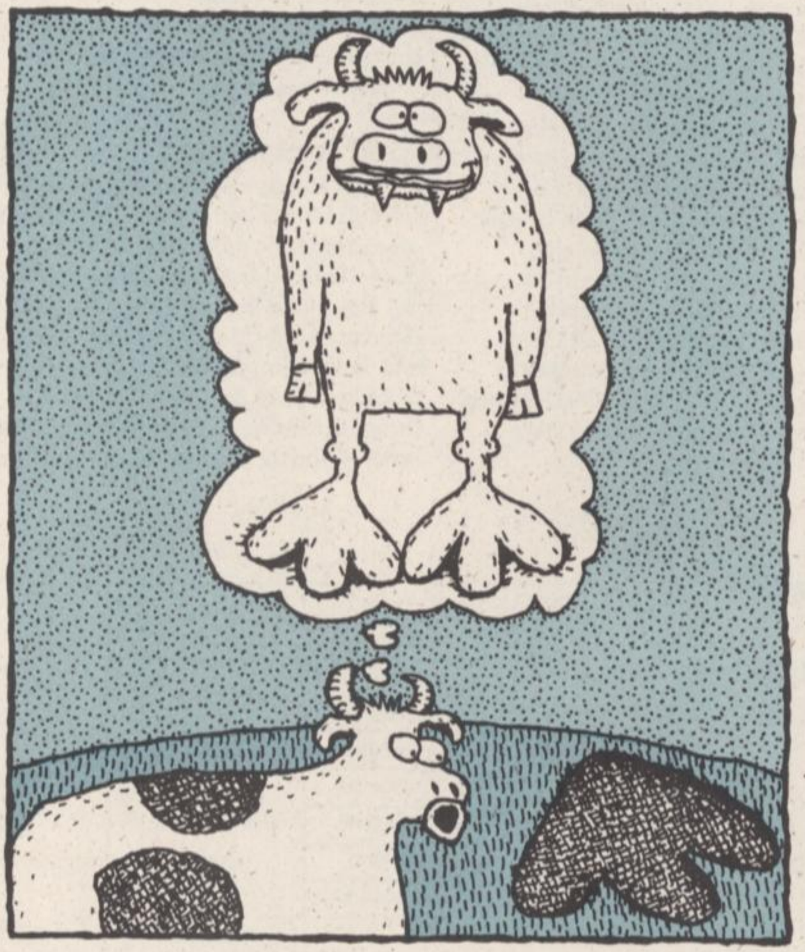
LITE geology

A quarterly publication for educators and the public–
contemporary geological topics, issues and events



Daisy could not believe her eyes, yet she knew these only could be the tracks of the legendary *Cowasaurus*.

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New Mexico Bureau of Mines and Mineral Resources (NMBM&MR)

Earth Briefs

Triassic Tracks Trigger Dig on Prison Grounds

An ordinary day turned eventful for prison inmate Wayne Covington when he unearthed a section of the largest dinosaur trackway ever discovered in Pennsylvania. The trackway is located on the grounds of Graterford Prison, outside of Philadelphia. The inmate, employed by the facility's dairy farm, had just finished his rounds checking cow fences when he took a shortcut through a ravine. As he passed by a shale outcropping along the ravine wall, he struck it with his fence-mending hammer and the rock split open, revealing a perfect, three-toed footprint of a 220-million-year-old dinosaur.

The fossilized footprint **(ichnite)** trackway was examined by Dr. Robert Sullivan, Curator of Paleontology and Geology at the State Museum of Pennsylvania, who determined the creature might be *Coelophysis*, a small, sharp-toothed, meat-eating dinosaur that walked on its hind legs. A trackway of this size can contain enough footprints to allow paleontologists to study how the dinosaurs moved through the area and learn something about their behavior.

Dr. Sullivan and other staff from the State Museum, along with Bill Kochanov, a geologist from the Pennsylvania Geological Survey, joined several of the prison staff members and inmates in excavating large pieces of the trackway for removal to Harrisburg, where the ichnites will be studied and exhibited. Prison officials have supported the inmates' participation in the dig, saying that the men "feel they are making a contribution to society by discovering these prints and sharing them with others."

Sources:

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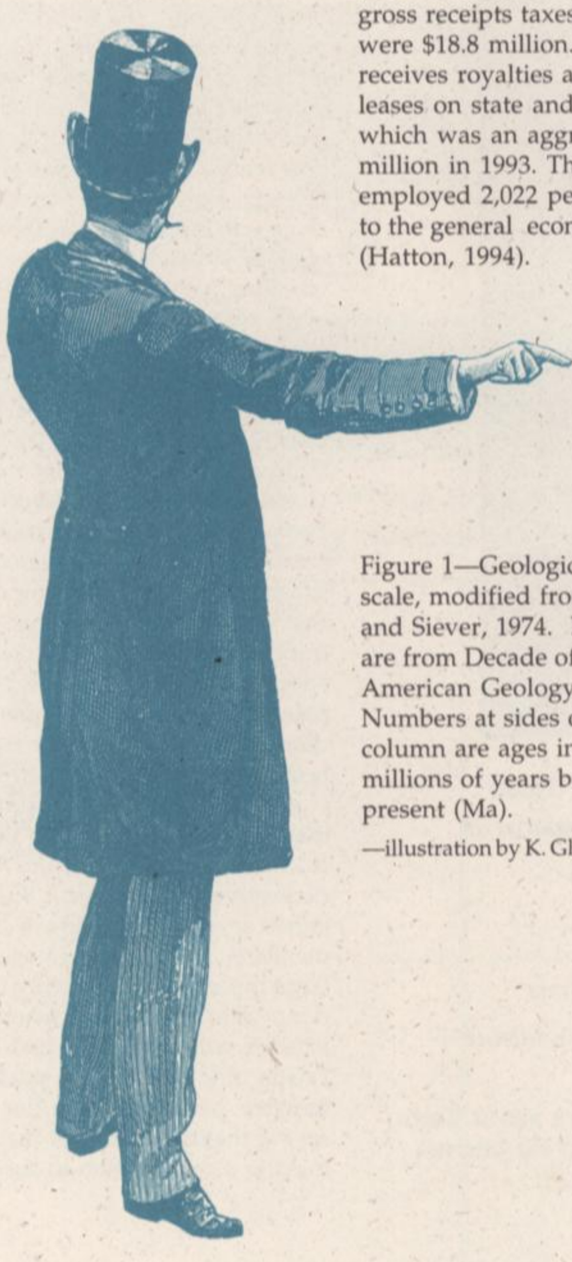
—story by S. Welch



Have You Ever Wondered...

... About Coal?

Gretchen Hoffman
Senior Coal Geologist, NMBM&MR

Introduction

Coal makes an important contribution to New Mexico's state budget. It is the third largest source of revenues in the state from mineral and energy production. In 1993, state revenues from **severance, resources excise, and conservation** taxes were $34.7 million. State revenues from gross receipts taxes on the sale of coal were $18.8 million. The state also receives royalties and rentals from coal leases on state and federal lands, which was an aggregate of $11.8 million in 1993. The coal industry employed 2,022 people in 1993, adding to the general economy of the state (Hatton, 1994).

Coal-bearing rocks cover one-fifth of New Mexico, but most New Mexicans have little direct contact with coal or the coal industry. The following explores the nature of coal. **Boldface terms are defined in the glossary beginning on page 9**. In the next issue of *Lite Geology* we will explore coal production and uses, and how it is mined today.

Coal formation

Coal is a readily combustible rock formed by the compaction of decaying plant material deposited in ancient **peat swamps** or **bogs**. Pressure from the weight of the overlying sediments, deposited over time by rivers, lakes, and seas, compresses the peat. Compaction of the plant material forces out some oxygen, hydrogen, and other **volatile matter**, leaving carbon.

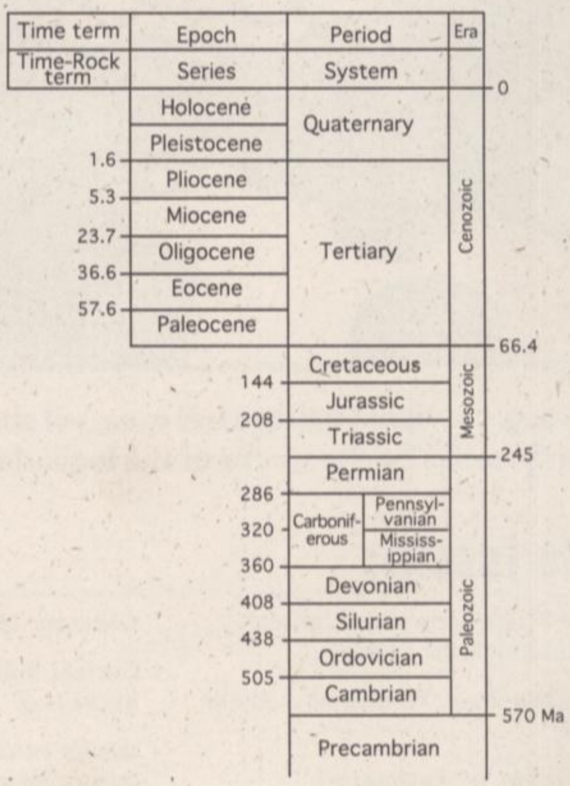


Figure 1—Geologic time scale, modified from Press and Siever, 1974. Dates are from Decade of North American Geology, 1983. Numbers at sides of column are ages in millions of years before present (Ma).

—illustration by K. Glesener

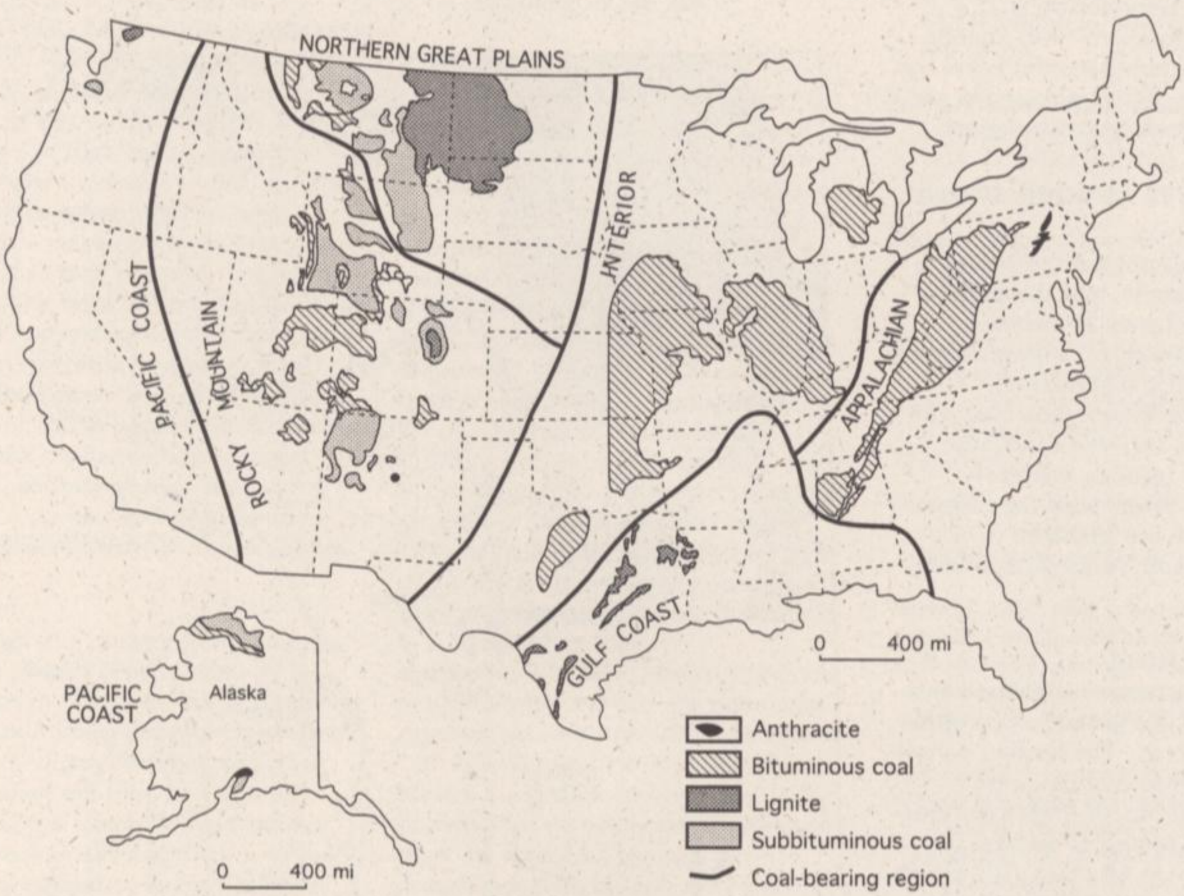


Figure 2—Coal-bearing areas of the United States. Modified from Energy Information Administration, December, 1994.
—illustration by K. Glesener

It takes 15 to 20 feet of peat to make 1 foot of coal. Heat, from nearby **igneous activity** or from the regional **geothermal gradient**, along with time are the most effective elements in transforming lignite or subbituminous coal to bituminous coal or anthracite.

Land plants evolved on the Earth during the Devonian Period (Fig. 1) about 400 million years ago (Ma) but plant cover was not abundant enough until 320 Ma (Pennsylvanian Period) to form peat swamps that would later become coal. Although coal deposits are found from most geologic time periods since 320 Ma, there are two major coal-forming ages throughout the world. Pennsylvanian–Permian coal deposits (320–245 Ma) make up most of the **anthracites** and high grade **bituminous coals.** Eastern coal fields in the Appalachian and in the Interior provinces are Pennsylvanian and Permian in age (Fig. 2). The second major coal-forming age, with deposits on every major continent, belongs to the Cretaceous and Tertiary periods. These coals range in **rank** from **lignite** to **anthracite**. In the United States, coals in the Rocky Mountains, Northern Great Plains, and the Gulf Coast regions (Fig. 2) are Late Cretaceous to Tertiary (95–2 Ma) in age.

United States coal reserves

Coal makes up 82% of the United States **recoverable energy reserves;** this nation's reserves represent 26% of the world's total coal (Maksimovic and Mowrey, 1993). Coal reserves and production are reported in short tons, equal to 2,000 pounds, referred to as tons in this article. The Department of Energy's (DOE) **Demonstrated Reserve Base** (DRB) for the United States is 483.8 billion tons (Energy Information Administration, February 1993; Hoffman, 1994). Of the total reserve base, 264.6 billion tons are considered recoverable with present mining techniques. Montana ranks first with demonstrated reserves of 119.92 billion tons. New Mexico's demonstrated reserve base is 12.6 billion tons (Hoffman, 1994; Energy Information Administration; February 1993, Pillmore, 1991), ranking ten out of twenty-six in state coal reserves.

Coal reserves ranking system

Lignite coal

Lignite coals in North Dakota, Montana, Colorado, and the Gulf Coast region (Texas, Louisiana, Arkansas, Mississippi, Alabama) make up 9% of the U.S. coal reserves. Lignites are the lowest rank coal with heating values between 6,300 and 8,300 **Btu/lb** (**moist, mineral-matter-free**). States with the largest lignite reserves are Montana (15.7 million tons) and Texas (13.3 million tons).

Subbituminous coal

Most of the nation's **subbituminous** reserves (37%) are in states west of the Mississippi River. The heating values of subbituminous coal range from 8,300 to 11,500 Btu/lb (moist, mineral-matter-free). The largest reserves of these coals are in Montana (102 billion tons) and Wyoming (62 billion tons; Energy Information Administration, February, 1993). Most of New Mexico's San Juan Basin coal reserves and those in smaller coal fields (9.3 billion tons) are subbituminous in rank (Fig. 3). Electrical generation is the primary use of the lignite and subbituminous coals.

Bituminous coal

Bituminous coal is the most common rank in the United States, particularly in the older, eastern coal fields, comprising 52% of the nation's total coal reserves. High volatile bituminous coal heating values range from 11,500 to 14,000 Btu/lb (moist, mineral-matter-free). Medium and low volatile bituminous coals are classified according to their **fixed carbon** content, ranging from 69 to 86%.

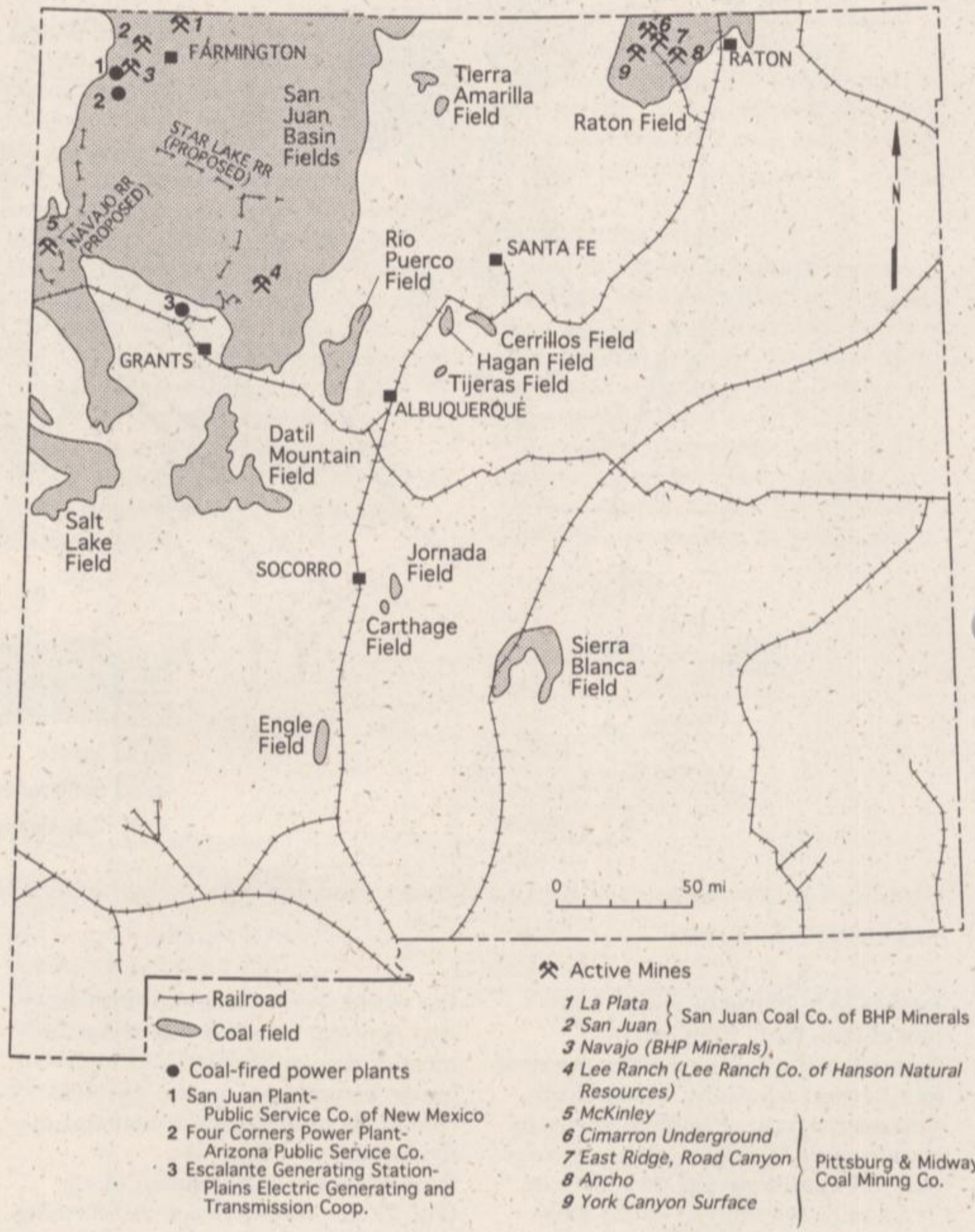


Figure 3—Map of coal mines and major coal fields in New Mexico. Modified from New Mexico Energy, Minerals, and Natural Resources Department, 1994.

—illustration by K. Glesener

Illinois has the largest bituminous reserves (78.1 billion tons) in the nation. The Raton coal field in northeast New Mexico has significant reserves (1.3 billion tons) of high volatile bituminous coal, the lowest division of this rank. Coal beds in the northern San Juan Basin, along the New Mexico-Colorado border, are also high-volatile bituminous in rank. These coals make up two billion tons of the state's total reserves. The high rank of these beds is a product of depth of burial and heat generated from the San Juan **volcanic complex**, north of the basin. Primary uses of bituminous coal are electrical generation and most of the **coke** production for the steel industry. Industrial and commercial uses are a smaller part of bituminous coal consumption in the United States.

Anthracite

Most of this country's anthracite is in north-central Pennsylvania (7.2 billion tons). This area has undergone significant folding and faulting during a major mountain-building period in the Paleozoic era (Fig. 1). Virginia, Arkansas, and Colorado have minor anthracite deposits and there is a small reserve of anthracite in New Mexico, near Madrid, south of Santa Fe. Here, **igneous sills** came in contact with one or two of the coal beds and raised the rank of the coal from bituminous to semianthracite and anthracite. Other coal beds that were farther from the igneous intrusion are lower ranking, bituminous coals.

Quality of U.S. coal

The DOE divides the U.S. coal reserves by heat (million Btu/tons) and sulfur content (lbs of sulfur/million Btu). There are 168.5 billion tons of low-sulfur coal in the United States. Most (83%) of this low-sulfur coal, defined as containing less than 0.6 lb of sulfur/million Btu, is in the western coal fields. Burning low-sulfur coal emits 1.2 pounds of sulfur dioxide or less for every million Btu produced. This assumes total conversion of the sulfur to sulfur dioxide (SO_2) with none remaining in the **ash**.

Clean air act

Sulfur dioxide emissions are of concern because they are considered the major cause of acid rain. The level of emissions with low-sulfur coal meets the 1971 Clean Air Act New Source Performance Standards for power plants without scrubbers (Energy Information Administration, February 1993). The 1990 Clear Air Act revisions require SO_2 emissions from existing large power plants to be no greater than 2.5 lb SO_2/million Btu by 1995. Emissions must be lowered to 1.2 lb SO_2/million Btu by the year 2000 for all generating units that existed before 1990. Several options are allowed under the act to bring the power plants into compliance, including switching to a lower sulfur fuel.

One third of New Mexico's reserves are low-sulfur coal and the remaining reserves are medium-sulfur coal (0.6 to 1.67 lb sulfur/million Btu). New Mexico low-sulfur coal has the potential for export to eastern states to meet the need for Clean Air Act compliance coal. In 1990, the New Mexico Legislature reduced the severance surtax on new coal contracts enabling Pittsburg and Midway to secure a 15-year contract with Wisconsin Electric Power Company, beginning in 1993. To help meet state and federal emission standards, two million tons per year of low-sulfur coal will be transported from the Raton Basin to Wisconsin via the Atchison, Topeka and Santa Fe Railroad. Although this contract shows New Mexico can compete in the low-sulfur coal market, the main rival for this market is Wyoming coal because of the lower cost and better transportation network. Blending or cleaning the medium-sulfur coal in New Mexico could reduce the sulfur content to meet emission standards.

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Glossary begins on page 9.

The Origin of Enchanting Landscapes

New Mexico's active geologic history has shaped its terrain into the enchanting scenery that New Mexicans and visitors treasure. Here are photos of New Mexico landscapes along with descriptions (see page 8) of the local geology. How many do you recognize?

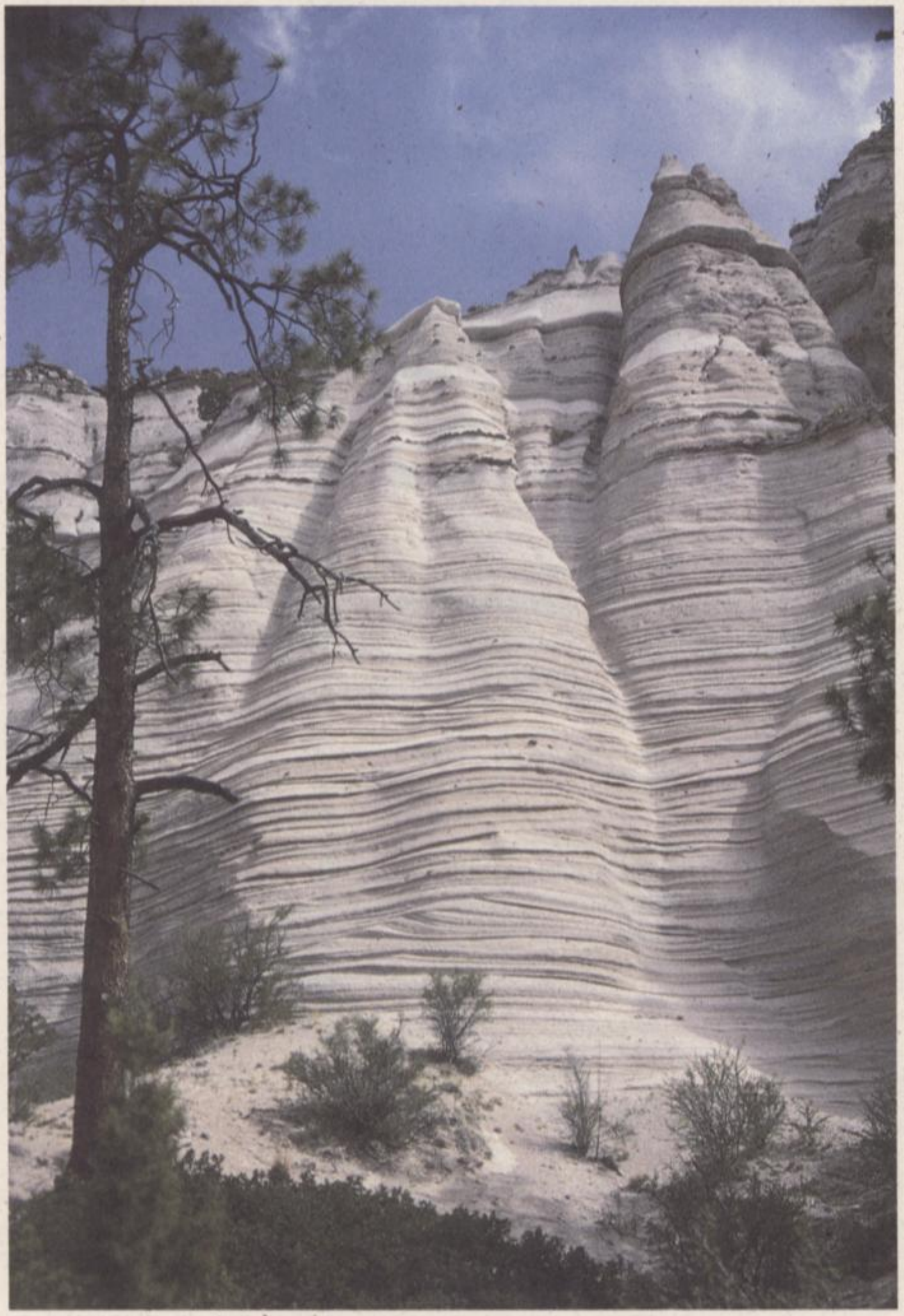


Photo A

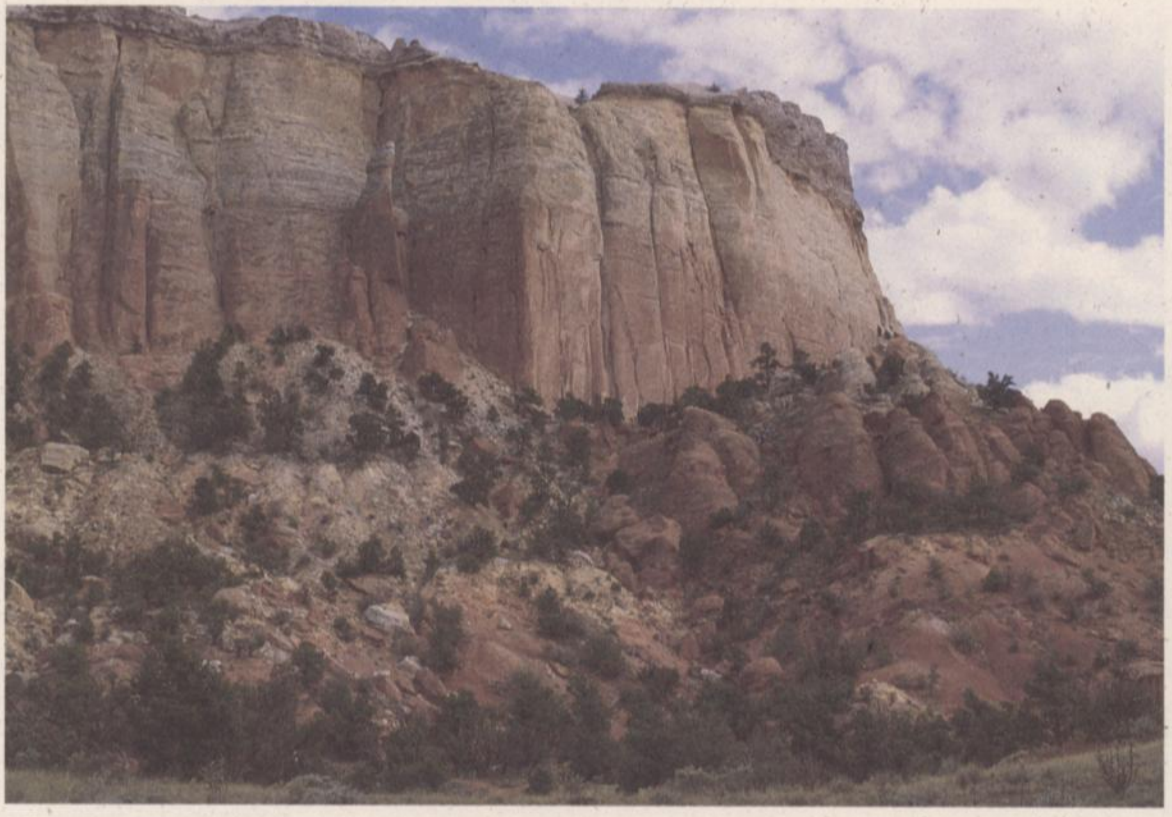


Photo B

Photo C

Photo A— **Tent Rocks** is a truly magical area! Delicately layered gravels and volcanic ashes of the Peralta Tuff Member of the Bearhead Rhyolite have been eroded into interesting shapes, including spires with a balanced rock at the top. The deposits are about 6.8 million years old and were shed off volcanic domes of the Jemez volcanic field. Designated the "Tent Rock Area of Critical Concern" by the Bureau of Land Management, this scenic area is located about 5 miles northwest of Cochiti Pueblo in Sandoval County.

Photo and description by Charles Chapin, NMBM&MR.

Photo B— Mesozoic sedimentary rocks provide much of the beauty, mystique, and charm of north-central New Mexico. This cliff scene near **Ghost Ranch**, is the result of hundreds of thousands of years of erosion along the Chama River valley. Here a tributary of the Chama, Canjilon Creek, has carved into the Entrada Sandstone (Jurassic age) to expose its subtle colors in a near-vertical cliff. The slightly darker, grayish edge capping the cliff is formed by the Todilto Formation. The Todilto is composed of limestone ($CaCO_3$) and Gypsum ($CaSO_4{\cdot}2H_2O$) precipitated from a salina lake associated with the southern margin of an inland seaway during Middle Jurassic time.

The talus at the base of the cliff conceals much of the fine-grained rock of the Chinle Group, which underlies the Entrada Sandstone. The upper part of the Chinle, known as the Rock Point Formation, contains fossils of land vertebrates, the most famous one being New Mexico's state fossil, the dinosaur *Rioarribasaurus colberti* (formerly known as *Coelophysis*).

Photo by Jan Thomas; description by Orin Anderson, NMBM&MR.

Photo C— Morning sun illuminates a four-tiered landscape west of **Bosque Del Apache National Wildlife Refuge**, about 15 miles south of Socorro, New Mexico. On the lowest tier, salt cedar and cottonwoods in fall colors rise from Rio Grande floodplain deposits that are less than 10,000 years old (Holocene age). These alluvial deposits bury still older sediments that fill a broad channel cut by the ancestral river during the last ice age (Late Pleistocene—15,000 to 25,000 years ago). This inner-valley fill is, in turn, inset against older river-channel and alluvial-fan deposits of middle Pleistocene to Pliocene age (0.15–5 million years old).

The top of the second lowest tier, above the bluffs, represents a time when the alluvial basin floor was approximately 300 feet above this camera station. The alluvial basin south of Socorro outlines the depressed half of an east-tilted fault block (half-graben) that formed during a late stage of crustal extension along the Rio Grande rift.

The uplifted halves of east-tilted blocks form the crest of the Chupadera Mountains in the middle skyline (tier three) and the Magdalena Mountains on the distant skyline (tier four). These tilted-fault-block ranges and more strongly tilted fault blocks *within* the ranges provide evidence that the Earth's crust has been extended (stretched toward the west) about 50 percent in the last 28 million years. In other words, the 50-mile-wide north-trending zone of crustal extension near Socorro known as the central Rio Grande rift was only about 30–35 miles wide when it started to pull apart 28 million years ago.

The Magdalena and Chupadera range blocks are superimposed on giant volcanic collapse structures (calderas) that formed 29–32 million years ago, in Oligocene time. Several hundred cubic miles of red hot ash and crystals flowed out across the ancient land surface as these enormous volcanoes sank into the underlying magma chambers that were as much as 12 miles across.

Photo by Dave Love, NMMB&MR; description by Richard Chamberlin, NMBM&MR.

Glossary of Coal Terms

Agglomerate—Collected into a ball or mass; agglomeration.

Anthracite—A rank class of coals defined as having more than 86 percent *fixed carbon* and less than 14 percent *volatile matter* on a *dry, mineral-matter-free basis*. This rank is divided into semianthracite, anthracite, and meta–anthracite groups on the basis of increasing *fixed carbon* and *decreasing volatile matter*.

Ash—The inorganic residue remaining after complete incineration of coal.

Bog—Similar to *peat swamps* but generally lacking trees.

Bituminous coal—A rank class of coals defined by the ASTM (see rank) as having less than 86 percent *fixed carbon*, and more than 14 percent *volatile matter* and more than 10,500 *Btu/lb* on a *moist, mineral-matter-free basis*. An overlap of bituminous and subbituminous heat values from 10,500 to 11,500 *Btu/lb* is dependent on whether an *agglomerate* button with swelling characteristics is formed during *volatile matter* analyses. There are several divisions of bituminous coal. High–volatile C, B, and A are divided by increasing heat value. Medium and low-volatile bituminous coals are classified on the basis of increasing *fixed carbon* and decreasing *volatile matter*.

Btu—Btu is British thermal units. The Btu is the amount of heat needed to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Coal reserves—Parts of the in-place demonstrated resource that could be economically extracted at the time of determination considering environmental, legal, and technological constraints.

Coal resources—Deposits occurring in such forms and amounts that economic extraction is potentially feasible.

Coke—Material derived from heating *bituminous coal* in the absence of air and driving off the volatile constituents, so that the fixed carbon and ash are fused together.

Conservation tax—Tax (0.18%) on sales value less Federal, State, and Indian royalties. Revenues from this tax go into the state's general fund.

Demonstrated reserve base—A term used by the Department of Energy for the part of the coal in the ground (coal resource) that meets certain criteria for geologic reliability and economic minability. The U.S. Geological Survey used the term reserve base instead of demonstrated reserve base.

Dry, mineral-matter-free-basis—A calculated, analytical value of a coal sample expressed as if total moisture and mineral matter had been removed.

Fixed carbon—The solid residue, other than *ash*, remaining after the *volatile matter* has been liberated from coal during combustion.

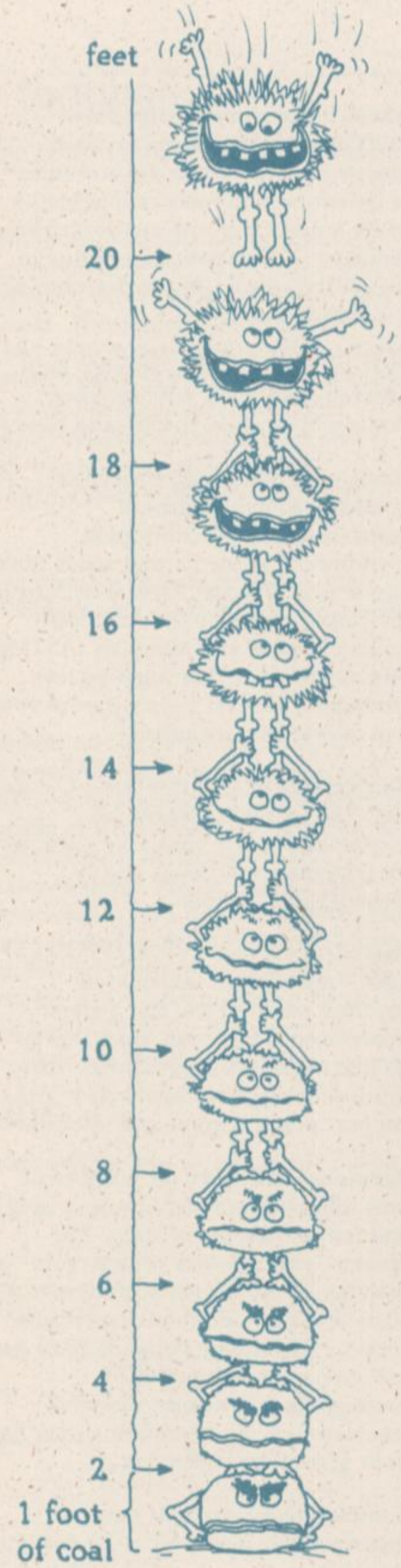
Geothermal gradient—The increase in temperature of the Earth with depth.

Igneous activity—Formation of solid rock from molten material either beneath the Earth's surface or at the surface, with the eruption of volcanoes.

Igneous sills—A horizontal, tabular intrusive body of rock formed from molten material.

Lignite—Lowest rank of coal, with low heat values between 6,300 and 8,300 *Btu/lb, moist, mineral-matter-free basis*.

It takes 20 feet of peat to make one foot of coal.



Moist, mineral-matter-free basis—A calculated number based on basic analytical data—*Btu/lb*, *ash* and sulfur—to determine a number representative of the value if mineral-matter had been removed and the natural moisture in the coal retained. Used in determining the *rank* of coal.

Peat swamp—A low, spongy land, generally saturated with moisture, dense with grasses, shrubs, and trees.

Rank—The classification of coals according to their degree of metamorphism or coalification (maturation) in the natural series from lignite to anthracite. Rank is defined in the United States by the American Society Testing and Materials (ASTM) classification based on *agglomeration* characteristics, heat values, *fixed carbon*, and *volatile matter* content.

Recoverable energy reserves—Oil, gas, coal, and uranium that can be economically recovered after allowing for environmental, legal, and technological controls.

Resources excise tax—Tax (0.75%) on sales value of coal, less sales or royalties paid to State and Federal governments. Revenues from this tax go into the state's general fund. Two-thirds of the general fund helps support public schools and education.

Severance tax—Tax on number of tons sold or consumed instate or sold and transported out of state. The severance tax consists of two parts—a base tax ($0.57 per ton surface-mined, $0.55 underground) and a severance surtax. The present surtax is $0.61 per ton surface-mined and $0.59 underground. For some new coal contract sales the severance surtax has been waived by legistation.

Scrubbers—Equipment used to remove sulfur oxides from combustion gases of a boiler plant before discharge to the atmosphere. Chemicals, such as lime, are used as scrubbing media.

Subbituminous coal—A *rank* class of coals having a heat value content of more than 8,300 *Btu/lb* and less than 11,500 *Btu/lb* on a moist, mineral-matter-free basis. This class of coal is divided by increasing heat value into subbituminous C, B, and A coal groups.

Volatile matter—-In coal, those products, exclusive of moisture, given off as gas and vapor, determined analytically by prescribed methods.

Volcanic complex—A system of volcanoes; vents in the Earth's surface from which molten material from the interior of the Earth is ejected.

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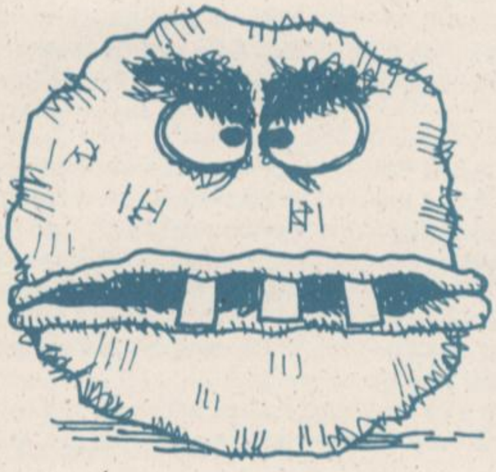

COAL
It may not be pretty—but it burns.

Sources for Earth science information

Teachers can receive free materials including curricula, student handouts, and reference materials for school resource media centers by contacting:

U.S. Bureau of Mines
Guy Johnson, Staff Engineer
Building 20
Denver Federal Center
Denver, CO 80225–0086

A free teacher's packet including a poster, lesson plans, activities, and a list of mineral resource information can be obtained by calling or writing to:

Mineral Information Institute
Jackie Evanger
475 17th Street; Suite 510
Denver, CO 80202
(303) 297–3226

The Environmental Protection Agency Provides a free information hotline for radon. Call:

1–(800) SOS–RADON

Information on Earth science programs, projects, reports, products and their sources is available from:

US Geological Survey
Earth Science Information Center (USGS ESIC)
Call 1–(800) USA–MAPS

or in New Mexico, contact:

Amy Budge
Earth Science Information Center
Earth Data Analysis Center
University of New Mexico
Albuquerque, NM 87131
(505) 277–3622

Information on earthquakes in New Mexico is available by contacting:

Bob Redden
Program Manager
New Mexico Earthquake Preparedness Program
Department of Public Safety
P.O. Box 1628
Santa Fe, NM 87504
(505) 827–9254

summer opportunities for teachers...

National Minerals Education Conference, June 19–21, 1995 at the Regal Riverfront Inn, St. Louis, Missouri

This conference is an opportunity for teachers to obtain valuable information and materials to become more effective in teaching mineral science. Participants will learn about minerals—how and why they are mined, what they are used for—and gain some hands-on techniques for classroom use. The Central New Mexico Section of the Society for Mining, Minerals and Exploration **will send one New Mexico teacher to the conference with all expenses paid.** If you are interested in a grant application form and more information about the conference, send your name and school address to: George S. Austin, GEM Chair, Central New Mexico Section of SME, c/o New Mexico Bureau of Mines and Mineral Resources, Campus Station, Socorro, NM 87801. Phone: (505) 835–5230, Fax: (505) 835–6333.

also...
Minerals Education Workshop for teachers, August 10–12 in Farmington, NM. For more details, call Teri Conrad, Education Coordinator, at BHP Minerals, (505) 327–6587 after 4:00 p.m.

Lite Geology evolves:

Lite Geology began as a small Earth science publication designed and scaled for New Mexico. Our subscription list has grown tremendously during the past two years, and now includes a large number of out-of-state readers. In order to keep up with the demand for this publication from outside of New Mexico, we will charge **$4.00 per year for out-of-state readers**, which covers the cost of printing and mailing *Lite Geology*. The subscription year begins with the Fall issue, and ends with the Summer issue to correspond with the academic year. **If you reside outside of New Mexico and wish to keep your subscription active, please return this form with a check for $4.00.** We thank all of our readers for their enthusiastic support, and hope that all of you will continue to subscribe. If you have questions about your subscription, please call Theresa Lopez at (505) 835-5420. Thanks! —ed.

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what's on-line?... NMBM&MR!

Here's an e-mail address for the Geologic Extension Service at New Mexico Bureau of Mines and Mineral Resources:

susie@gis.nmt.edu (via Internet).

Educators can join a new geoscience education discussion group on the Internet called GEOED–L, which has been created to enhance communication among those involved in teaching the geosciences. The address is:

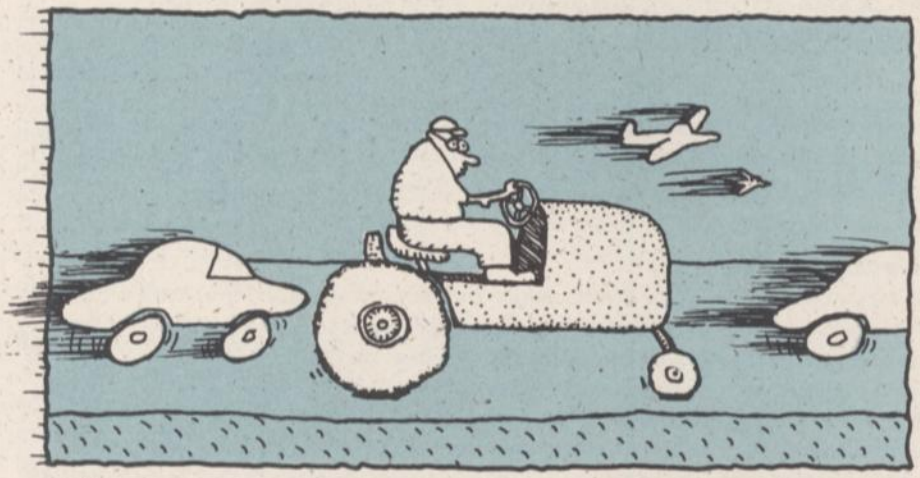
listserv@uwf.cc.uwf.edu (via Internet).

To subscribe, simply make the body of your *first message*:

Subscribe GEOED–L <your full name>

Doing so will automatically route any message posted on GEOED–L to you, and route your messages to everyone else on the GEOED–L list. We hope to see you on the Net!

—Susan Welch, Manager, Geologic Extension Service



Somehow farmer Bob made a wrong turn and got on the information super highway by mistake.

LITE geology

is published quarterly by New Mexico Bureau of Mines and Mineral Resources (Dr. Charles E. Chapin, *Director and State Geologist*), a division of New Mexico Tech (Dr. Daniel H. Lopez, *President*).

Purpose: to build Earth science awareness by presenting educators and the public with contemporary geologic topics, issues, and events. Use *Lite Geology* as a source for ideas in the classroom or for public education. Reproduction is encouraged with proper recognition of the source.

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