Lite Geology

The Evolution of the Rio Grande

fall 2012 issue 32

This view of the upper Rio Grande gorge looks north past Ute Mountain (the cone-shaped mountain beyond the snow) and into southern Colorado. The San Luis Hills, left and just beyond Ute Mountain, formed a topographic barrier to ancient Lake Alamosa. Between 450,000 and 300,000 years ago the level of this lake rose high enough to spill over topographic low points in these hills. The water flowed southward and started eroding the gorge that we see in the photograph. This gorge is still actively being eroded downward and is migrating northward. In the distant future, this erosion will eventually extend the gorge into the Alamosa area. *Photo courtesy of Chris Dahl-Bredine.*

2012 marks our 20th Anniversary!

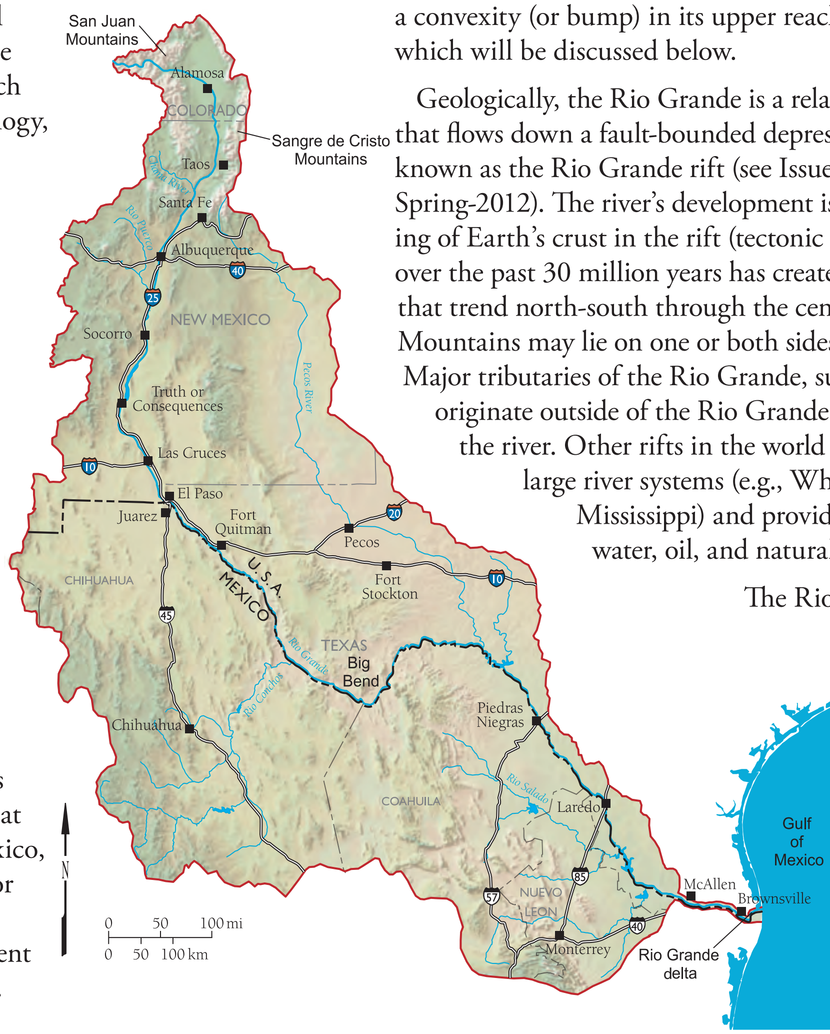
In This Issue...

New Mexico Bureau Of Geology & Mineral Resources a division of New Mexico Tech

http://geoinfo.nmt.edu/publications/periodicals/litegeology/current.html

 Daniel J. Koning and Sean D. Connell

The Rio Grande is an essential feature of New Mexico and the American Southwest, and much has been written about its geology, ecology, and history. From its headwaters in the Colorado Rockies, the Rio Grande flows through a wide range of environments before ending in the Gulf of Mexico. At 1,896 miles (3,051 km) in length, it is the fourth longest river in the contiguous United States. The Rio Grande owes its existence to the San Juan and Sangre de Cristo Mountains in southern Colorado and northern New Mexico, whose heights allow them to receive substantial precipitation. Streams from these mountains merge to form a single river that flows south through New Mexico, where it provides vital water for farms and communities. New Mexico would be a very different place without the Rio Grande. Like the Nile River is to Egypt, the Rio Grande is to New Mexico— supporting a verdant oasis in an otherwise brown and dry landscape.



Map showing the Rio Grande watershed. The river begins in the San Juan Mountains of Colorado and flows south through the center of New Mexico. South of El Paso, Texas, the Rio Grande coincides with the boundary between the United States and Mexico. It enters the Gulf of Mexico at Brownsville, where it has formed a delta.

Rivers are an integral part of the hydrologic and rock cycles. They are conduits that move water from the mountains and across the continent. Many rivers ultimately flow into the sea; however, some desert rivers empty into closed basins where water eventually evaporates into the air. Rivers also act as conveyor belts for sediment (such as sand, gravel, and mud) eroded from nearby hillslopes and mountain ranges. Water currents transport sediment downstream, breaking it down along the way. Ultimately, much of the sediment is laid down in a delta at the river's mouth. For a number of reasons, including sediment break-down and addition of water from tributaries, rivers commonly develop a concave-up, "graded" profile in which erosion and deposition tend to smooth out major irregularities. Although generally concave-up, the profile of the Rio Grande contains a convexity (or bump) in its upper reaches, the reasons for which will be discussed below.

Geologically, the Rio Grande is a relatively young feature that flows down a fault-bounded depression of Earth's crust known as the Rio Grande rift (see Issue 31 of Lite Geology, Spring-2012). The river's development is closely tied to lowering of Earth's crust in the rift (tectonic subsidence), which over the past 30 million years has created a series of basins that trend north-south through the center of New Mexico. Mountains may lie on one or both sides of these basins. Major tributaries of the Rio Grande, such as the Rio Chama, originate outside of the Rio Grande rift and add water to the river. Other rifts in the world commonly contain large river systems (e.g., White Nile, Rhine, lower Mississippi) and provide important sources of water, oil, and natural gas.

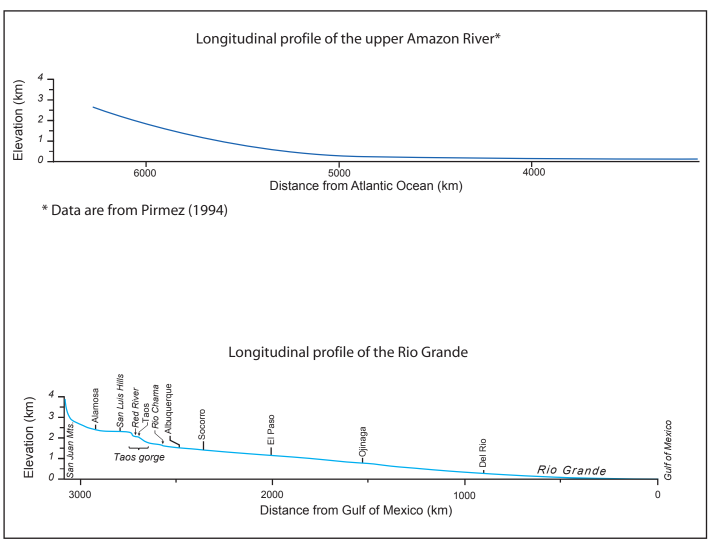
The Rio Grande has changed considerably since its formation. In fact, for most of its existence it never flowed to the sea, but ended in various inland basins. The Rio Grande mainly extended downstream over time, rather than upstream, reaching the Gulf of Mexico between 1,600,000 and 600,000 years ago. At times the Rio Grande carried relatively more water (discharge) and less sediment; at other times, it carried less discharge and more sediment. Over geologic time, changes in the balance of discharge versus sediment load filled rift basins and sculpted the landscape.

We begin the story of the Rio Grande at about 28 million years ago (abbreviated Ma), when its namesake rift was just starting to form in northern New Mexico. During and before this time, an episode of extensive volcanic activity left much of New Mexico covered in lava flows, volcanic ash, and volcanic sediment. This volcanism resulted in a rearrangement of earlier streams that flowed generally to the southeast. Tectonic stretching of the crust began to form fault-bounded basins of the Rio Grande rift. At this time, there was no through-going river like the modern Rio Grande. The map on page 4 (left column) shows an example of what north-central New Mexico and southern Colorado looked like about 23 million years ago. Volcanoes were present in the Taos area and southern Colorado, and streams flowed outward away from these volcanoes into surrounding basins.

Volcanic activity diminished between 17 and 16 Ma. This was followed by a period of extensive faulting (between 16 and 9 Ma) that formed rapidly subsiding basins. Northern streams flowed into a basin near Alamosa, Colorado. Streams draining the southern Sangre de Cristo Mountains, between Taos and Santa Fe, converged to form a south-flowing river that is considered the ancestral Rio Grande. This ancestral river merged with southeast-flowing rivers draining the Colorado Plateau. The Rio Grande ended in a playa (a shallow lake that occasionally dries up) in the southern Albuquerque Basin, where it deposited extensive reddish-brown clay and silt between Belen and Socorro. Rivers and streams had difficulty filling the Albuquerque Basin, one of the largest and deepest basins of the rift, with sediment because the rate of tectonic subsidence exceeded the rate of sedimentation. This created a closed topographic depression, from which the Rio Grande could not escape for several millions of years.

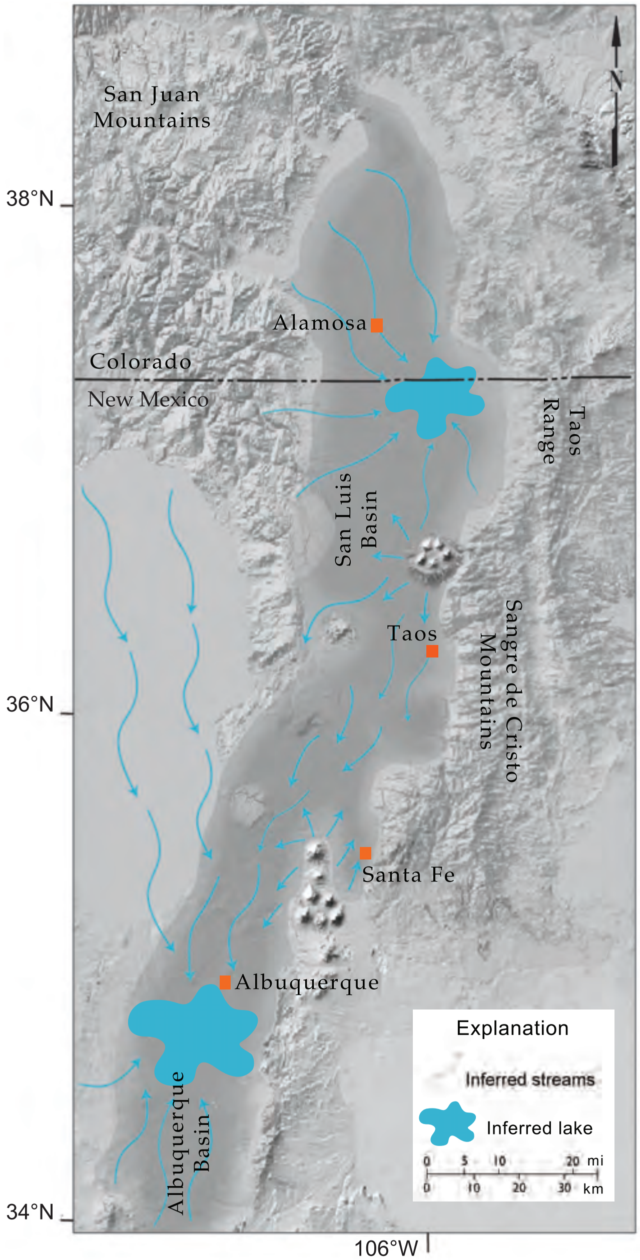
At around 5 Ma, sedimentation filled the Albuquerque Basin, and the river lengthened southward, flowing through smaller rift basins near Socorro, Truth or Consequences, Hatch, and Las Cruces. Between 5 and 2 Ma, the river alternatively ended in various perennial, shallow lakes and playas near the southern boundary of New Mexico, collectively called Lake Cabeza de Vaca. After 2.3 Ma, the Rio Grande extended past the El Paso area and began to flow along the southwestern Texas border toward Big Bend. Finally, the Rio Grande reached the Gulf of Mexico between 1.6 and 0.6 Ma and began forming a delta along the coast.

Rectified aerial photograph (orthophoto) showing the junction of the Rio Grande (right) with one of its major tributaries, the Rio Chama (left). The rivers are flowing to the lower right corner of the photo (to the south-southeast). Note the straighter shape of the Rio Grande and the more sinuous, meandering shape of the Rio Chama. When this photo was taken, the Rio Chama was carrying more suspended clay than the Rio Grande, which accounts for its light-brown color. Rivers that carry more clay tend to have a more meandering shape, and that seems to be true for the two rivers in this photograph. *Image from New Mexico Geospatial Data Acquisition Coordination Committee (State of New Mexico), published by Bohannan–Huston, Inc., Albuquerque, NM, 2006.*



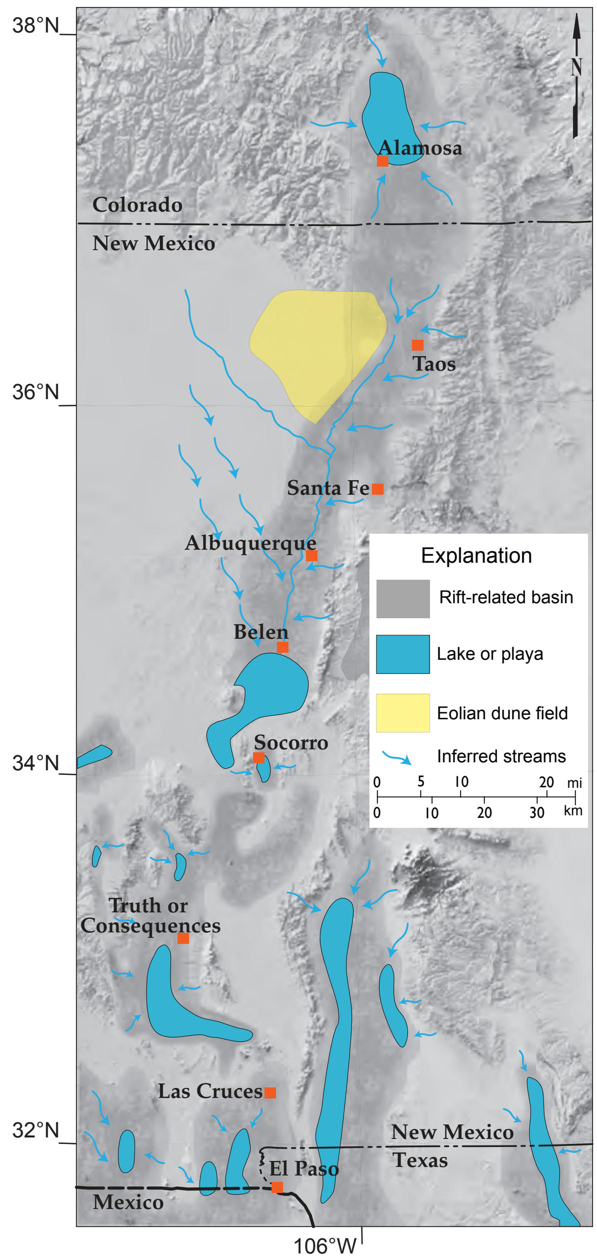
Longitudinal profile of the Rio Grande and comparison to the Amazon River. A profile refers to the shape of something seen from the side. To create a profile view of the river course, one plots the elevation of a river for progressive distances upstream from its mouth. The profile of the Amazon River exhibits a concave-up shape expected for "graded" rivers. Note the bump in the upper part of the Rio Grande, coinciding with the Taos gorge. The river here is undergoing relatively rapid erosion that will slowly lengthen the gorge upstream toward Alamosa. Eventually, erosion will result in a smoother longitudinal profile.

This downstream progression of the Rio Grande is thought to be the result of a balance of competing factors. Evidence suggests that fault activity and basin subsidence began to diminish after about 5 Ma. This slowing of subsidence meant that sedimentation of the ancestral Rio Grande could establish a sufficient slope to allow southward flow across the Albuquerque Basin and smaller basins to the south. Also, after 7 Ma regional climatic changes resulted in an overall increase in precipitation and the beginning of the monsoonal summer storms. These climatic changes would allow rivers to deliver more sediment to basins as well as increase the amount of water in the river, the latter facilitating lake spill-over.

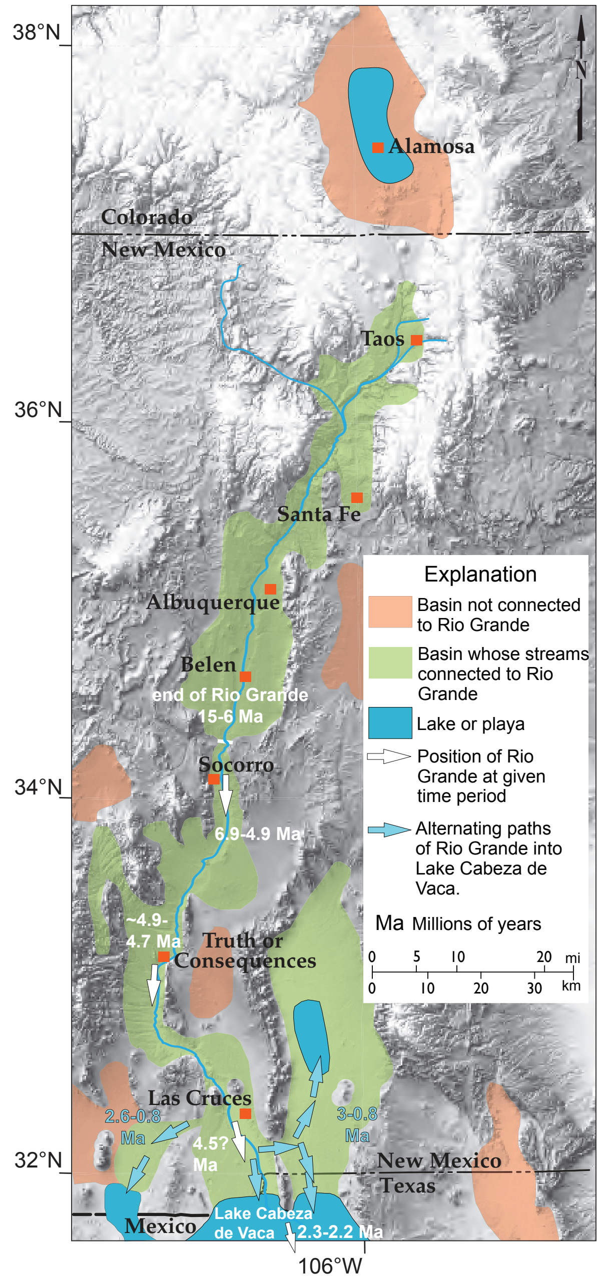


Paleogeographic map of north-central New Mexico for 23 million years ago, showing streams flowing off of volcanic highlands into the Albuquerque and San Luis Basins.

An example of an ancient lake spill-over event is interpreted near Alamosa, Colorado, near the present-day headwaters of the Rio Grande. For most of the past 2.6 million years, streams draining high peaks around the northern San Luis Basin were not connected with the Rio Grande, but rather ended in a closed basin containing Lake Alamosa, which slowly filled in with sediment. Glacial-interglacial climate cycles characterized this time period; these cycles affected stream discharges and caused the lake to vary in size. Exciting new research by Michael Machette and Cal Ruleman (U.S. Geological Survey) indicates that this lake spilled over a low volcanic ridge at its southern end between 450,000 and 300,000 years ago, probably during major glacial climatic events (ice ages) that probably increased stream discharges into the lake. Once this ridge was breached, a new river flowed south and joined the Rio Grande. This integration event created a major irregularity in the river profile in the form of a bump in the Taos area, shown in the longitudinal profile—called a knickzone. The river has been eroding in the area of the bump ever since, in an attempt to achieve a semblance to a graded river profile. This erosion has created the Taos gorge, whose steep upper end coincides with lots of rapids and erosion. Erosion in the Taos gorge will continue over geologic time until much of the knickzone is smoothed out by the river.



Paleogeographic map of central New Mexico for 13 million years ago. At this time, the Rio Grande flowed from the Taos area into a playa south of Albuquerque. *Modified from various works by Greg Mack and personal communication from John Hawley.*



Paleogeographic map of central New Mexico for 3.0–2.6 million years ago, showing the timing of extension of the Rio Grande from its former terminus between Belen and Socorro. At this time period, the river ended in a group of perennial, shallow lakes and playas in the El Paso area, collectively called Lake Cabeza de Vaca. The extent and shape of this lake probably changed over this time period, depending on where the Rio Grande was flowing into it. The river spilled out of Lake Cabeza de Vaca about 2.3–2.2 million years ago and flowed southeast toward the Gulf of Mexico. *Modified from various works by Greg Mack and personal communication from John Hawley.*

Over the past few million years, Earth's climate alternated between glacial and interglacial periods (including the present day). This resulted in episodic changes in the balance of river discharge and the sediment load carried by rivers. Times of high discharge and low sediment loads increased the erosive capability of the Rio Grande and caused it to progressively carve a river valley over the past 800,000 years. Before then, the river was mostly depositing sediment, and its older courses sometimes were quite far from its present position. In the Albuquerque area, for example, the ancestral Rio Grande once flowed within a mile of the western front of the Sandia Mountains. Only later did it shift west and erode its present valley. Sand-filled channels from these older river pathways are buried under Albuquerque and are valuable aquifers.

In summary, the Rio Grande has responded in various ways to tectonic and climatic changes. Between 23 and 5 Ma, it ended in a playa located between Belen and Socorro. High subsidence rates in the Albuquerque Basin hampered the river's ability to fill it with sediment. Not until tectonic subsidence rates decreased after about 5 Ma did the Rio Grande extend into playas and shallow lakes in the El Paso area, where it remained between 5 and 2 Ma. The Rio Grande eventually reached the Gulf of Mexico between 1.6 and 0.6 Ma, ending its long journey to the sea. Times of higher water discharge and lower sediment load balances during glacial-interglacial cycles over the past 800,000 years resulted in erosion of the present-day valley of the Rio Grande. Higher stream discharges into Lake Alamosa between 450,000 and 300,000 years ago, following progressive sedimentation of the basin, caused the lake to spill over to the south and connect with the Rio Grande—an interesting example of upstream extension in what is otherwise a story of downstream lengthening.

Additional Reading

The Rio Grande— a River Guide to the Geology and Landscapes of Northern New Mexico by P. W. Bauer, 2011. New Mexico Bureau of Geology and Mineral Resources, 120 pp.

Late Cenozoic drainage development in the southeastern Basin and Range of New Mexico, southeasternmost Arizona and western Texas by S. D. Connell, J. W. Hawley, and D. W. Love, 2005. *In* New Mexico's Ice Ages, New Mexico Museum of Natural History & Science Bulletin No. 28, pp. 125–150. S. G. Lucas, G. Morgan, and K. E. Zeigler (editors).

History of Cenozoic North American drainage basin evolution, sediment yield, and accumulation in the Gulf of Mexico Basin by W. E. Galloway, T. L. Whiteaker, and P. Ganey-Curry, 2011. Geosphere, v. 7, n. 4, pp. 938–973.

A View of the River by L. Leopold, 1994. University of California, Berkeley, 298 pp.

Ancient Lake Alamosa and the Pliocene to middle Pleistocene evolution of the Rio Grande by M. N. Machette, D. W. Marchetti, and R. Thompson, 2007. *In* Rocky Mountain Section Friends of the Pleistocene Field Trip—Quaternary Geology of the San Luis Basin of Colorado and New Mexico, by M. N. Machette, M.-M. Coates, and M. L. Johnson (editors). U.S. Geological Survey, Open-File Report 2007-1193, pp. 157–167.

Pliocene and Quaternary history of the Rio Grande, the axial river of the southern Rio Grande rift, New Mexico by G. H. Mack, W. R. Seager, et. al., 2006. USA: Earth-Science Reviews, v. 79, pp. 141–162.

How Do Volcanoes Help Us Understand River History? Nelia Dunbar

In order to understand how river systems work, geologists need to be able to determine the time scales over which rivers form and deposit sediments. This can be very difficult, because most river sediment is made up of older rocks that have been eroded from surrounding highlands, so dating the sediment itself does not provide an accurate age of the sedimentation, only of the ages of the sediment source. For instance, in Rio Grande sediments there are pieces of rocks that are more than a billion years old, but the river itself is much younger.

Fortunately, some rivers, such as the Rio Grande, are surrounded by volcanoes that give scientists one good way to date rock layers. When these volcanoes erupt, they produce lava flows or ash fall deposits that can be interlayered with the river sediments. These volcanic eruptions typically take place over a period of days to months, very short time scales, geologically speaking. When a volcanic deposit is interlayered with river sediments it forms a bed of known age, which is called a "time-stratigraphic marker." Many lava flows or ash fall deposits can be dated very accurately and precisely using radioisotopic techniques. Once the age of one of these time-stratigraphic marker beds is known, then the age of the river sediments on either side of the bed can be inferred. Wherever you find that volcanic deposit, you know that the sediments below are probably slightly older than the marker bed, and the sediments above are slightly younger. You can also say that sediments associated with a given marker bed, even if they are in geographically different areas, are probably close to the same age.

Lava flows tend to travel only a few tens of miles from their source, so are only useful for determining the age of river sediments in a very local area. However, ash fall eruptions from powerful supervolcanoes like the Jemez Mountains, can deposit a thin layer of ash hundreds or even thousands of miles from the vent. So, these ash layers, when found in river sediments, can be used to determine ages of sediments over very large areas. Volcanic ashes from two large Jemez Mountain eruptions, one erupted 1.6 million years ago and the other 1.2, have been used as marker beds in Rio Grande sediments. Well-dated volcanic ashes from supervolcanoes in Yellowstone, Wyoming, and Long Valley, California, have also been recognized in New Mexico river sediments, providing time lines to understand the chronological history of the Rio Grande.

Earth Briefs—Catastrophic Sedimentation, New Mexico Style

Douglas Bland

When we think of accumulations of gravel, sand, silt, and clay that eventually form sedimentary rock layers, most people envision a gradual buildup of material over long periods of time. Picture a gently flowing river or stream, quietly moving small amounts of sediment with the current. While this process accounts for most sedimentary deposits, major sedimentation events can occur very quickly, deposited by devastating torrents of water, mud, and debris. Although uncommon, very large rainfall events can cause catastrophic sedimentation, but modest rains that fall on barren or disturbed ground can yield the same result. Recent examples include flash floods that followed the 2011 Las Conchas wildfire in the Jemez Mountains of northern New Mexico. This fire denuded the slopes of mountains and canyons of vegetation that previously held the soil in place. In addition, the heat and ash made the soil hydrophobic, meaning water does not easily soak in. Therefore, during the typical summer rains, the amount of runoff into arroyos and once quiet streams was much higher than usual, eroding the landscape, carrying huge amounts of ash, soil, sand, boulders, and plant debris with it. As flows moved into lower elevations, sediment was deposited as the flood waters spread out over flatter areas, slowed down, and lost the energy needed to carry sediment. Damage was extensive. Similar effects occurred in 2012 when the largest fire in New Mexico's history, the Whitewater–Baldy fire, scorched more than a quarter of a million acres in the Gila Wilderness. At the same time, the Little Bear fire near Ruidoso burned 242 residential structures.

Flash flood deposits in 2011 at Dixon Apple Orchard. *Photo courtesy of Channel 13 News.*

Dixon's Apple Orchard sits in the bottom of Cochiti Canyon north of Cochiti Reservoir. The Las Conchas fire burned much of the drainage area for the creek that flows in the bottom of the canyon, as well as the ranch house, other outbuildings, and about 10 percent of the trees in the orchard. Less than two months later flash floods roared down the canyon, tossing trucks and tractors, filling in irrigation ponds that were 30 to 40 feet deep, and depositing several feet of sediment in parts of the orchard and stream valley. If this sediment is preserved, the rock record will show a thick layer of material that was laid down in just one night.

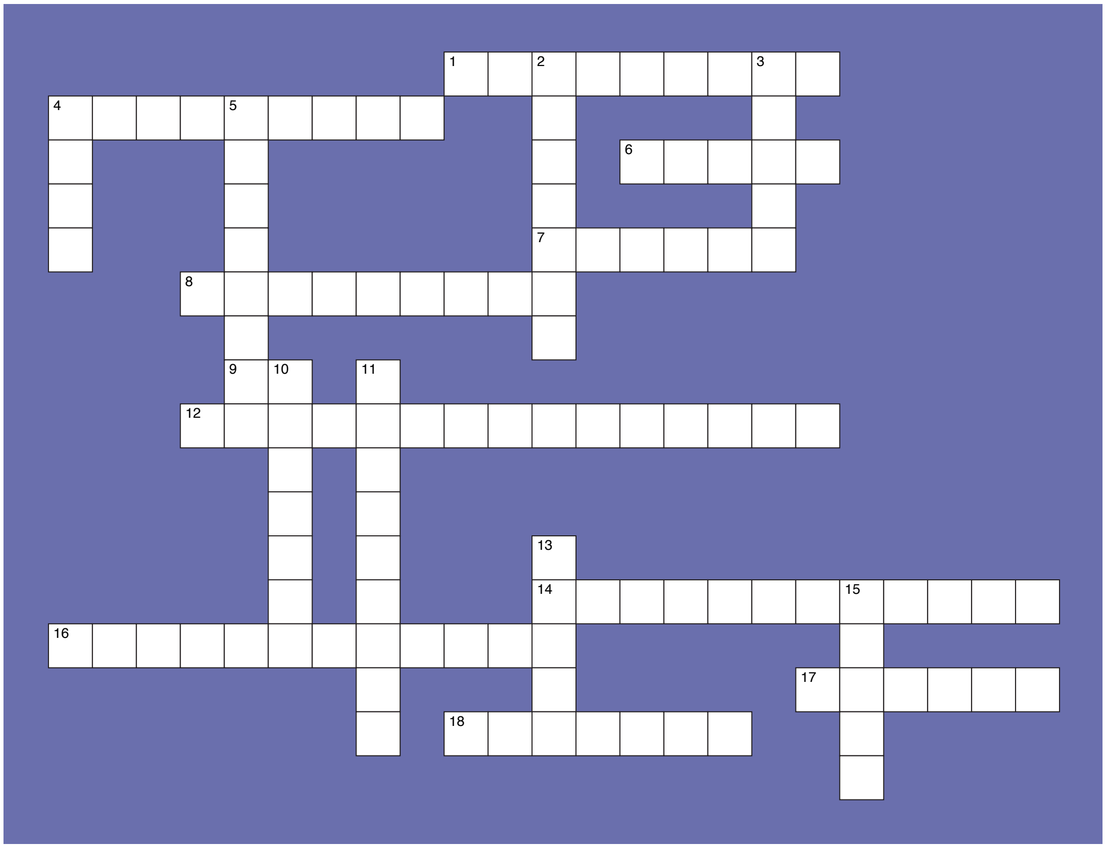
U.S. Senator Tom Udall (top), Kris Schafer (bottom right), and Walter Dasheno, governor of Santa Clara Pueblo at Santa Clara Pueblo on July 7, 2012. Flooding followed the 2011 Las Conchas fire. *Photo courtesy of the U.S. Army Corps of Engineers.*

More than 65 percent of Bandelier National Monument burned in the fire. The main Visitors Center is located in the bottom of Frijoles Canyon. Although the fire spared most of the archaeological ruins and the Visitors Center, the watershed for the canyon was torched. Scientists anticipated flash floods that could wipe out all the facilities. To prevent disaster, walls of sandbags and concrete barriers were placed around the Visitors Center and adjacent buildings. The main bridge across the creek was removed, because floods carrying debris would collect against the bridge, causing water to back up and flood the buildings. Flash floods in September 2011 ravaged the canyon, and washed out the remaining bridges. Sand bags and barriers were displaced, but the measures were successful in protecting the newly renovated Visitors Center. A flash flood in Frijoles Canyon in early July of 2012 once again took out bridges that had been replaced in the past year.

Some of the sediment and debris washed down the canyons will be preserved in place, but much of it has been washed into the Rio Grande. The current will eventually move most of it downstream, depositing it in Cochiti Reservoir. Geologists in the distant future may puzzle over an unusually thick layer of ash-laden sediment from the early 21st century in the Rio Grande valley north of Albuquerque. Today's geologists find similar deposits all over the world.

Rio Grande Crossword Puzzle

Douglas Bland



Across

1. direction of Taos gorge propagation
4. fourth longest river in the U.S.
6. tectonic subsidence creates this
7. glacial climate
8. river in African rift
9. abbreviation for "million years ago"
12. type of map
14. type of river profile
16. prehistoric lake near El Paso
17. rivers may end in this type of basin
18. rivers carrying clay tend to do this

Down

2. the Rio Grande begins here
3. river in European rift
4. fault bounded depression
5. tributary to the Rio Grande
10. location of southern Colorado basin
11. river profiles are generally this
13. type of prehistoric lake north of Socorro
15. rivers entering the ocean form this

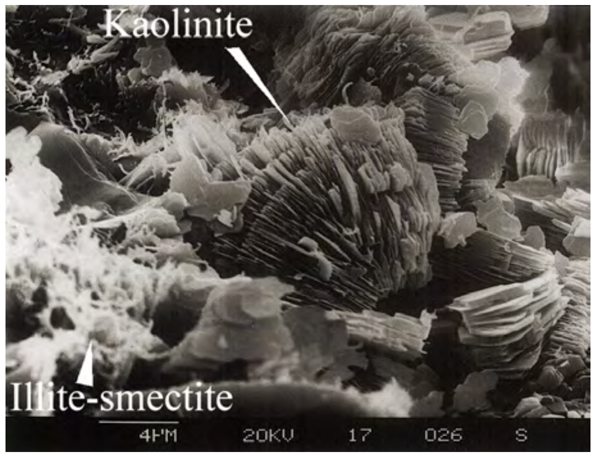
The answers to the clues are located in the Evolution of the Rio Grande article in this issue of *Lite Geology.*

The solution to the puzzle is found on the last page of this issue.

New Mexico's Most WANTED MINERALS

Virgil W. Lueth

CLAY



Scanning electron microscope image of a typical mixture of clay minerals found in shale. Scale bar is approximately 10 microns. *Photo courtesy of the U.S. Geological Survey.*

DESCRIPTION: Clay is a term applied to a variety of fine-grained minerals with many different properties such as plasticity and a sheet structure similar to mica. Most clay minerals consist of combinations of aluminum and silica with water, and they are known generically as hydrous aluminosilicates. These minerals commonly are mixed with other minerals like quartz, feldspar, carbonates, and micas (their close relatives). These particles require analytical methods like X-ray diffraction or electron microscopy for identification.

WANTED FOR: Humans have used clay minerals for thousands of years. More than one-half of the world's population lives in clay structures, New Mexico being famous for adobe clay buildings. Clay has long been used to make pottery, and the earliest forms of writing are preserved on clay tablets. It is used for cement, filtering, and paper making (giving magazine paper its shiny coating), and we even use clays for certain medical conditions where absorption of fluid is necessary, especially poultices and anti-diarrheals. The impermeable nature of clay makes it useful for water barriers in landfills and for blocking the spread of toxic elements.

HIDEOUT: Clays form from the long-term chemical weathering of feldspar, the most abundant mineral on Earth, accumulating in most soils and becoming the most abundant sedimentary rock on Earth, shale. Clays also form by the interaction of hydrothermal solutions on silicate rocks.

LAST SEEN AT LARGE: Clay is found throughout New Mexico: in the air during windstorms, suspended in our rivers, and in the shale rocks under our feet. Large deposits of clay are found in the Mancos Shale in northwest New Mexico, in the Pierre and Lewis shales in the northeast, and in the Percha in southern New Mexico. Hydrothermal clay can be found in the natural alteration scars associated with molybdenite ore deposits along the Red River canyon.

ALIASES: Today, clays are commonly classified into five groups, and individual clay minerals are given a unique species name. These five groups are: kaolinite (20 species), smectite (a mixed-layer group with 27 species), illite (a mica group with 49 species), sepiolite (3 species), and chlorite (11 species). In most clay samples, more than one clay species usually is present.

New Mexico's Enchanting Geology

Paul Bauer

WHERE IS THIS?

Photo courtesy of Chris Dahl-Bredine.

The Rio Grande has cut a deep, photogenic canyon through the basalts of the Taos Plateau volcanic field. This downstream, aerial view of the southern Rio Grande gorge displays the Gorge Bridge, the Servilleta Basalt in the gorge walls, and the Paleoproterozoic metamorphic rocks of the Picuris Mountains in the distance. The lands east (left) of the gorge belong to Taos Pueblo. The western rim of the gorge (designated as part of the National Wild & Scenic River System) provides stunning views of the gorge along the 9-mile BLM West Rim Trail.

Although the exact age of the gorge is unknown, it must postdate the youngest Servilleta Basalt flows (2.6 million years). Recent work by USGS geologists suggests that the Rio Grande in Colorado first became integrated with the Rio Grande here in New Mexico about 300,000 years ago, and therefore much of the river incision must be that young.

The river has cut through approximately 650 feet of basalt here, one of the thickest sequences known in the volcanic field. By volume, the Servilleta Basalt dominates the Taos Plateau and may contain as much as 50 cubic miles of olivine tholeiite lava. Most of the basalts in the gorge have erupted from known vents to the west, although nothing precludes the existence of buried volcanic vents to the east. Here the basalt consists of three thick flow-packages of basalt (lower, middle, and upper), which are typically separated by thin gravel layers. Each flow-package is composed of hundreds of coalesced individual flows.

This 15-mile Taos Box section of the Rio Grande is arguably the finest day-long whitewater adventure in the country. From the launch site at Arroyo Hondo to the take out at the Taos Junction Bridge, the river drops 400 feet, for an average of 27 feet/mile. For comparison, the Colorado River through the Grand Canyon drops about 8 feet/mile. The thrilling grand finale of the Box, starting with the formidable 12-foot drop at Powerline Falls, is 3.5 miles of near-continuous whitewater known as the Rio Bravo section.

The Gorge Bridge is 650 feet above the river, and 1,272 feet long, making it the 2nd or 3rd highest bridge on the national highway system, and the 2nd longest steel deck truss bridge in the U.S. Completed in 1965 at a cost of $2,153,000, the roadway contains pumice in the concrete mix, thus substantially lightening the structure. This bridge was deemed the most beautiful span in the U.S. in 1966. Hollywood scouts have taken note of the location, and the bridge has appeared in many movies, including Easy Rider (1969), Twins (1988), Natural Born Killers (1994), and Terminator Salvation (2009).

Topographic Model of Northern White Rock Canyon

Grade Level: Grades 6–12

Objectives:

Students will gain understanding of what a topographic map is, what it represents, and how it is used. They will accomplish this by constructing a cross-sectional elevation diagram from elevation data on a topographic map, and build a three dimensional landform model from a topographic map.

Teacher Background:

The topographic map we will use in this activity represents an area bisected by the Rio Grande in north-central New Mexico. It includes the northern part of White Rock Canyon and Otowi Peak, east of Los Alamos. The cliffs on both sides of the river were formed during multiple episodes of volcanic activity over the past 10 million years, including the gigantic eruptions that formed the Valles caldera and Jemez Mountains between one and two million years ago.

A topographic map is a two-dimensional representation of a three-dimensional object or area. Contour lines connect points of equal elevation. A contour interval is the difference in elevation between two adjacent contour lines.

1. All points on a line are of equal elevation.

2. Contour lines do not cross or divide.

3. Contours that are widely spaced indicate a gentle slope.

4. Contours that are close together indicate a steep slope.

5. Contours always "V" upstream.

6. All contours eventually close, either on the map or beyond its margins.

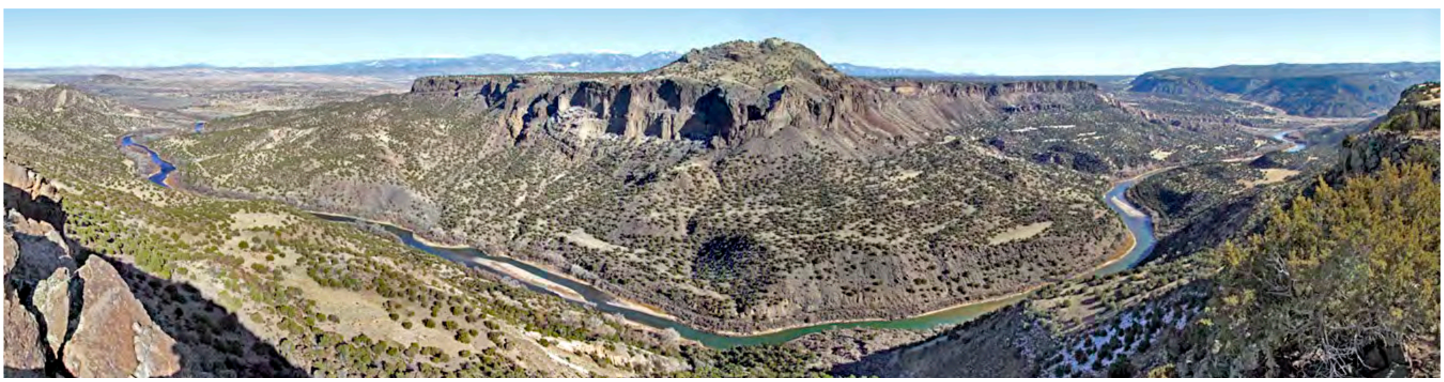
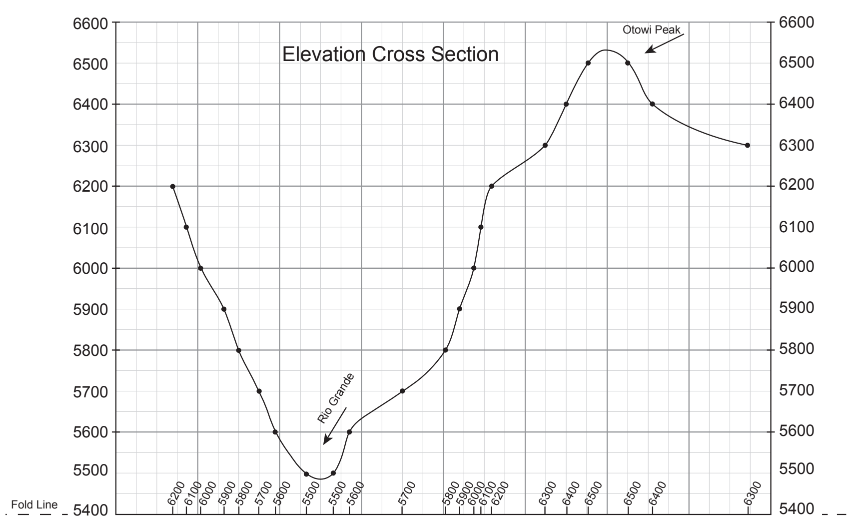
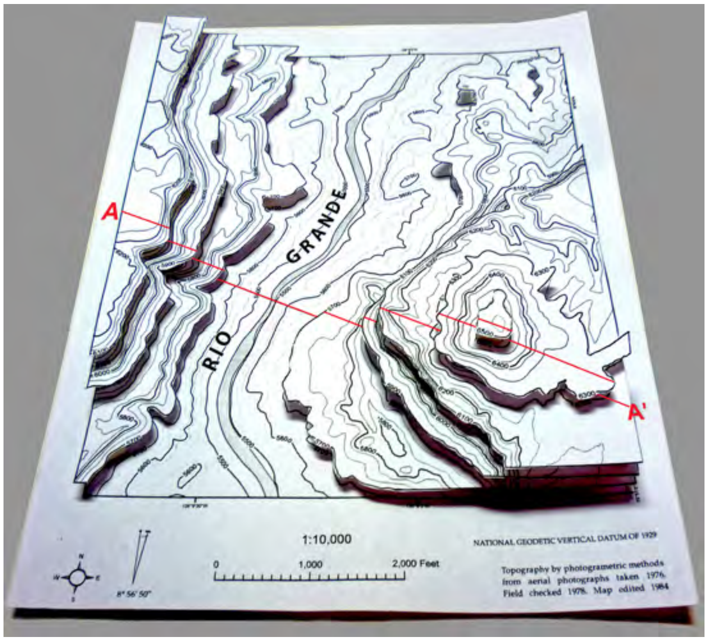


Photo of the Rio Grande and Otowi Peak, looking east. *Photo courtesy of Kirt Kempter.*



Cross section elevation profile along line A-A'.



3-D model of topographic map in northern White Rock Canyon.

Method Overview:

1. Students will use the topographic base map and graph paper to construct an elevation profile by extracting elevation data along the reference line A–A'.

2. A paper pattern of a topographic map will then be used to construct a three-dimensional model of the area represented in the map. Each layer of the model represents an elevation corresponding to an index contour line. Students will cut the elevation layers out from the pattern and attach them to the base map using spacers to represent elevation changes.

Materials:

1. One sheet of 8.5 inch by 11 inch graph paper

2. Scissors

3. Ruler

4. Topographic base map printed on card stock, which can be found at: **http://geoinfo.nmt.edu/education/exercises/topo_map/base_map.pdf**

5. Topographic layers representing 200-foot elevation contours printed on card stock, which can be found at: **http://geoinfo.nmt.edu/education/exercises/topo_map/topo_layer_contours.pdf**

6. Double stick mounting tape with foam in the center for spacers (2 mm thickness or greater) such as Scotch indoor mounting tape

Materials needed for constructing the elevation profile and 3-D model.

Method:

To construct the cross section elevation profile:

1. Using the ruler, measure the length of the line on the topographic map labeled A–A'.

2. Turn the graph paper so the long side is at the bottom. Draw a line of the same length as A–A' near the bottom of the sheet of graph paper.

3. Starting at the left side of the line, draw a vertical line 6 inches high. Do the same on the right side. Each half inch represents 100 feet of elevation gain.

4. Label the bottom of these vertical lines as 5,400 feet. Continue labeling the vertical lines every half inch at increasing increments of 100 feet (5,500 feet, 5,600 feet, etc.) until you reach 6,600 feet (see illustration of cross section on page 11).

5. Fold the graph paper along the line representing A–A'. Place the A–A' line on your graph paper on top of the A–A' line on the map, lining up the beginning and ends of each line.

6. Make a small mark on the graph paper on the A–A' line each time a 100-foot contour is intersected. Write the elevation next to each mark.

7. Remove the graph paper from the map and unfold. Project the points to the correct elevation on your graph according to the numbers on the vertical lines.

8. Connect the dots. You now have a vertical profile, or cross section, of the landscape along line A–A'.

To build the topographic model:

1. Locate the base map and find the scale. This will help you decide how many layers of spacers you will use to get the correct elevation in your model. The map scale can be used to estimate the vertical distance, or elevation change between contours, or layers in the model. Find the interval on the map scale that represents the elevation change of 200 feet, and figure out how many of spacers you need to stack together to achieve that vertical distance between layers in the model. (Hint: If you use the product shown in the photo, four pieces stacked together will equal ¼ inch, the equivalent of 200 feet on the map scale.)

2. Cut out the patterns of the individual elevated topographic layers.

3. Locate the topographic cutouts that match the 5,700-foot contour line and align them to the same contour line on the base map. You will have 5,700-foot cutouts for both sides of the Rio Grande.

4. If using Scotch mounting tape, cut four strips about six inches long and stack them together, leaving the top and bottom backing in place on the outside pieces, but removing the backing on the rest so they stick together. Cut the stack into small pieces as shown in the illustration.

5. Attach the spacers to the cutout and the base map, lining up the contour lines. You can use the same number of spacers between each layer of the model because the vertical distance between all the cutouts is the same.

6. Continue attaching cutout layers of increasing elevation to the model with the stacked spacers until the model is complete.

Analysis:

1. Looking at the base map, what other features can you find on the map besides contour lines?

2. Why is the river lower than the surrounding cliffs? Hint: think about erosion.

3. Do you think the river was higher or lower in the past than it is today? Why?

4. One million years from now, do you think the river will be higher or lower than it is today? Why?

5. The term "vertical exaggeration" in a topographic reconstruction, such as the one you just did, refers to how the vertical scale is stretched or compressed compared to the true vertical scale of the natural landform. For instance, your topographic reconstruction was made with no vertical exaggeration (the horizontal scale is equal to the vertical scale). But, if you had put in twice as many spacers, the reconstruction would have two times vertical exaggeration. What would this make the model look like compared to the real one? What would be the advantage of vertical exaggeration when studying a landform?

6. How long is line A–A'? Compare the amount of distance represented by the horizontal and vertical lines on your cross section. Does the vertical profile have vertical exaggeration? Compare the slopes on your cross section to the slopes on the model.

7. For extended inquiry, construct another cross section without vertical exaggeration. Compare the two cross sections and discuss the advantages of each.

Additional Resources

Building a Topographic Model by Ellen P. Metzger
http://www.ucmp.berkeley.edu/fosrec/Metzger1.html

Contributions from: Nelia Dunbar, Gretchen Hoffman, and Phil Miller.

Profile of a New Mexico Earth Science Teacher

Gary Bodman teaches science at Madison Middle School in Albuquerque. For Gary, teaching was a second career that he had aspired to while working as a project manager for a mill-work company. Although he has only been teaching for five years, his lifelong enthusiasm for science made becoming a science teacher a logical choice. He enrolled in the alternative licensure program with Central New Mexico Community College and was among the first teachers to graduate from this program in secondary education. He is currently working on his master of science for teachers at New Mexico Tech and is enjoying courses in chemistry, optics, astronomy, and geology. Gary has been a regular participant at the Rockin' Around New Mexico workshops, which offer MST credit, including the 2012 session in the Jemez Mountains. Gary is active in The Albuquerque Astronomy Society (TAAS) where he serves on the Education Committee and won the **Outstanding Service Award** for 2011. Gary uses one of the TAAS 6-inch reflecting telescopes and helps with star parties with the club at different schools around Albuquerque. Gary Bodman is one of a select group of educators who can claim the nickname of **Space Cadet**. In 2010, Gary was chosen to participate in the **Weightless Flights of Discovery** program sponsored by Northrop Grumman Foundation.

School, grade level and subjects taught:
Sixth grade earth science and eighth grade physics

Educational background:

- Bachelor of science in biology, chemistry minor, University of New Mexico
- Teaching certificate through Central New Mexico Community College
- Currently enrolled in New Mexico Tech's Master of Science for Teachers program

Awards and other recognition:

- Excellence in science teaching award, Sandia National Laboratories, 2009–2010
- Educator of the year, honorable mention, The American Institute of Astronautics and Aeronautics (AIAA), 2011
- American Institute of Astronautics and Aeronautics grant, used with science club, 2010
- Air Force Association classroom grant, used with science club, 2011
- Civil Air Patrol classroom grant, used with science club, 2011
- First place Energy STARS model hydrogen fuel cell car challenge, race, 2010
- First place Energy STARS model hydrogen fuel cell car challenge, race and overall competition, 2011

Gary in his NASA flight suit on the first day of school at the Weightless Flights of Discovery summer program. *Photo courtesy of Gary Bodman.*

How do you find ways to network with scientists?
I use Facebook to network and keep in contact with scientists and other teachers I meet at professional development sessions. When I am at a workshop, I can post my experiences on Facebook. Having a network of scientists who can visit my classroom is helpful. It is difficult arranging field trips because students miss instruction on other subjects. One really great connection is with Mark Boslough, a Sandia Labs scientist who traveled with the BBC to make a documentary film exploring evidence of an enormous meteorite impact in the Libyan Desert. Mark brought some desert glass from one site in Egypt that was created in the heat of the impact. Inviting scientists to speak with students dispels any stereotypes the students may have about scientists, and perhaps help them consider a career in a STEM field.

What projects are you doing with students this year?
We are looking at climate change using dendochronology because climate conditions are recorded in tree rings. We will involve students in the Global Tree Banding Project that empowers students all over the world to become citizen scientists tracking how trees respond to climate. This Smithsonian-sponsored program has free tree banding kits available to teachers. See the resources section below for a

link to view data submitted by Madison Middle School. The Sandia Natural History Center has offered to support this project and offers a wide variety of habitats to study. Climate change is a highly politicized topic, and teaching the students to read the data and draw their own conclusions puts the scientific method into practice. The Forest Service has some excellent publications aimed at middle school students, with free reading materials that include lesson plans and activities. The publication is *Natural Inquirer*, and the website is posted below.

I was awarded a NASA Summer of Innovation grant for $2000. This money will be used on a robotics project where kids will build Parallax Boebots. This project is supported by the Air Force Research Laboratories La Luz Academy. The culminating task is to have the students design and build their version of an interplanetary rover that uses radio waves to control sensors and servos, along with a video feed from a laptop computer. My science club this year is going to focus on aeronautics, so students will learn the physics of aviation. We plan on building foam gliders with the help of Carlos Reyes, an avid radio control modeler and consultant on unmanned aerial vehicles (UAV), before moving on to powered flight with electric model planes. I hope to integrate electronics and accelerometers by the end of the year using quadracopters.

Do you have any advice or suggestions for other earth science teachers? Be yourself, and learn to listen. Don't answer questions that students raise; learning is about discovery. Be open to learning from your students, they are great teachers. Don't be afraid of being afraid, going out on a limb with your teaching; you will be surprised with the results. Vocabulary and content are important, but problem solving and engineering skills provide a foundation for life skills. Encourage curiosity; once the students start asking their own questions, they have ownership of the answers. Guided playful inquiry can lead to all sorts of outcomes you wouldn't expect. Being a lifelong learner inspires and excites me, and I'm sure it also inspires the students in the classroom. Having access to the latest videos from NASA is much more exciting than a dated textbook. NASA's educational outreach is fantastic.

What is your favorite lesson in earth science? My favorite lesson is the sand magnification lesson published in *Lite Geology* (Issue 29, Spring 2011). I became interested in collecting sand after the Rockin' Around New Mexico 2010 session where Dr. Bruce Harrison presented several lessons on soils. I use the magnification lesson to help my students compare sands from various sources to learn about their origins, methods of transport, etc. I have stereoscopes in class, and I use the grid paper with scale markings provided in the sand lesson. I will also experiment with a new digital scope. My scopes and other lab equipment were purchased with stipends I received for professional development programs I attend each summer. Whenever I travel, I bring sand back to add to our class collection. The link to the sand lesson is listed below.

When did you fall in love with geology? I fell in love with geology when my dad gave me rocks that my great grandfather had collected from around the world as a merchant marine. Beautiful amethyst, native copper, large chunks of polished marble, and myriad fossils pulled on my imagination at a young age. I have always loved being outdoors, camping solo when I was 16, caving when 17 and 18. I spent time exploring mine shafts in Golden and Tijeras Canyon, digging through tailings. New Mexico is a state that begs you to learn more about geology. I also shared hiking and camping experiences with my sons, and it appears to have steered my youngest son's academic choices. He is currently studying geology at the University of New Mexico.

What hobbies do you have that relate to your science teaching? I collect rare antique books, mostly about science and exploration. Reading a first edition book by Alfred Russell Wallace, Percival Lowell, or reading a magazine article written by Nikola Tesla is amazing.

Being a teacher has led me to reach out to the community and make connections I can bring back to the classroom. I have been on field trips with friends prospecting for uranium ore near Grants, finding thorium laden monazite near Petaca, and exploring the broken arrow site south of Albuquerque where a nuclear bomb accidentally fell out of the belly of a B-36 in 1957. Sharing astronomy with The Albuquerque Astronomy Society is a pleasure. I have been able to teach elementary kids about the size of the universe at star parties and gaze through telescopes I could never afford.

What is your favorite geologic feature in New Mexico? The Bisti Badlands is an amazing place. I have never felt like I was on another planet as much as there. The fossilized trees and concretions create an alien landscape. The Valles caldera is an amazing combination of faults, geothermal sources, different types of volcanic activity, and beauty. Attending the "Rockin' Around New Mexico" courses through New Mexico Tech gave me a greater appreciation for this area.

Hoodoos in the Bisti Badlands, located in the Bisti/De-Na-Zin Wilderness south of Farmington, New Mexico. *Photo courtesy of Gary Bodman.*

Reaching across time on a petroglyph in the Ojito Wilderness south of San Isidro, New Mexico. *Photo courtesy of Gary Bodman.*

What are your favorite web links for science resources?

The Weightless Flights of Discovery program for educators was sponsored by Northrop Grumman Foundation from 2006–2010. The website has a downloadable *Zero G Guide for Educators* curricula used by the teachers who attended these workshops along with resources for K–12 students. Visit the website at:
http://www.northropgrumman.com/goweightless/

The Global Tree Banding Project is sponsored by the Smithsonian Institution. You can see recent data collected by Madison Middle School at: **https://treebanding.si.edu/**

The Natural Inquirer publication can be downloaded from the USDA Forest Service website at:
http://www.naturalinquirer.org/

Polar Bear Video—Here is a brief recording of a close encounter with a polar bear while I was part of an EarthWatch volunteer team in 2011 heading to Churchill Northern Studies Center, Canada. **http://www.youtube.com/watch?v=4VI_kubulWk&feature=youtube**

Larger Than Life: Magnification of Sand—This lesson can be downloaded for classroom use at: **http://geoinfo.nmt.edu/education/exercises/sandmag/home.html**

2012 marks our 20th Anniversary!

This year we celebrate the twentieth anniversary of *Lite Geology*. First published in 1992, the periodical originated when then-director Chuck Chapin assembled a team of staff members to create an informative yet entertaining publication focused on earth science topics and current issues in New Mexico, one that would appeal to a broad audience and serve as an outreach tool for educators and the public. Early issues of *Lite Geology* contained whimsical cartoons, creative short features, and articles on topics ranging from mineral resources to geologic hazards to New Mexico's enchanting geology. Over the years the original quarterly print publication evolved into a semi-annual online publication. Today *Lite Geology* is available as a free download from the New Mexico Bureau of Geology and Mineral Resources website, along with the entire collection of back issues. Each issue now includes short articles, classroom activities, puzzles, and links to online resources. Some of the early editors are still on the job and have been joined in recent years by other bureau staff. We welcome your input for future issues.

Rockin' Around New Mexico 2012: Jemez Springs, New Mexico

Susie Welch

Rockin' instructors Dave Love (in red hat) and Jamie Gardner explain the geology of the Valles caldera at the overlook on Highway 4 in the Jemez Mountains. *Photo courtesy of Linda Brown.*

Jemez Springs, New Mexico, was the location for the 2012 session of Rockin' Around New Mexico. The 3-day teacher workshop was held July 9–12, 2012, with a total of 27 teachers from grades K–12 participating. Field trips and classroom instruction allowed teachers to learn about the geology of the Valles caldera and surrounding mountains and its influence on seismic and volcanic hazards. Geothermal resources in the area are related to the caldera, and several site visits included discussions on the potential for producing geothermal energy.

During the first day of field trips, teachers explored various sites along the Jemez River in San Diego Canyon to perform water quality measurements on surface and geothermal well waters. Three parameters were measured at each site: pH, temperature, and electrical conductivity. Sampling locations included the Jemez Pueblo, the village of Jemez Springs, Soda Dam, and Battleship Rock. Participants compared differences in test results between surface and geothermal water samples, as well as between sampling sites and types of testing instruments. The group also examined faults at several locations and discussed current and future seismic risks.

On the second day of field trips, our teachers made several stops in the Valles Caldera National Preserve, where they learned about the history of the volcanic eruptions and the resurgent domes, and explored the potential for future eruptions. Damage to the forest from the 2011 Las Conchas fire was evident during the tour, which prompted discussions on how a managed forest responds in a more beneficial way to fire.

Back at the Science Education Center classroom, teachers completed their volcanic rock collections and heard presentations on fire ecology and the history of the Valles Caldera National Preserve. Teachers participated in lessons about earthquake safety in schools and had several talks about seismic safety for buildings, with examples of damage from the Christchurch, New Zealand, earthquake in 2011, and other historic quakes.

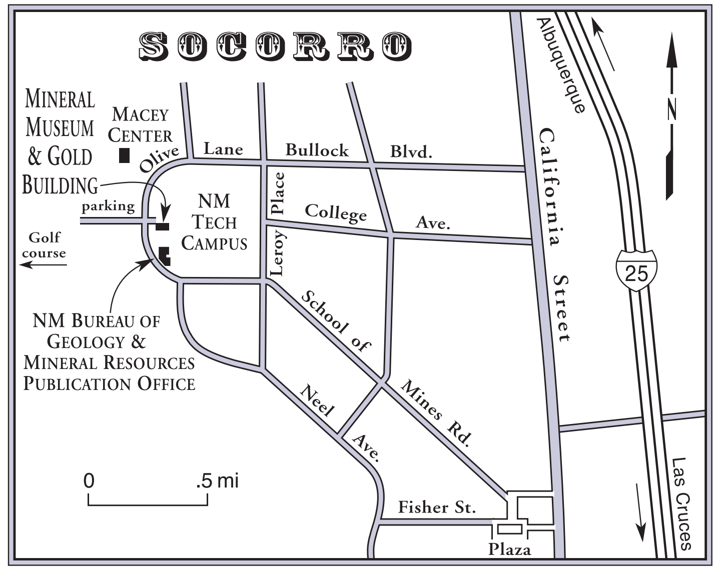
Bureau geologist Shari Kelley (center) leads a discussion with Lynn Heizler (left) and Wendell Eoff on how differences in eruptive mechanisms can be explained by comparing particle-size distributions of adjacent pumice layers. *Photo courtesy of Linda Brown.*

Carol Thompson tests the water of sediment-laden streams at Battleship Rock. The high sediment load in the stream is due to the Las Conchas fire one year ago that denuded hillsides, causing increased soil erosion and ash to wash into the streams. *Photo courtesy of Linda Brown.*

Classroom teachers in grades 1–12 are encouraged to apply for the 2013 Rockin' Around New Mexico, which will be held on the campus of New Mexico Tech in Socorro. Optional graduate credit for this workshop is available through the Master of Science for Teachers program at New Mexico Tech. There is a $40 materials fee in addition to tuition and fees if participants register for the graduate credit. Registration begins in April 2013. For more information, contact Susie Welch at the New Mexico Bureau of Geology at **susie@nmt.edu**, or 575-835-5112.

Our Partners: Rockin' Around New Mexico relies on partnerships between the New Mexico Bureau of Geology/New Mexico Institute of Mining and Technology, New Mexico Department of Homeland Security and Emergency Management, New Mexico Geological Society, and other agencies and private companies that provide funding and instructor support. In 2011 and 2012, we also collaborated with the Valles Caldera National Preserve/Science Education Center in Jemez Springs.

Short Items of Interest to Teachers and the Public



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The Mineral Museum is located in the Gold Building on the campus of New Mexico Tech in Socorro. The bureau's mineralogical collection contains more than 16,000 specimens of minerals from New Mexico, the United States, and around the world, along with mining artifacts and fossils. About 2,500 minerals are on display at a time.

For teachers, students, and other groups, we offer free tours of the museum. We like to show off our home state minerals, as well as give students an idea of how minerals end up in products we use every day. Museum staff can also identify rocks or minerals for visitors. Please call ahead to ensure someone will be available. For more information on the museum, please visit our website at: **http://geoinfo.nmt.edu/museum/**

Dr. Virgil W. Lueth
Senior Mineralogist and Curator
vwlueth@nmt.edu
575-835-5140

Bob Eveleth
Senior Mining Engineer and Associate Curator (emeritus)
beveleth@nmbg.nmt.edu
575-835-5325

To Schedule a Museum Tour, Contact:

Susie Welch
Manager, Geologic Extension Service
susie@nmt.edu
575-835-5112

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UPCOMING EVENTS FOR TEACHERS AND THE PUBLIC

National Earth Science Week

October 14–20, 2012

Help celebrate Earth Science Week 2012! The American Geological Institute, which sponsors this event each year, encourages people everywhere to explore the natural world and learn about the geosciences. "Discovering Careers in the Earth Sciences," the theme of ESW 2012, encourages everyone to explore the many possibilities of working as an earth scientist or in a related field. You can request your Earth Science Week Planning Toolkit with cool resources and ideas about how to plan your own celebration online at:
http://www.earthscienceweek.org/

Fall Conference for Math, Environmental and Science Educators

October 11–13, 2012
Albuquerque, New Mexico

This conference will be held at the Bosque School in Albuquerque with the theme "Soar to Greater Heights: Growing STEM for the Next Generation." Session topics will address the opportunities and techniques for preparing the next generation for science, technology, engineering, and mathematics (STEM). The conference opens with a keynote address from Dr. Kenneth Wesson titled: "How Children Learn: Brain Research and Inquiry-Based Science." Find out more about the conference and register at the New Mexico Science Teachers Association website: **http://www.nmsta.org/**

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