WINTER 2024

New Mexico EARTH MATTERS

Published by the New Mexico Bureau of Geology and Mineral Resources • A research and service division of New Mexico Tech

Alamosaurus
The Last of the Super-Giant Dinosaurs from New Mexico

The New Mexico Museum of Natural History & Science is showcasing the gigantic New Mexican sauropod dinosaur *Alamosaurus* with a permanent exhibit that opened in March 2023. The display explores the history behind its fossil discovery in northwestern New Mexico in 1921—a discovery that not only unearthed one of the largest animals to ever set foot in what's now New Mexico but also provided clues for how, when, and where this massive family of dinosaurs lived.

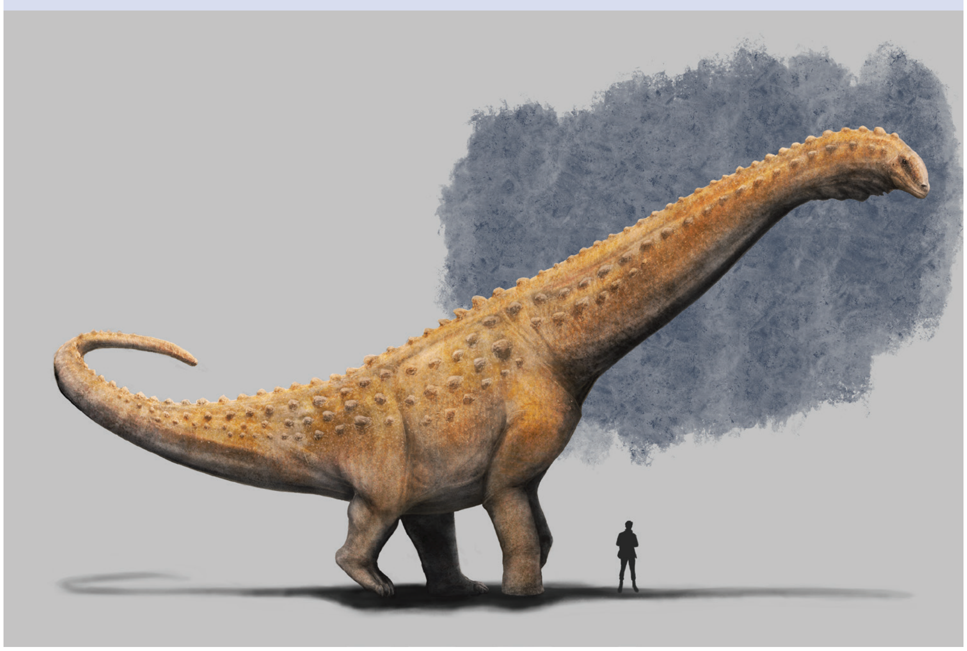
Although the museum does not have a full skeleton of an *Alamosaurus*, the gorgeous display includes bones, teeth, and other fossil material. The exhibit poses questions about the massive sauropod's lifestyle: How did such an enormous animal digest food with such small teeth? Were they solitary creatures or did they roam in herds? Did they have any predators, such as *Tyrannosaurus rex*?

For information about visiting the exhibit, go to **nmnaturalhistory.org/exhibits/exhibits/alamosaurus-new-mexico-icon** or call (505) 841-2800.

In June 1921, U.S. Geological Survey geologist John B. Reeside Jr. discovered fossils from Barrel Springs Arroyo, near Ojo Alamo in the San Juan Basin of northwestern New Mexico, that would radically change our understanding of sauropod dinosaurs. Sauropod dinosaurs are among the most iconic of all dinosaurs, easily recognizable by their small head at the end of a long neck, long tail, and pillar-like legs under stout trunks. Sauropods include the largest dinosaurs of all time, such as *Brachiosaurus*, *Alamosaurus,* and *Argentinosaurus*—the largest vertebrate animals ever to walk the earth.

Dead As a Dinosaur

Up until the early 1920s, scientists believed that the world's largest terrestrial vertebrates—sauropod dinosaurs—had declined and were extinct by the end of the Early Cretaceous Period about 100 million years ago, long before the end of the Mesozoic Era 66 million years ago. Although researchers reported discoveries of sauropod fossils from Upper (younger) Cretaceous rocks of South America, Europe, Africa, and Asia in the late 1890s, serious objections had been raised about their identification or age.

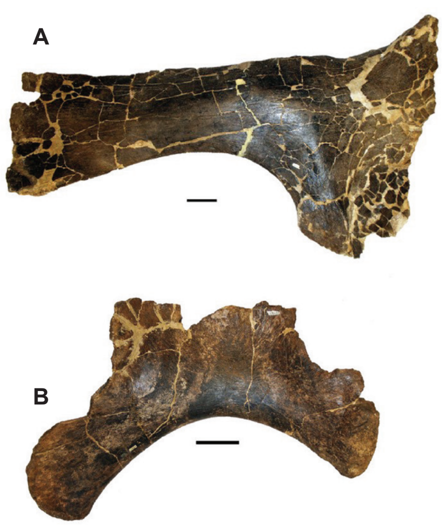


Reconstruction of the super-giant titanosaur *Alamosaurus sanjuanensis*. *Alamosaurus* had an estimated mass of at least 33 tons (66,000 lbs), approximately the mass of a fully loaded cement truck. A paleoartist can express in a picture much of what paleontologists have gleaned from fossils after years of research. This depiction of *Alamosaurus* draws on careful analysis of fossil bones from museum collections, examination of mounted skeletal reconstructions, research from scientific publications, and study of large, living animals. *Artwork by Ian Hutchinson*

Stumbling Upon History

After walking badlands outcrops along the wagon trail leading to the Ojo Alamo Trading Post, John Reeside discovered two large bones, a partial scapula (shoulder blade) and a partial ischium (a bone of the pelvis), that were found in the same rock layer but about 200 feet apart. The area where Reeside made this momentous discovery encompasses Upper Cretaceous strata that are rich in fossil vertebrates. This particular interval is called the Naashoibito Member of the Ojo Alamo Formation and, based on recent research, is Maastrichtian in age (about 66 million years old).

Although Reeside considered himself to be a paleontologist, it's not clear that he understood the significance of his find. Regardless, he promptly collected the specimens, crated up the large bones, brought them down to the railhead near Crownpoint, and shipped them to Charles W. Gilmore, a vertebrate paleontologist at the Smithsonian Institution in Washington, D.C. Reeside knew that Gilmore was one of the leading dinosaur experts of the time and would appreciate his find. Gilmore first mentioned the discovery in the journal *Science* that year, and in 1922, he gave a more thorough description, naming the new dinosaur *Alamosaurus sanjuanensis*. The name *Alamosaurus sanjuanensis* means the "Alamo lizard of the San Juan" and refers to Alamo Spring. (Alamo is the Spanish word for cottonwood.) Gilmore noted the significance of this find in the journal *Smithsonian Miscellaneous Collections*,



Fossil specimens of *Alamosaurus sanjuanensis* collected in 1921 by U.S. Geological Survey geologist John Reeside and now housed at the National Museum of Natural History in Washington, D.C. (A) A nearly complete left scapula (USNM 10486); (B) a nearly complete right ischium (USNM 10487). Scale bar equals 10 cm. *Pictures courtesy of Robert Sullivan*

where he wrote, "The great importance of these particular bones lies in the fact that the remains of Sauropodous dinosaurs have not previously been known to occur above the Lower [older] Cretaceous in North America, so that the extension of their geological range into the Upper Cretaceous is of the greatest paleontologic and geologic interest."

The Find That Keeps On Giving

More than 100 years after Reeside discovered *Alamosaurus* and Gilmore described and named the giant, scientists are continuing to learn more about the biology and evolutionary history of *Alamosaurus* and of all sauropod dinosaurs. In the past few decades, our knowledge of sauropod dinosaurs has expanded immensely, and *Alamosaurus* has played a critical role in this new understanding.

It's Complicated

Sauropod dinosaurs have a complex evolutionary history. After originating in the Late Triassic about 210 million years ago, or perhaps earlier, sauropods rapidly diversified into several distinct groups. Sauropods ultimately spread to all major land masses and flourished to the very end of the Mesozoic, a remarkable span of well over 130 million years.

Sauropoda include the very largest of all dinosaurs. However, not all sauropods were giants. Scientists have learned that some sauropods were comparatively small or "dwarfish." The smallest of these "dwarfs" attained sizes of only about 13 to 20 feet in length, with a total mass of only about a ton (2,000 lbs), about the size of a modern Angus cattle bull. That is absolutely tiny compared to the largest sauropods.

The largest sauropods weren't just big, they were immense. The largest, probably the Cretaceous titanosaurian *Argentinosaurus*, was a behemoth, measuring over 100 feet in length and weighing over 75 tons (150,000 lbs). *Argentinosaurus* had a mass comparable to that of seven bulldozers! *Alamosaurus* was also very large, falling into the "super-giant" category of sauropods. Mass estimates, arguably the best way to compare the relative size of various sauropods, indicate that *Alamosaurus* was at least 33 tons (66,000 lbs). Some paleontologists have proposed that it attained an even greater size based on a very large, single bone of the spine found near Alamo Wash that rivals that of the very largest sauropods.

Remarkably, recent meticulous studies of the evolutionary history of sauropods with body mass estimates for over 100 different species reveal that sauropods evolved from a modest body mass of about 5 tons to a gigantic size (about 20 tons, a size that exceeds the mass of the largest land mammals) over 30 times throughout their long 130-million-year history.

Sauropods reached their zenith in terms of diversity and apparent abundance in North America during the Late Jurassic, approximately 150 million years ago. This is a time when the Rocky Mountains were populated with well-known dinosaurs such as *Camarasaurus*, *Barosaurus, Diplodocus*, *Brontosaurus*, *Amphicoelias*, *Apatosaurus,* and *Brachiosaurus. Apatosaurus* has undergone an interesting evolution of its own in terms of nomenclature. Although scientists for many years have regarded *Brontosaurus* as a junior synonym of *Apatosaurus*, scientists have recently suggested that both *Brontosaurus* and *Apatosaurus* are valid names.

Scientists have discovered fossils of these giant sauropods in the Upper Jurassic Morrison Formation. New Mexico's own *Seismosaurus hallorum* was collected from the Morrison Formation within what is now the Ojito Wilderness area near San Ysidro, about 50 miles north of Albuquerque. Most scientists regard *Seismosaurus* as a synonym of *Diplodocus*. In popular media, *Seismosaurus* is famous as the world's longest dinosaur, but recently, scientists have suggested that it had a length ending with its whiplash tail of only about 100 feet. This new evidence diminishes *Seismosaurus'* notoriety as "the world's longest dinosaur" because it falls short of the lengths estimated for the very large sauropods.

You Are What You Eat

All sauropods were plant eaters. These humongous animals required enormous quantities of food to grow and maintain their sizes. Sauropods likely ate diets of lower-quality nutritional value because, out of necessity, they had to focus on food that was sufficient and available. To get their daily requirements of nutrition, sauropods had to eat a lot. One recent estimate found that a 13-ton sauropod ate about 1,150 pounds of food a day. Sauropods had to eat almost continuously. Still, even with the vast quantities of food that sauropods consumed, scientists have pondered why and how they achieved such titanic dimensions.

It may be that sauropods could evolve into huge animals because of their unique combination of features. Sauropods had long necks that enabled them to gather foliage that was out of reach to most other animals, and with relatively little effort. A sauropod could stand in one place for hours without moving because their long necks and heads could do all the work.

Sauropods replaced their teeth throughout their lives, shedding old, worn teeth as new teeth grew in from beneath. Studies of the growth lines preserved in teeth reveal that some sauropods replaced their teeth very swiftly, no doubt due to the rapid wear caused by their ceaseless use. Sauropods must have eaten nearly constantly to fuel their giant bodies. *Diplodocus*, which has pencil-shaped teeth similar to those of *Alamosaurus*, replaced its teeth at a rate of about one per month, whereas *Camarasaurus*, which has larger, spoon-shaped teeth, replaced them at a slower but still rapid rate of about one every two months.

Sauropods had another anatomical feature that helped them succeed: enormous guts that allowed them to digest and ferment poor-quality plant material efficiently. Sauropods also had bird-like lungs that provided ample oxygen (much more than mammalian lungs can take in) and a surprisingly light spine due to the air sac extensions from their bird-like lungs.

Although sauropod dinosaurs were long depicted as slow and sluggish animals, recent studies of their development based on growth rings preserved in their bones indicate that most sauropods reached sexual maturity and adult size in 30 to 40 years and lived up to about 70 to 80 years. This means that sauropods grew very quickly, at rates comparable to those of mammals. Such high growth rates require ferocious metabolisms, and therefore sauropods likely rambled across the landscape in a way similar to that of large mammals such as elephants.

Alamosaurus, Member of an Exclusive Club

Alamosaurus is a member of the titanosaurs, one of only two lineages of sauropod dinosaurs that persisted into the Late Cretaceous. Titanosaurs were the only group of sauropods that continued until the very end of the Mesozoic. Titanosaurs include the very largest of all dinosaurs, *Argentinosaurus,* and were widely distributed in the late Mesozoic. Scientists have discovered fossils of titanosaurs on every continent on Earth.

Complete fossilized hind foot (pes) of *Alamosaurus sanjuanensis* (NMMNH P-49967) from the San Juan Basin. The clawed front of the foot is toward the viewer. The foot measures about 2 feet across.

A femur (upper leg bone) of the super-giant titanosaur *Alamosaurus sanjuanensis* in the process of being uncovered from the Naashoibito Member, Ojo Alamo Sandstone, Barrel Springs Arroyo (now De-Na-Zin Wash), within the Bisti/De-Na-Zin Wilderness Area in early 2023. Noah Clayborne for scale.

Titanosaurs had wide bodies with widely spaced feet, giving them a very distinctive appearance and gait. Paleontologists instantly recognize titanosaur tracks by their wide-gauge handprints and footprints, which are spread out farther from the midline of their trackways than in other sauropods. Trackways show that sauropods walked slowly at speeds of 2 to 2.5 miles per hour without dragging their tails.

The forefeet of titanosaurs lacked the broad, fleshy pads that cushion the footfalls of large mammals such as elephants, and, strangely, the forefeet of most titanosaurs lacked ossified toe bones. Instead, their forefeet ended in stumps at the end of their metacarpals, giving their handprints a distinctive horseshoe shape. The hind feet were broad, and each bore at least three large claws. A nearly complete hind foot from the Naashoibito Member of New Mexico that almost certainly belongs to *Alamosaurus* measures about 2 feet across, which is large relative to the hind feet of other sauropods.

Another feature unique to titanosaurs is that they were the only sauropods to possess osteoderms (bone embedded within their skin). Osteoderms were discovered with a partial skeleton of *Alamosaurus* collected in the 1940s from the North Horn Formation of central Utah. These osteoderms consist of only a few fragmentary masses of spongy bone, the most complete of which is an oblong, flattened, and bumpy lump about 10 inches long. Titanosaurs probably had only a few osteoderms, and they were likely arranged in a single paired row along the back. Scientists do not know the function of such osteoderms, but perhaps they served as calcium reservoirs to make eggshells. Paleontologists have discovered nesting sites for at least one titanosaur. The females apparently laid large clutches of at least 25 eggs, possibly amounting to hundreds of eggs per year per female titanosaur. Some preserved titanosaur eggs were only about 5 inches in diameter, surprisingly small considering the enormity of the adults. Sauropod dinosaurs owed at least some of their long success to their ability to produce many offspring without investing much energy or resources in their later care.

The Long Hiatus

In North America, sauropod dinosaurs declined in diversity into the Early Cretaceous, and by the beginning of the Late Cretaceous, about 100 million years ago, they were gone. Scientists do not understand the reason for this disappearance, but it appears to coincide with a complete reshuffling of North American terrestrial ecosystems during the middle part of the Cretaceous. About this time, specifically on the northern continents of Laurasia (a large continental mass representing northern Pangea, including North America, Europe, and Asia), duck-billed dinosaurs and ceratopsian dinosaurs appear to replace sauropods and other herbivores. Not only were plant eaters affected during this time period, but large tyrannosaurs replaced the top predators, the allosaurs. Inexplicably, many of the dinosaur groups that disappeared from the northern continents continued to thrive on the southern continents of Gondwanaland (a large continental mass representing southern Pangea, including South America, Africa, Antarctica, Australia, and India).

Sauropod dinosaurs are completely absent from the North American fossil record for most of the Late Cretaceous, an interval spanning about 30 million years that is called the "sauropod hiatus." The hiatus finally came to an end with the appearance of a single sauropod genus and species, *Alamosaurus sanjuanensis*, in the American Southwest around 69 million years ago. Since Reeside's initial New Mexico discovery in 1921, scientists have discovered fossils of *Alamosaurus* in latest Cretaceous rocks of West Texas (Javelina and Black Peaks Formations), central Utah (North Horn

Formation), and south-central New Mexico (McRae Formation).

Unfortunately, paleontologists have had to base their research on mostly incomplete specimens of most sauropod taxa, and especially of titanosaurs. Fortunately, *Alamosaurus* is much better known than most titanosaurs due to the larger number of specimens available for research. Some of these specimens include partially associated and even articulated (connected) parts of the skeleton, which makes *Alamosaurus* one of the better-known giant titanosaurs. This wealth of specimens has greatly helped us understand the biology and evolutionary history of these astonishing animals.

New In Town

Alamosaurus appeared abruptly in the fossil record near the very end of the Cretaceous, around the beginning of the Maastrichtian Age (about 72 million years ago). It likely emigrated from outside of North America, bringing to an end the 30-million-year-long “sauropod hiatus.” However, some researchers have suggested that sauropods continued in North America throughout this interval but were restricted to highland environments, thus leaving no fossils, or leaving fossils that are so rare that they have yet to be found. This seems unlikely, considering that the reappearance of sauropods in the Maastrichtian consists only of a single genus and species that does not appear to be especially closely related to any Early Cretaceous North American sauropods. There has also been debate regarding the origin of *Alamosaurus*. Did it come from South America or Asia? A dispersal from South America is more likely for two reasons. First, evolutionary studies indicate that *Alamosaurus* is more closely related to Late Cretaceous South American species than to any Asian titanosaurs. Second, while a dispersal route appears to have been open between North America and Asia, at least intermittently, through most of the Late Cretaceous, based on the many closely related dinosaur groups shared between the two land masses, sauropods did not appear until the very end of the Cretaceous. What would explain the delay? South America, on the other hand, was almost completely isolated from other continents throughout the Late Cretaceous. The sudden appearance of *Alamosaurus* in the American Southwest coincided with the dispersal of hadrosaurs into South America. This coincidence suggests a sudden opening of a land bridge between the two continents near the end of the Cretaceous, allowing both groups of dinosaurs to disperse, though in opposite directions. Why *Alamosaurus* remained restricted to just the American Southwest after entering North America is an ongoing mystery.

After entering North America, *Alamosaurus* apparently flourished in the American Southwest for several million years, where it coexisted with iconic Late Cretaceous dinosaurs like hadrosaurs and ceratopsians, such as *Torosaurus*, and perhaps the most iconic Late Cretaceous dinosaur of all, *Tyrannosaurus rex*. It is unknown if *T. rex* actively preyed upon adult *Alamosaurus*, but it undoubtedly fed on their gigantic carcasses. That would have been a sight to behold!

Mounted reconstructed skeleton of *Alamosaurus sanjuanensis* at the Perot Museum of Nature and Science in Dallas, Texas, dwarfs a mounted skeleton of *Tyrannosaurus rex*, a potential predator of the super-giant sauropod during the latest Cretaceous of the American Southwest.

From Dull to Dynamite

The discovery of *Alamosaurus* has helped to change our understanding of sauropod dinosaurs. Scientists once believed that sauropods were huge, lumbering, tail-dragging, often water-bound behemoths, doomed to extinction through their obsolescence. Now we know that they were vibrant and successful members of diverse dinosaur faunas that were thriving right up until that last dreadful day of the Cretaceous when a killer asteroid fell from the sky and Earth burned.

Dr. Thomas E. Williamson

Tom Williamson is curator of paleontology at the New Mexico Museum of Natural History & Science.

Dr. Stephen Brusatte and Dr. Michael D’Emic are gratefully acknowledged for reviewing the manuscript.

Bureau News

Mike Timmons Selected as Director and State Geologist

After 31 years of extraordinary service to the Bureau of Geology and New Mexico Tech, bureau director and state geologist Dr. Nelia Dunbar has retired. Hired in 1992 as a research-focused geochemist, Nelia served as deputy director starting in 2011 and was promoted to director in 2016. She directed the electron microprobe laboratory for many years, published 111 peer-reviewed articles, and served as an adjunct faculty member in the Earth and Environmental Science Department at NMT, where she taught classes and advised graduate students. The NMT Board of Regents has granted Nelia emerita status, and she will remain active at the bureau, focusing on research, outreach, and education.

After completing a Grand Canyon PhD in 2004, Dr. Mike Timmons joined the bureau as manager of the geologic mapping program. He was promoted to associate director in 2010 and deputy director in 2014. Mike writes that "Global climate change will impact New Mexico in ways that will challenge the health and economic well-being of the state and its citizens. We will build capacity and modernize the Bureau of Geology to meet the natural resource challenges facing the state. We are already working to position the bureau as a center of cutting-edge applied research and as an online library of information accessible to all New Mexicans. Our work in water, natural hazards, hydrogen and carbon sequestration, and critical and strategic minerals will help position the state as a leader in a sustainable global economy."

Ginger McLemore in Mining Hall of Fame

"Anyone who wants to know anything about mining in New Mexico goes to Ginger to get their answers," according to the New Mexico Mining Association, which inducted Dr. Virginia "Ginger" McLemore into the New Mexico Mining Hall of Fame. Ginger was hired by the Bureau of Geology in 1980, and in her role as principal economic geologist and minerals outreach liaison, she studies Earth materials and minerals that can be used for economic and industrial purposes. Her work explores how such minerals form, how to find and mine them, and how to reclaim mined sites. As an adjunct faculty member at New Mexico Tech, she has taught and advised scores of graduate students over the years.

Workshop to Advance Geothermal Energy

A Bureau of Geology-hosted workshop designed to accelerate in-state geothermal energy development was held at New Mexico Tech. Forty representatives from national labs, universities, the geothermal industry, and the state legislature attended in person. An additional 25 people, mostly from the national and international geothermal industry, attended remotely. The workshop's goals included encouraging discussions among members and identifying barriers to and opportunities for local geothermal development. The workshop ended with a discussion of the next steps for the 2024 state legislature and planning to create a partnership that will propose ways to eliminate barriers to developing clean geothermal energy in New Mexico.

Aquifer Mapping, Water Education, and Hydrologic Data

Beginning with the Aquifer Mapping Program (AMP) in 2006, hydrogeology programs at the bureau have expanded in response to public and state demands. In 2016, with Healy Foundation grants, the AMP broadened to include 3D groundwater maps and launched the Healy Collaborative Groundwater Monitoring Network, which tracks groundwater levels across the state. In 2019, after passage of the New Mexico Water Data Act, a collaborative, multi-agency effort known as the Water Data Initiative was established to develop modern data standards, online databases, and data-sharing tools, while enhancing data literacy with collaborating agencies. In 2022, through philanthropic support from the Thornburg Foundation, the Water Education Program was developed. In 2023, with state appropriations, this program hosted two Chama River educational experiences for water leaders and has Water Leaders Workshops planned for 2024. Additionally, 2023 special appropriations and junior funding from state legislators have launched a Rio Arriba County regional hydrogeology and aquifer study and supported data system upgrades and new staff for the Water Data Initiative. The continued growth of hydrogeology programs at NMBGMR supports the expanding demands for modern water research, online information, and water education in the state.

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Volume 24, Number 1

Published twice annually by the
NEW MEXICO BUREAU OF GEOLOGY
AND MINERAL RESOURCES

A research and service division of
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Cover photo of intrusive igneous rocks of the Florida Mountains by Ethan Mamer

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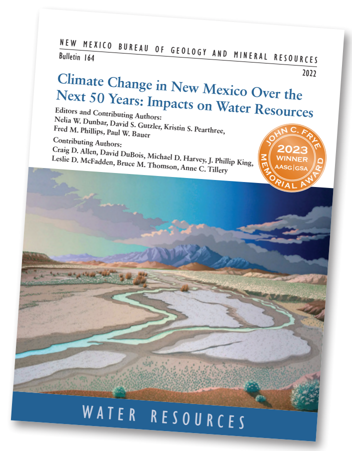
Publication News



Climate/Water Bulletin Wins National Award

The Bureau of Geology received the Geological Society of America (GSA) and the Association of American State Geologists 2023 John C. Frye Environmental Geology Award for a landmark report entitled "Bulletin 164: Climate Change in New Mexico Over the Next 50 Years: Impacts on Water Resources." This annual award recognizes the best paper on environmental geology published by a state geological survey or the GSA. The bulletin represents the scientific foundation for New Mexico's 50-Year Water Plan. The impacts of climate change on New Mexico's waters are overwhelmingly negative, but the report will help scientists and decision makers plan for a more arid future.

2024 Calendar Now Available!

Our 2024 Bureau of Geology calendar features gorgeous photos from across New Mexico taken by the bureau's many fine amateur photographers. Available now at our bookstore on the New Mexico Tech campus, or scan the QR code to purchase online.