In Socorro
801 Leroy Place
Socorro, NM 87801
505.835.5420

In Albuquerque
2808 Central Avenue SE
Albuquerque, NM 87106
505.366.2530

In Carlsbad
C/O Carlsbad Environmental Monitoring and Research Center
1400 University Drive
Carlsbad, NM 88220
505.234.5560

Brown Hall, the bureau’s first home, ca. 1940.

On March 14, 1927, the New Mexico State Legislature approved an act establishing the New Mexico Bureau of Mines and Mineral Resources, assigning it the responsibility for applied research into the geology and mineral resources of the state. From the very beginning the bureau has worked cooperatively with other state and federal agencies, including the U. S. Geological Survey, the Bureau of Indian Affairs, the Atomic Energy Commission, the Bureau of Land Management, and the National Aeronautics and Space Administration (NASA).

As a division of the New Mexico Institute of Mining and Technology (New Mexico Tech), the bureau has a long tradition of working closely with undergraduate and graduate students from New Mexico Tech and other universities throughout the state, teaching and providing cooperative and financial support. In recent years the director has served as state geologist. We are headquartered on the campus of New Mexico Tech in Socorro, with satellite offices in Albuquerque and Carlsbad.

In 2001 our name was changed to the New Mexico Bureau of Geology and Mineral Resources.

The bureau is a service and research division of the New Mexico Institute of Mining and Technology. It acts as the geologic survey of New Mexico with these main goals:

To conduct research and interact with state, local, and federal agencies and industry to facilitate prudent exploitation of the state’s geologic resources

To distribute accurate information to scientists, decision makers, and the New Mexico public regarding the state’s geologic infrastructure, mineral and energy resources, and geohydrology (including water quantity and quality)

To provide timely information on potential geologic hazards, including earthquakes, volcanic events, soils- and subsidence-related problems, and flooding

To create accurate, up-to-date (digital and GIS-based) maps of the state’s geology and resource potential

To act as a repository for cores, well cuttings, and a wide variety of geological data. To provide convenient physical and internet access for New Mexicans to such resources

To provide public education and outreach through college teaching and advising, the Mineral Museum, and teacher- and student-training programs

Cover photo: Tohilicon Wash, Todilto Park area, New Mexico.
Contents page: Buckman Crossing.
Below: Socorro Peak.
THE NEW MEXICO BUREAU OF GEOLOGY and Mineral Resources has served as the state geological survey for 75 years. We are a non-regulatory, research-oriented state agency and a division of the New Mexico Institute of Mining and Technology. We focus on fundamental geologic mapping and research in support of responsible resource development for the benefit of New Mexico’s citizens. Our employees teach, run sophisticated analytical facilities, do collaborative research with university faculty and students, support other land- and resource-based agencies, and conduct geoscience outreach education for K-12 students, teachers, and the general public. We are a data repository for much of the state’s geoscience information, maintaining libraries of geologic publications, petroleum well cores and cuttings, mining and energy-related paper documents, and the like.

Although these efforts are ongoing, our directions have shifted in response to the changing needs of those we serve. In our formative years we concentrated primarily on hard-rock mining, but the scope of our studies rapidly expanded to cover much broader areas, including geologic mapping, basic research on the geologic history of the region, and applied studies on the location and quality of industrial minerals, uranium, coal, oil, and natural gas. More recently, water-supply and water-quality issues have moved to the forefront of New Mexico’s needs, and so we have expanded our hydrologic and geochemical efforts in those areas, as well as in areas of environmental hazards, climate change, and related topics.

As I write this, I face a large bookcase filled with our traditional paper publications — learned volumes authored by leading scientists throughout the state. Many are classics of geologic literature; in aggregate they represent the essence of our knowledge of New Mexico’s geologic past. The repeated flooding and retreat of ocean waters over hundreds of millions of years; the uplift and erosion of great mountain ranges; the appearance and disappearance of ancient organisms; the massive volcanic explosions that dominated the past 40 million years of New Mexico’s history (and perhaps its future as well); and the emplacement of metallic ore deposits and energy resources are all recorded there. These publications represent outstanding science. They have yielded (and continue to yield) enormous economic benefits for the state. However, they were written primarily for (and are read mainly by) geologic or hydrologic professionals.

Part of our ongoing shift involves the “democratization” of this knowledge base. We are digitizing all of our publications, putting many on the Internet for free downloading. We are converting our databases to digital formats and making them available on CD-ROM. All of our current geologic mapping is distributed in GIS format for easy incorporation into computerized planning systems. In short, we, like the rest of the world, are going through the digital revolution.

FROM THE STATE GEOLOGIST

PETER A. SCHOLLE

We are “democratizing” in other ways as well. All of our technical publications now include non-technical summaries, we are expanding our museum and outreach activities, and we have started a new semiannual publication, Earth Matters, that presents bureau news and editorial views on earth science issues for the general public. Our most extensive effort comes in the area of Decision-Makers Field Conferences. These events, co-sponsored with many other state, federal, local, and tribal organizations, are designed to provide legislators, top agency officials, journalists, educators, and others with an opportunity to hear balanced assessments of current scientific knowledge and future policy needs. We take these folks into the field to see (and hear) about salient issues, and we publish an extensive color guidebook for each conference, which is available to the public. To date we have run two such trips — on water and energy — and have had excellent participation and results.

Throughout its existence, one hallmark of the bureau has been our exceptional willingness to work with partner agencies, with industry, and with the general public. Our staff spends many hours per week in direct interaction with a host of such collaborators. That is one activity we have no plans to change — indeed, we look forward to serving an ever wider audience. I hope that this report will further such interactions.
HYDROGEOLOGY is the science that deals with the occurrence and movement of ground water and related geologic aspects of surface water. By combining geologic maps and subsurface geologic data with hydrologic and chemical data from New Mexico’s streams and aquifers, we can address complex issues such as: How does the subsurface distribution of porous and impermeable rock and geologic structures affect the flow of water, the potential for contamination, and the amount of water available for use?

Recent studies are focusing on the supply of surface water in the Rio Grande. In 2001 the New Mexico Bureau of Geology and Mineral Resources sponsored a summer internship program with the New Mexico Interstate Stream Commission to monitor flow conditions and seepage in the Rio Grande and adjacent channels between Isleta and Elephant Butte Reservoir. This research continues with graduate students at New Mexico Tech in a study of ground-water and surface-water interactions along a critical reach of the Rio Grande south of San Acacia. This is the primary habitat for the endangered Rio Grande silvery minnow. Such studies are essential for effective water management on the Rio Grande.

BRUCE ALLEN’S research in the Estancia Basin of central New Mexico is providing a better understanding of the basin’s hydrology and past changes in climate. At Estancia, a remarkable paleohydrologic record is preserved in geologic deposits and landforms that formed during the last 30,000 years. This record includes shorelines formed by a perennial lake during a period of wetter climate, and large dunes deposited by desiccating winds during periods of drier climate. Reconstructions of changes in lake level and water-table elevation provide information about long-term climate variability in the region, and associated changes in the basin’s water budget. Field measurements related to rates of ground water discharge and evaporation are also relevant to questions regarding the long-term viability of ground water resources in the basin.
Geothermal Studies and the Environment

Geophysicist Marshall Reiter has studied the thermal regime of the earth’s crust for 30 years, making precision subsurface temperature measurements in bore holes over regions of interest. Unperturbed temperature measurements should demonstrate a linear temperature increase with depth across a uniform rock interval. The data from these studies can be related to tectonic and magmatic activity, and can offer some insight into geothermal resources and hydrocarbon maturation.

Both ground water flow and climate variations affect subsurface temperatures. For the past several years Marshall Reiter has been working with the U.S. Geological Survey, the New Mexico Office of the State Engineer, the City of Albuquerque, the Pueblo Nations, and private companies to take precision temperature logs in several dozen observations wells within the Albuquerque Basin, providing information on ground water flow. Earlier efforts to study ground water movement using geothermal techniques were conducted in the San Juan and Roswell Artesian Basins. Paleo-ground water flow in the San Juan Basin, advecting heat from the San Juan volcanic field, is believed to have influenced the distribution of hydrocarbons and coal in the area. Deep recharge along the Pecos River is suggested from analysis of bottom hole temperature data.

A new project in the Albuquerque Basin is investigating possible surface warming during the past 50 years. The study involves taking temperature data above the water table. Data will be taken in air using an ultra fast time response sensor, with a thermistor about the size of a pepper flake, so that depth-representative temperatures can be measured as the sensor is lowered continuously in the well. We hope the data will provide information concerning possible climatic warming in the Albuquerque area.

Ground Water Studies

The bureau places a major emphasis on studying the quality of New Mexico ground water. Arsenic has been of particular interest, since the Environmental Protection Agency (EPA) published a new maximum contaminant level of 10 ppb (parts per billion) arsenic in drinking water. Arsenic occurs in ground water used for drinking at levels above 10 ppb in many parts of New Mexico. Samples from wells and springs along the Rio Grande from the Sevilleta Wildlife Refuge to the Bosque del Apache Wildlife Refuge were analyzed for major and minor constituents and many trace elements as well as arsenic. Arsenic distribution ranged from less than 2 ppb to 43 ppb. This study, published in the February 2001 issue of New Mexico Geology, led to an expanded study currently underway to analyze ground water samples from all around New Mexico and to compile water quality results in one database. Products of this study, including an arsenic map of New Mexico, will be available on the bureau’s Web site.

In 2000 we began an investigation of Socorro’s water supply system, in cooperation with the City of Socorro. Monthly samples from the six sources are taken and analyzed, and data are collected on monthly usage figures. This will result in a comparison of water quality with usage and time.

The bureau is also involved in studies of uranium levels in ground water. EPA has proposed a maximum contaminant level for uranium in drinking water of 20 ppb. Uranium has not previously been an element of concern in drinking water, and levels have not been readily available. Uranium levels are above the recommended maximum contaminant level in two of Socorro’s six municipal wells.
THE NEW MEXICO BUREAU of Geology and Mineral Resources is a non-regulatory agency. This simplifies one of our primary responsibilities, which is to conduct research that will facilitate the prudent exploitation of the state’s geologic resources. We work in close cooperation with state, local, and federal agencies and industry in that effort. We serve as a repository for cores, well cuttings, and a wide variety of geological data, particularly with regard to oil, gas, and coal resources of New Mexico. We are charged with distributing information regarding the state’s geologic infrastructure, and mineral and energy resources.

New Mexico is a national leader in energy production and reserves. We have substantial coal, oil, gas, and uranium resources, and enormous potential for the development of solar and wind energy. Geothermal resources, particularly in the southwest corner of the state, have long played a part in our energy mix.

Much of the state is still considered underexplored frontier. Several scientists at the bureau are focused on research to help extend the life of known reserves and to study potential new resources. We conduct research in conjunction with the Petroleum Recovery Research Center at New Mexico Tech, and we work hand-in-hand with commercial energy companies, particularly smaller, independent companies, to provide technology and knowledge that stimulates exploration and generates income for New Mexico. The latest project in our program to evaluate petroleum resources in nonproductive frontier areas of New Mexico involved analysis, mapping, and assessment of petroleum source rocks in the Tucumcari Basin.

As part of a larger U. S. Department of Energy-funded project at New Mexico Tech, we are working to reduce exploratory risk, developing a substantial database of well and production data for the Permian-age Brushy Canyon Formation in southeast New Mexico. This pilot project may indicate potential for new oil and gas wells in this prolific reservoir and has greater implications throughout the oil patch.

Ongoing studies include:
A regional study of the stratigraphy, basin analysis, and petroleum geology of Paleozoic rocks. Paleozoic reservoirs are prolific producers of oil and gas.
Research into the characteristics of low-permeability natural gas reservoirs common to the northwestern part of the state. Such reservoirs tend to be underdeveloped.
A study of potential availability of coal and coaled methane production. Coal is used in the generation of electricity, an important export to the regional power grid. Coalbed methane makes up a third of the state’s current natural gas production and may become more important in the future.
Coal availability studies in the San Juan Basin, including the Chacra Mesa, La Ventana fields, Fruitland and Navajo fields. Studies are partially funded by the U. S. Geological Survey and available from the bureau as open-file reports.
A Twenty Year Reasonable Foreseeable Development Scenario for Oil and Gas in the San Juan Basin, Northwestern New Mexico, funded primarily by the Bureau of Land Management and conducted by researchers at the New Mexico Institute of Mining and Technology Department of Petroleum Engineering, and the bureau. This study will help land managers in the orderly development of federal oil and gas leases.
In 2001 the bureau sponsored a conference on Low Permeability and Underdeveloped Natural Gas Reservoirs of New Mexico, in cooperation with Petroleum Technology Transfer Council. With the help of such research, and with an active, healthy private industry, we see a substantial future for both conventional and unconventional energy development in the state of New Mexico.

The bureau monitors uranium resources and production, and related environmental issues, throughout the state.
SINCE ITS INCEPTION the New Mexico Bureau of Geology and Mineral Resources has conducted studies and disseminated information on mineral resources and extractive metallurgy of New Mexico. One of the most richly endowed states in the U. S., New Mexico ranked 18th in non-fuel minerals production in the year 2000. Most of that production comes from copper and potash. Significant reserves of copper, potash, molybdenum, aggregate, other industrial minerals, and uranium are identified in the state. Our staff keep informed about mining technology, mine safety, and mining law, on local, state, and federal levels.

The bureau is developing a computerized inventory of existing abandoned, inactive, and active mines, occurrences, deposits, and mills throughout New Mexico. This database will include uranium, metallic, and industrial minerals mines, occurrences, deposits, and mills. Production data for gold, silver, copper, lead, zinc, uranium, vanadium, potash, manganese, barite, fluorite, and other commodities (excluding oil and gas) will be available for many districts. Geochemical data for mining districts in New Mexico will include multi-element chemical data of mineral deposits obtained from the bureau, the U. S. Geological Survey, the U. S. Bureau of Mines, and other sources for both solid materials and water samples.

The purpose is to provide decision makers, scientists, and the public with information on mining districts in New Mexico in order to identify potential sites that may be contributing metals to surface and ground water; to aid in prioritizing mine sites for remediation; and to provide an understanding of the environmental geochemistry of mining districts in New Mexico and their potential input of metals to the watershed.

In collaboration with the Petroleum Recovery Research Center on the campus of New Mexico Tech, the bureau is involved in collecting data on corrosion and scaling problems in oil and gas production in the state, and in disposal of oil field brines. Interactive corrosion and scale identification and prediction tools are being developed that will be made available to the producers on the internet. In addition, the bureau has been providing metallurgical and analytical support to producers in the identification of corrosion failures and production scales.

Current research on the mineral deposits of New Mexico includes:

- The origin and evolution of mineralizing fluids that form mineral deposits in New Mexico, specifically at Copper Flat, Hillsboro district (Sierra County), Steeple Rock (Grant County), Victorio (Luna County), Lordsburg (Hidalgo County), Organ Mountains (Doña Ana County), Orogrande (Otero County), and Questa molybdenum deposit (Taos County).
- Several studies on the geochronology of New Mexico’s mineral deposits will increase our understanding of the formation, distribution, and resource potential of mineral deposits throughout the state. Research on argon dating of hydrothermal manganese in New Mexico provides the exciting prospect of determining the direct age of an ore mineral and relating that age to associated volcanic activity.
- The mineral jarosite has been found to encode information about the formation and natural destruction of ore deposits. Argon age dating coupled with stable isotope analysis provide the means for determining the age of weathering while also revealing paleoclimate information.
- Continuing research has also found that jarosite forms as a primary mineral in some fluorite deposits along the Rio Grande rift and that some deposits are still forming in the subsurface today.
- The bureau is studying construction aggregate for the state land office. Data collected include surficial and bedrock geology, state aggregate leases, and land status. The scattered and incompatible aggregate data are converted into a highly practical GIS format. Both the aggregate industry and resource administrators use this information to ensure efficient and responsible use of the aggregate resource in New Mexico.

VIRGINIA L. MCEMORE, Senior Economic Geologist
JAMES M. PARKER, Senior Industrial Minerals Geologist
IBRAHIM GUNDURE, Senior Extractive Metallurgist
VIRGIL W. LUETH, Mineralogist/Economic Geologist
ROBERT W. EVELETH, Senior Mining Engineer
GEORGE S. AUSTIN, Emeritus Senior Industrial Minerals Geologist
STATEMAP, the New Mexico Bureau of Geology and Mineral Resources geologic mapping program, is part of the National Cooperative Geologic Mapping Program, a federal program administered through the U. S. Geological Survey. We are in the 10th year of a project designed to rapidly produce and distribute state-of-the-art, detailed geologic quadrangle maps of select areas of the state. Our mapping program is especially important to New Mexico: less than 20% of the state has been mapped at the standard scale of 1:24,000. The most critical unmapped areas are the population and agricultural centers along the major rivers, areas of vital economic, social, and scientific importance to the state. By June 2003 we will have mapped 80 quadrangles (approximately 4800 sq. miles), mostly along the Rio Grande watershed from Taos to Socorro, but including areas of critical concern in the Pecos River, Great Plains, and the Colorado River watersheds.

Our program is cooperative in the broadest sense. Mapping priorities are set annually by a 35-member State Geologic Mapping Advisory Board, composed of hydrologists, geologists, and planners from state, local, federal, pueblo, and private agencies and entities. Quadrangles are selected based on their potential to provide essential earth science data to planners, hydrologists, engineers, citizens, and geologists. Much of the success of STATEMAP is due to the requirements that maps must be designed to address critical societal and/or scientific problems, and that mapping is completed within a single year. The program is a cooperative effort between bureau geologists, university faculty and students, private sector consultants, and the U. S. Geological Survey. Our program has received widespread support and acclaim from political leaders, government agency scientists, university professors, professional hydrologists and engineers, water planners, and others.
Modern geologic maps are the fundamental tool for displaying information required to identify and protect valuable resources and make wise use of our land. From the beginning, our project objective has been to characterize the geology of each area in sufficient detail to allow use of the information in matters of practical, economic, and environmental concern to governments, communities, and planners, as well as to satisfy the fundamental goals of basic science. Detailed, publicly available earth science information is essential for making informed decisions. High-quality maps made by objective scientists also have very important intangible values. In particular, users of geologic maps find that the quality of their work is enhanced and the credibility of their findings is increased. A study in Kentucky estimated that the economic benefits of 1:24,000 scale geologic maps exceeded mapping costs by 50 to 1 on a $21 million investment over the life of the program.

New quadrangle maps produced by the bureau are supporting a great variety of environmental and hydrologic work, and they are the primary source of information on the state’s aggregate resources (sand, gravel, crushed stone). Like all investment in good science, the value of geologic maps endures—in addition to their immediate value, they always yield unexpected future benefits.

The project is partially funded by the National Cooperative Geologic Mapping Program, a federal program administered through the U. S. Geological Survey. New Mexico has been the most successful state survey in the country competing for STATEMAP funds. As of July 2002 the bureau has received a total of $1,482,226 from the U. S. Geological Survey, the highest total in the nation. The program is a matching-funds program; the bureau or partner agencies match all federal monies dollar-for-dollar.
Other Field Studies

Richard Chamberlin and colleagues Bill McIntosh and Ted Eggleston have made detailed geologic maps of the Socorro caldera and determined the timing of many eruptions associated with this large volcanic collapse structure that formed 31.9 million years ago. This ancient “supervolcano” is partially exposed in fault-block mountain ranges of the Rio Grande rift southwest of Socorro. Calderas are large volcanic depressions, often 10 to 20 miles in diameter, that form when a gas-charged viscous magma body ejects huge ash columns that inundate the surrounding countryside with a thick blanket of welded ash (called ignimbrite) while the shallow roof of the chamber collapses. Caldera-forming eruptions are rare catastrophic events, second only in scale to large asteroid impacts. Deep magma systems that feed these “supervolcanoes” appear to march to the beat of their own drummer; eruptions are both episodic and irregular in timing and intensity. Our research indicates that the Socorro caldera became unusually quiet shortly after the primary ignimbrite eruption. Waning-stage pulsating eruptions and the crystal-rich character of the ignimbrite magma imply that the magma body literally ran out of gas to drive the explosive eruptions and that the magma body became immobilized and locked by crystals soon thereafter. Comparison of the unusual Socorro caldera with young “restless” calderas may help volcanologists predict the probability of future eruptions associated with calderas.

Phil Kyle, Bill McIntosh, Nelia Dunbar, and Rich Esser are involved in National Science Foundation-funded research at Mt. Erebus, the earth’s southernmost active volcano. Current research efforts at Mt. Erebus include remote monitoring of seismic events and ground deformation, continuous video observations of explosive events within the crater, and analysis and sampling of gases in the volcanic plume. The crater contains a unique permanent lake of molten lava, which serves as a window into the magma chamber deep within the volcano. A primary goal of this work is to better understand the geometry and eruptive behavior of the magma chamber, in hope...
of applying this knowledge to less accessible magma chambers elsewhere in the world. Although there are no currently active volcanoes in New Mexico, eruptions were common in the geologic past, and have occurred as recently as 3000 years ago. There is also strong seismic evidence for a fluid magma chamber, termed the Socorro magma body, beneath the Socorro area. Many of the small earthquakes in the state are associated with this magma body. We are currently building a hybrid instrument package for Mt. Erebus that combines a seismometer, high precision GPS, tiltmeter, and other environmental sensors into a single, integrated, remotely operated monitoring device. Part of our research plan is to deploy one of these hybrid instrument packages in the Carthage area to monitor the Socorro magma body.

Research in the Albuquerque and the San Luis Basins is currently using borehole cuttings to characterize the subsurface geology. By combining surface mapping and geophysical methods with borehole cuttings analysis one can further refine existing models and more accurately develop the subsurface picture. This can lead to more accurate hydrogeologic models and other resource related products.

Staff at the Albuquerque Office are principally engaged in geologic mapping, ground water, and environmental geologic studies in north-central New Mexico, home to much of the population of the state. They regularly respond to public inquiries and outreach about the geology of the region. The Albuquerque Office also archives donated data from water wells so that this data is available to help solve future problems. Work through the Albuquerque Office has significantly revised our understanding of the region’s natural resources and the role geology plays in utilizing and protecting these resources.

The bureau recently hosted a field excursion to highlight recent findings in the Ortiz Mountains and Madrid-Cerrillos areas. The distribution of rock types and geological structures, such as faults, greatly influence the location and quality of aquifer water. Many of these faults influence ground-water flow and future movement could cause potentially damaging earthquakes. Results of the geologic mapping effort have led to a better understanding of how the central New Mexican landscape developed and how geologic studies can be used to delineate areas with potentially unstable soils that can cause considerable damage to buildings.

Dr. Ibrahim Gundiler, standing on a minette, an inclusion in 1.4-billion-year-old granite in the Burro Mountains. These dark inclusions of mantle material are the same age as the surrounding (lighter-colored) granite. Together they offer evidence of mixing of deeper mantle material with the shallower magma of the crust at the time the granite was formed.
NEARLY ALL HUMAN ENDEAVORS have a geographic component, and nowhere is that more true than in the earth sciences. In the past twenty-five years, the way in which we gauge those components has changed dramatically. For geologists, the end product is often a map; like every other discipline, mapping and cartography have grown and changed as we’ve entered the digital age.

Geologic mapping is integral to all of our research efforts. Maps are also one of our most important products. Responsibility for final map products—printed or electronic—is shared by our Cartography group and the Computer and Internet Services group, as well as the staff devoted to the STATEMAP project.

The creation of geologic maps from field data has always been something of an art. Today map data from the field are compiled into a Geographic Information System (GIS) and integrated digitally with electronic databases of all sorts. This allows compilers the flexibility of including on a single sheet those layers that are most appropriate to the task at hand.

The Cartography group also provides graphic support to the entire staff, and plays an important role in creating and modifying graphics for our publications. Increasingly involved in publication layout and Web design, the group distributes its products in a wide variety of formats, including on the Web.

The Computer and Internet Services group provides technical support, manages the computer network and Web servers, and runs the Geographic Information Systems group. They have recently acquired a site license for ESRI software, allowing them to provide GIS services throughout the bureau and to other departments on campus. They recently installed a new 60-inch plotter and a 50-inch scanner. GIS work has been completed for the Tularosa Mountain (1:100,000) geologic map, and work progresses on the geologic map of the Albuquerque Metropolitan Area. The group has provided support for other projects, including the STATEMAP project and completion of the Geologic Map of New Mexico (1:500,000), due out in 2003.
ENVIRONMENTAL GEOLOGY is the use of geologic principles to predict and evaluate the impact of geologic processes on human endeavors (geologic hazards) and the consequent impact of humans on the environment. Environmental geology considers geologic materials and landforms as resources, evaluating the impacts of mineral exploitation, intensive or specialized land use, and the preservation of areas with scientific, cultural, or scenic values. One aspect of environmental geology is its application to human-related inventory, planning, and site-selection processes for specific uses, such as aggregate quarries, residential or commercial developments, wellhead protection areas, geologic influences on the availability of ground water, and potential environmental impacts of ground water exploitation and aquifer degradation.

Our staff includes scientists with backgrounds in many geologic disciplines, including sedimentology and stratigraphy, engineering geology, hydrogeology, geochemistry, and economic geology. Our goal is to help New Mexico develop its diverse natural resources (from minerals and water to scenic vistas), while minimizing damaging and long-term effects on the environment.

In 2001 the bureau deployed three tiltmeters capable of measuring microradian changes in tilt around the margins of the Socorro magma body, which covers 1300 square miles at a depth of 12 miles beneath Socorro. The area above the Socorro magma body (about 1.6 percent of the state) 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. New Mexico's Department of Public Safety provided matching funds to update the tiltmeter-support electronics, drill shallow wells for the tiltmeters, and install them in secure locations above the magma body. To date the tiltmeters have shown a large amount of microradian tilting, which appears to be related to earth tides, seasonal changes, and surface waves from distant earthquakes. It is still too early to say if the measurements have detected tilting from the uplift above the magma body.
THE BUREAU houses state-of-the-art laboratory facilities that serve the analytical needs of the public and support ongoing research efforts of the entire university community. The chemistry lab, established in the early 1960s, has expanded to meet needs and stay current with new techniques. The facility features flame and graphite furnace atomic absorption, ion chromatography, and flow injection analytical equipment used to determine inorganic water and rock chemistry. With growing concerns about water quality and EPA-mandated state and federal regulations, accurate and precise measurements of a wide variety of trace contaminants (arsenic, lead, fluoride, etc.) and water quality discriminators (TDS, Hardness, Alkalinity) take on heightened importance. Recently the chemistry lab has begun processing samples for a relatively new surface exposure dating method using the $^{36}$Cl isotopic system. This technique allows absolute age determination on (for instance) young (1,000 to 600,000-year-old) lava flows, glacial moraines, and fault scarps.

The X-ray fluorescence (XRF) and X-ray diffraction (XRD) analyses are mainly used to determine the chemical composition of solid materials (including rocks) and identify mineral species, respectively. XRF is a valuable technique as it can analyze a wide range of elements down to low concentrations in almost any solid material. Knowledge of whole rock chemistry helps us to better understand their origin and geological setting. Identifying the mineral components in fine grained rocks has many uses. For instance, rocks in economically important mining districts may be made up of a complex assemblage of very fine-grained clays and alteration minerals. The mineral assemblages define the deposit type and constrain the nature of the mineralizing fluids. Characterizing mineral types has taken on greater recent importance as improved dating techniques allow unusual minerals (jarosite, alunite, and some clays) to be dated directly, thereby helping us understand the age and genesis of economic deposits.

A Cameca SX-100 electron microprobe came online at the bureau in 1996. Unlike bulk chemistry techniques, the electron microprobe is well suited to non-destructive quantitative chemical analysis of very small spots (as small as one micron) on a sample surface. The electron
The electron microprobe can also produce fine-scale chemical maps of polished samples, and three-dimensional, high-magnification Scanning Electron Microscope (SEM) images of rough sample surfaces. Because of the versatility of the technique, electron microprobe analysis is applicable to a wide range of earth and material science research questions.

One major area of research involves chemical fingerprinting of volcanic ashes from New Mexico and Antarctica. Ash beds that can be chemically fingerprinted and identified using the electron microprobe, and dated by the New Mexico Geochronological Research Laboratory, can be used to help determine the age of the sediment or ice in which they are found. This information has been used to help unravel the history of the Rio Grande basin, and to learn about the past behavior and dynamics of the Antarctic ice sheets. Detailed chemical and physical examination with the electron microprobe is also used to assess the quality of volcanic samples for $^{40}$Ar/$^{39}$Ar dating (see below), which has allowed more accurate age determinations for basaltic lavas in New Mexico. The electron microprobe is also used in the investigation of the physical character of faulted rocks, the assessment of mineralized samples, analysis of experimental alloys and ceramic glazes, and imaging and chemical analysis of fly ash from coal-fired power plants, among many other research areas.

The New Mexico Geochronology Research Laboratory, established in 1993, utilizes a variation of the K-Ar ($^{40}$Ar/$^{39}$Ar) dating method to determine highly precise ages for rocks and minerals. Rock ages are important to geologic mapping efforts in helping to correlate mappable rock units, and in determining the timing of folding and/or faulting. Geochronology is also useful for determining the age of rocks intersected during drilling programs, providing critical age ties to help map and correlate rocks in the subsurface. Recent student studies of volcanic terranes in the Raton-Clayton, Taos, and Ocate areas have combined geochronology measurements with analysis of landforms (such as mesas and river channels) in order to understand the climate history of New Mexico. Extensive studies of the very old Precambrian rocks exposed along the Rio Grande rift (including the Manzano, Sandia, and Sangre de Cristo Mountains) are revealing many details of how the southwestern USA landmass was originally formed.

The bureau also continues to offer analytical facilities important to metallurgy and industrial minerals research. The Perlite Lab, established in 1985, is the main perlite testing facility for North America. The lab has a 4" x 40" vertical expansion furnace that is used for basic perlite testing, including perlite density, yield, sinkers, brightness, and others.
The Geologic Information Center responds to hundreds of inquiries each year. Requests originate from geologists exploring for mineral deposits, developers seeking information on geologic hazards, researchers seeking obscure historical data, and state and federal government officials in need of data on a variety of topics and issues, including ground water, radiation hazards, and mineral resources. We can provide copies of maps up to 36” wide on either paper or mylar at cost. Requests for information or library services may be made by phone at 835-5145 or via e-mail at gic@gis.nmt.edu.

New Mexico Library of Subsurface Data

The New Mexico Library of Subsurface Data is an important source of information regarding exploration and development of oil and gas, water, coal, uranium, carbon dioxide, and helium in New Mexico. The data are available to the public and are used regularly by those in industry, academia, federal, and state agencies. The library includes data on:

Well cuttings from 17,000 wells
Cores from over 1,500 wells
Well records for 95,000 wells
Driller's logs for 17,000 wells
Electric and other geophysical logs for 50,000 drill holes
Biostratigraphic data for 150 wells
Sample descriptions and logs for 4,300 wells
Source rock analyses for over 130 wells
Petroleum exploration maps from 26 counties.

Facilities are available for onsite study of cuttings; both microscopes and work tables are provided for visitors. Photocopies of records including maps and well logs are available at a nominal cost.
The core library serves as a repository for rock cores from throughout New Mexico. Cores are made available to researchers onsite and may be sampled for research and analysis. Occupying seven warehouses on campus, the library includes over 1,500 cores that have been donated by over 150 companies and organizations. Three of the core buildings are devoted to archiving representative cores from oil and gas reservoirs in New Mexico; another building is devoted to cores from water wells and geothermal energy exploration wells. Two of the buildings were constructed in the last three years through funds from private-sector donations.

**National Coal Resource Data System (NCRDS)**

Coal has been mined in New Mexico since the 1880s. Information compiled on these mines is now part of a computerized database. Files include information on coal depth and thickness, chemical analyses of locatable coals, and a limited number of petrographic analyses. Information may be used for resource estimates of coal fields and coal-bearing formations in New Mexico. Includes an annotated bibliography of New Mexico references on coal.

**Mining Archives**

These archives include mineral data, maps, photos, and reports pertaining to mining in New Mexico. The photo archives include over 5,000 historic images, mostly associated with mining in New Mexico but including other images from New Mexico, as well. The archives are maintained by bureau staff under the auspices of the Mineral Museum and are available for examination by the public.

**National Uranium Resource Evaluation (NURE) Database and Collections**

This computerized database includes data on more than 1,500 uranium mines, prospects, occurrences, and mills in the state. Data were assembled from reconnaissance surveys as part of the NURE program (1974-1984), whose purpose was to provide an assessment of the nation’s uranium resources and to identify areas favorable for uranium mineralization. The database includes maps and open-file reports, geochemical and geophysical surveys, quadrangle assessments for uranium resources in New Mexico, and miscellaneous geologic investigations.

**Coal Library**

We maintain a coal library that includes geophysical logs, chemical analyses, maps, and reports from coal exploration projects in New Mexico. For more than 19 years the bureau has collected coal data, including more than 3,500 logs, for various studies. Much of this collection is from the San Juan Basin, in northwest New Mexico, but data are also available from other coal fields, including the Salt Lake, Sierra Blanca, Rio Puerco, Cerrillos, and Raton fields. Log data are available for searching in a computerized database.

Research often results in compilations of data that are shared with industry and the public in the form of digital databases. These are particularly useful to resource exploration companies and consultants. The bureau has been involved in the compilation of the following databases:

- *The New Mexico Petroleum Source Rock Database*, compiled in conjunction with the Oil Conservation Division of New Mexico’s Energy, Minerals, and Natural Resources Department (available on CD ROM)
- *New Mexico Oil and Gas Pool Maps, with Additional Emphasis on the Morrow Play and Geographic Information System Well Location Database*, compiled in conjunction with the Petroleum Recovery Research Center and the Petroleum Technology Transfer Council
- *Play Analysis and Digital Portfolio of Major Oil Reserves in Southeast New Mexico*, funded by the U.S. Department of Energy and carried out in conjunction with the Texas Bureau of Economic Geology
In 2001 the bureau embarked upon the first of a series of conferences designed to educate decision makers on important geologic issues throughout the state. Designed to present New Mexico decision makers with the opportunity to learn first-hand about current opportunities, problems, and solutions from top scientific and policy experts, these conferences offer a chance to visit sites that are the focus of legislative concerns and to hear balanced scientific presentations. The conferences are run by the bureau in cooperation with other state, federal, and local governmental agencies. They bring together a mix of state, tribal, federal, and local political leaders; state agency directors and cabinet secretaries; and influential citizens (journalists, environmental leaders, teachers, business officials) to examine a wide range of issues related to geology, hydrology, natural resources, geologic hazards, and the environment, in a hands-on, field-oriented setting.

In May 2001 the first field conference, titled Water, Watersheds, and Land Use in New Mexico, was held in the Santa Fe region. The 2002 conference to the San Juan Basin focused on New Mexico’s Energy, Present and Future, with a look at both conventional and renewable/alternative energy resources throughout the state. In 2003 invitees will visit the Pecos River drainage for a look at some of the most significant water issues in New Mexico.

These conferences are accomplished through the dedication and cooperation of the entire staff.
K-12 Outreach

Rockin’ Around New Mexico, our annual summer workshop for teachers, draws three to four dozen participants from around the state. Located in a different area of New Mexico each year, these conferences share the common goal of supporting earth science education. Sponsored and run by the bureau, the conferences are supported by a consortium of state agencies and private industry. Funding has been provided by the New Mexico Earthquake Program, administered through the New Mexico Department of Public Safety acting through the Office of Emergency Services and Security, as well as BHP Billiton and Phelps Dodge. During the 3-day workshops, teachers learn about rocks and minerals, earthquakes and faults, volcanoes, mining, maps, fossils, and more. Each year teachers who attend receive teaching tools, curricula, and other resource materials to bring these lessons back to the classrooms. Recent workshops included:

Grants, New Mexico, in 2000, with field trips to the Lee Ranch coal mine, El Malpais lava flows, Ice Caves, and Bandera Crater.

Socorro, New Mexico, on the campus of New Mexico Tech. The 2001 workshop received the Award in Excellence for Outreach to Schools from the Western States Seismic Policy Council.

Farmington, New Mexico, in 2002, with field trips to Ship Rock, New Mexico, and Silverton, Colorado.

In 2001 the bureau hosted for the first time a reception for sponsors, teachers, and parents at the New Mexico State Science and Engineering Fair. Three lively bureau speakers entertained the audience with talks about their research, under the theme "Excellent Adventures in Research at New Mexico Tech." Topics included rafting for data in the Grand Canyon (Dr. Matt Heizler), photographing eruptions of Mt. Erebus in Antarctica (Dr. Nelia Dubar), and magnificent minerals in the Hansonburg mining district (Dr. Virgil Lueth). This has become an annual event.

In celebration of National Earth Science Week (the second full week in October), the bureau promotes earth science at several teacher and public events each fall. These include the New Mexico Science Teachers Association and the Environmental Education Association of New Mexico fall conferences, along with open house events at the New Mexico Museum of Natural History and Science.

K-12 Outreach
Susan J. Welch, Manager, Geologic Extension Service

El Malpais, Rockin’ Around New Mexico 2000.
MINERAL MUSEUM

Located on the campus of New Mexico Tech in Socorro, the Mineral Museum has been welcoming visitors for over 100 years. Currently housed in the Workman Addition, the museum boasts a large reference and research collection from around the world, with a focus on the minerals of New Mexico and the Southwest. Over 2,000 mineral specimens are on display in the main hall. The museum collection has been enhanced over the years through generous contributions from private donors.

Each fall the museum hosts the New Mexico Mineral Symposium on the campus of New Mexico Tech. It consists of a day and a half of talks, a banquet, keynote speech, and silent auction. Symposium attendance has grown over 50% over the last five years. The 2001 symposium (the twenty-second) was attended by 166 people from all over the nation.

The museum hosted over 40 special tours and was represented at nine traveling exhibitions, including the two largest mineral shows in the U.S. (Denver and Tucson). Museum staff also provided over a dozen educational programs to adult groups both on campus and around the state, including programs for the Festival of the Cranes, Socorro Rockhounding Days, and many on-campus events (Science Fair, Olympiad, Orientation, Exploration Day, etc.). The museum continues to host the “Rock and Mineral” competition for the New Mexico Science Olympiad.

For more information visit the museum Web site at http://geoinfo.nmt.edu/education/museum.
The Publishing Program

The New Mexico Bureau of Geology and Mineral Resources has a long and distinguished publishing history. For all of our 75 years we have produced professional monographs, maps, circulars, and other publications. We have expanded the scope of that program in recent years, producing publications with a broader appeal. And we have embraced the technological opportunities available to us. Many reprints of older publications are now available on CD ROM, and we continue to explore publishing on the Web. Many of our maps and other publications are available online or as open-file reports on CD ROM.

Our Scenic Trip series made its debut in 1953. These books, with their regional, field-oriented approach to New Mexico geology, have long been our best-selling and most popular titles. We are redesigning the series and giving it a fresh look. The first in the revised series, a guide to the Albuquerque area, by Paul Bauer, Richard Lozinsky, and Carol Condie, will be out in 2003. We anticipate new Scenic Trips to the High Plains of northeastern New Mexico, Cimarron Country, and elsewhere.

Working in cooperation with the National Park Service, New Mexico State Parks, and other land-management agencies, we plan to produce two volumes on the geology of New Mexico's parks, monuments, and public lands. Written for a general audience and produced in full color, these books will serve as popular and authoritative guides to the most significant geologic landscapes in New Mexico.

We currently publish three periodicals. New Mexico Geology is published quarterly (available by subscription), and Lite Geology twice a year (fall and spring; available gratis to New Mexico educators). Earth Matters is published twice a year and is available free, upon request. After many years of work by many people, our new state geologic map of New Mexico (1:500,000) will be out in 2003. The final work has been done in close cooperation with (and with financial support from) the U. S. Geological Survey. All of this work is accomplished through the dedicated efforts of our publishing staff and with the support of the entire bureau. A complete list of our publications may be viewed at our Web site (geoinfo.nmt.edu).

Our most recent publications include:
Late Pennsylvanian and Earliest Permian Fusulinid Biostratigraphy, Robledo Mountains and Adjacent Ranges, South-central New Mexico by Gregory P. Wahlman and William E. King, Circular 208.
Minerals of New Mexico poster, produced in cooperation with the Mining and Minerals Division of New Mexico’s Energy, Minerals, and Natural Resources Department.
Satellite Image of New Mexico, Resource Map 23 (1:500,000).
Silver and Gold in New Mexico by V. T. McLemore, Resource Map 21 (1:1,000,000).
Mines, Mills, and Quarries in New Mexico 2001, produced in cooperation with the Mining and Minerals Division of New Mexico’s Energy, Minerals and Natural Resources Department, and the New Mexico Bureau of Mines Inspection.

Coming soon:
State Geologic Map of New Mexico, 1:500,000
Geology of the Caballo Mountains, New Mexico by William R. Seager and Greg H. Mack.
Tectonics, Geochronology, and Volcanism in the Southern Rocky Mountains and Rio Grande Rift, edited by Steven M. Cather, William C. McIntosh, and Shari A. Kelley.

SCENIC TRIP SERIES • NUMBER SEVENTEEN
A Guide to Its Geology and Culture
ALBUQUERQUE
NEW MEXICO BUREAU OF GEOLOGY & MINERAL RESOURCES
Most of our funding comes from state appropriations, supplemented by grants from a variety of sources (listed below) and income from publication sales. Figures shown are for the period from July 1, 2000 to June 30, 2001 (our FY 2000).

FINANCIALS
FY2000

Revenue
Exclusive of Grants and Contracts

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Appropriation</td>
<td>$3,467,600</td>
<td>97%</td>
</tr>
<tr>
<td>Carryover from Previous Year</td>
<td>$47,751</td>
<td>1%</td>
</tr>
<tr>
<td>Publication Sales</td>
<td>$43,685</td>
<td>1%</td>
</tr>
<tr>
<td>Other</td>
<td>$14,668</td>
<td>1%</td>
</tr>
</tbody>
</table>

Expenditures

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staff (salaries &amp; benefits)</td>
<td>$2,530,140</td>
<td>71%</td>
</tr>
<tr>
<td>Operating Expenses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed</td>
<td>$341,562</td>
<td>10%</td>
</tr>
<tr>
<td>Variable</td>
<td>$354,830</td>
<td>10%</td>
</tr>
<tr>
<td>Overhead to Tech</td>
<td>$232,000</td>
<td>7%</td>
</tr>
<tr>
<td>Students</td>
<td>$80,809</td>
<td>2%</td>
</tr>
</tbody>
</table>

Grants and Contracts

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grants and Contracts from outside sources</td>
<td>$389,198</td>
<td>83%</td>
</tr>
<tr>
<td>Overhead to Tech</td>
<td>$76,986</td>
<td>17%</td>
</tr>
</tbody>
</table>

Additional grant funding for 2000-2001 came to us from:

National Science Foundation
U. S. Geological Survey
National Aeronautics and Space Administration
U. S. Department of Justice
U. S. Department of Energy
U. S. Bureau of Land Management
New Mexico Department of Public Safety
New Mexico Office of the State Engineer/Interstate Stream Commission
New Mexico State Land Office
U. S. Bureau of Reclamation
The McCune Charitable Foundation
In partnership with New Mexico Tech: Teaching, Advising, Collaborative Research

Since our establishment in 1927, our primary partner has been New Mexico Institute of Mining and Technology. Most of our scientific staff actively teach, serve on graduate committees, and provide guidance for ongoing student research. Two of our professional staff hold joint appointments with the Earth and Environmental Sciences Department of New Mexico Tech. We are also involved in collaborative efforts with the Petroleum Recovery Research Center on campus.

Our laboratory facilities work in close collaboration with New Mexico Tech, supporting the research efforts of faculty and students. Grant funding, which provides substantial support for research at the bureau, comes to us through the university, and a portion of all grant funds goes to the university for overhead.

Many bureau staff members participate in New Mexico Tech’s annual Science Olympiad, as event coordinators and in other capacities. Brian Brister, Nelia Dunbar, Richard Esser, Gretchen Hoffman, Dave Love, Virgil Lueth, Lisa Peters, and Dana Ulmer-Scholle have all participated in recent years. Bureau staff are also involved in the annual New Mexico Science and Engineering Fair at New Mexico Tech. Nancy Gilson has served as judge coordinator for the past six years, and many bureau staff members judge in various categories.

Details on the activities of our staff may be found in their individual staff pages on our Web site at http://geoinfo.nmt.edu/.

Bureau Staff Awards 2000-2002

The Interstate Oil and Gas Compact Commission’s Best Practice Award for the 2002 Decision-Makers Field Conference.

The New Mexico Environmental Law Center’s Karl Souder Water Protection Award to Peggy Johnson.

The AAPG/Southwest Section’s A. L. Cox Award for best poster presentation to William D. Raatz.

The John C. Frye Memorial Award in Environmental Geology to Peggy Johnson, presented jointly by the Geological Society of America and the Association of American State Geologists.

The AAPG/Southwest Section’s Monroe G. Cheney Award for singular contributions to the science of petroleum geology to Ron Broadhead.

The AAPG/Southwest Section’s A.I. Leversen Memorial Award for best presentation to Ron Broadhead.


The Geological Society of America’s Roy Shlemon Distinguished Mentor Award to Sean Connell.

The Western States Seismic Policy Council’s Award for Excellence in Outreach to Schools to David Love and Susie Welch for Rockin’ Around New Mexico.

On the Front Lines

In the Director’s Office
Loretta Tobin, Executive Secretary

In the Publication Sales Office
Linda Ulricht, Administrative Secretary
Theresa Lopez, Administrative Secretary
Susie Kyle, Administrative Secretary

In the Business Office
Judy M. Vaiza, Assistant Director for Finance
Debbie Goering, Business Office Coordinator

In Albuquerque
Rita Case, Administrative Secretary

General Services
Ruben A. Crespin, Manager, Fleet/General Services
Albert Baca, Lead Maintenance Carpenter
Gregory Sanchez, Mechanic – Carpenter Helper
Manuel J. Vasquez, Mechanic

The Lyndon B. Johnson Space Center Group Achievement Award, in recognition of outstanding contributions toward Astronaut Candidate Training in Earth Science, from the National Aeronautics and Space Administration.

The American Institute of Professional Geologists’ Appreciation Award to Virginia McLemore.

The New Mexico Science Teachers Association Award for Service to Science in the State of New Mexico to Susie Welch.

New Mexico Geological Society’s Honorary Member Award to James M. Barker (2000) and Gretchen K. Hoffman (2002)

The 2003 Hal Williams Hardinge Award (from SME’s Industrial Minerals Division) to James M. Barker.
Bureau publications are available for sale through our Publication Sales office on the campus of New Mexico Tech. Purchase in person, by phone or mail, or online at geoinfo.nmt.edu. The office is open Monday-Friday, 8 a.m. to noon and 1 p.m. to 5 p.m. Phone orders may be placed at (505) 835-5420. A complete catalog of our publications is available online at our Web site.

High-resolution maps and cross sections are available for downloading from our Web site.

Details of current research are available on our staff Web pages.


Compilation and Editing: L. Greer Price, Jane C. Love

Design and Production: Carol Haralson

Graphics and Cartography: Bureau Staff

Photos: William Stone: cover, 16-17 (top), 19; Adam Read: 1, 8; New Mexico Tech photos by Steve Woit: 4, 12, 14, 15, 20; Virginia McLemore: 7, 11; Greer Price: 2, 3; Nelia Dunbar: 10.
COMING SOON: State Geologic Map of New Mexico (1:500,000). Published by the New Mexico Bureau of Geology and Mineral Resources, in cooperation with the U. S. Geological Survey.

AVAILABLE FROM OUR PUBLICATIONS OFFICE IN SPRING 2003.
FORMERLY KNOWN AS the New Mexico Bureau of Mines and Mineral Resources, we continue:

To conduct research and interact with state, local, and federal agencies and industry to facilitate prudent exploitation of the state’s geologic resources

To distribute accurate information to scientists, decision makers, and the New Mexico public regarding the state’s geologic infrastructure, mineral and energy resources, and geohydrology (including water quantity and quality)

To provide timely information on potential geologic hazards, including earthquakes, volcanic events, soils- and subsidence-related problems, and flooding

To create accurate, up-to-date (digital and GIS-based) maps of the state’s geology and resource potential

To act as a repository for cores, well cuttings, and a wide variety of geological data. To provide convenient physical and internet access for New Mexicans to such resources

To provide public education and outreach through college teaching and advising, the Mineral Museum, and teacher- and student-training programs.

In Socorro
801 Leroy Place
Socorro, NM 87801
505.835.5420

In Albuquerque
2808 Central Avenue SE
Albuquerque, NM 87106
505.366.2530

In Carlsbad
c/o Carlsbad Environmental Monitoring and Research Center
1400 University Drive
Carlsbad, NM 88220
505.234.5560