

Circular 212—Quaternary faulting and soil formation on the County Dump fault, Albuquerque, New Mexico by J. P. McCalpin, S. S. Olig, J. B. J. Harrison, and G. W. Berger, 2006, 36 pp., ISBN 1-883905-18-4. $10.00 plus shipping and handling.

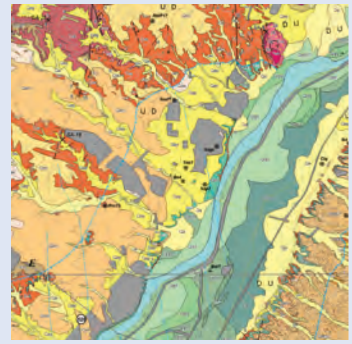


The Albuquerque–Santa Fe urban corridor is one of the fastest growing areas in the western United States. Twenty-seven Quaternary-age faults have been identified within 40 km of downtown Albuquerque. The faults are associated with the Rio Grande rift and are responsible for 10 earthquakes of MMI (Modified Mercalli Intensity) V or greater since 1849.

The County Dump fault is a 35-km-long, north-trending normal fault that is located in an area of suburban development west of the Albuquerque metropolitan area. The fault dips eastward under the city.

This study describes the recent activity of the County Dump fault and assesses its potential earthquake hazard. To more fully understand the fault's paleoseismic history, the authors undertook a study that included measuring the height of the scarp formed by the fault, opening multiple trenches across the fault, describing stratigraphic and structural features in the trenches and sampling soil horizons exposed, and collecting samples for thermoluminescence dating. The pattern observed in the trenches suggests that the fault moves at intervals of about 20,000–40,000 years and results in displacements of approximately 1 m or less. The last three ground ruptures have estimated ages of 30,000, 45,000, and 80,000 years ago. The publication includes detailed 2-color trench profiles and perspective drawings.

Open-file Report (OFR) 496—Preliminary geologic map of the Albuquerque–Rio Rancho metropolitan area and vicinity, Bernalillo and Sandoval Counties, New Mexico, compiled by Sean Connell, 2006. Available in electronic format only.



This digital geologic map is a compilation of sixteen 7.5-minute quadrangles and comprises an area of 2,500 square kilometers of the Albuquerque Basin of north-central New Mexico. Prepared at a scale of 1:50,000, the map depicts the geology underneath the cities of Albuquerque and Rio Rancho and surrounding areas. It was completed in order to better characterize geologic controls on ground water resources and geologic hazards in this rapidly growing urban region. It is currently available in electronic format only, free on the bureau's Web site at www.geoinfo.nmt.edu/publications/ or it may be purchased on CD ROM for $10 plus shipping. Digital files currently available include three plates, as follows:

Plate 1a: Geologic map and explanation (6.3 Mb PDF)
Plate 1b: Geologic map with shaded relief (21.9 Mb PDF)
Plate 2: Geologic cross sections & derivative maps (5.2 Mb PDF)

Digital GIS data and graphics files will be available soon, as well as a report on the geology of the map area. A printed map sheet (1:50,000) of this compilation will be available in 2007.

A complete list of open-file reports published by the New Mexico Bureau of Geology and Mineral Resources is available on our Web site. Some of these reports are available for free downloading directly from the site, all are available in electronic format on CD ROM for $10.00 plus shipping through the Publication Sales Office. For more information, visit our Web site at www.geoinfo.nmt.edu or call us at 505-835-5490.

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