



New Mexico EARTH MATTERS

SUMMER 2017

COELOPHYSIS, THE NEW MEXICO STATE FOSSIL

Many of us are aware that the State of New Mexico has a state gemstone (Turquoise), a state flower (Yucca), a state bird (Roadrunner), and even a state question (Red or Green?). But how many know that New Mexico also has an official state fossil? And that this particular fossil is one of the scientifically best-known and most important dinosaurs in the world? New Mexico has an incredibly rich fossil record and many remarkable fossil organisms have been recovered here. But one in particular, a relatively small, and at first glance, unassuming, animal was chosen by the New Mexico state legislature on March 17, 1981, to be the New Mexico State fossil. That honor was bestowed on the uniquely New Mexican dinosaur *Coelophysis bauri* (pronounced “see-low-fy-sis”). This is a brief account of its initial finding, and subsequent discovery of one of the most famous dinosaur quarries in the world, the Ghost Ranch *Coelophysis* Quarry. When discovered, *Coelophysis* was one of the oldest dinosaurs in the world, and the remains of this animal continue to inform us about the world of the Late Triassic (about 225 to 202 million years ago) and the rise of the ruling reptiles, the dinosaurs.

Discovery

The bones of *Coelophysis* were first discovered by David Baldwin, a little-known figure who worked as a packer for the 1875 Wheeler Survey in northern New Mexico. Baldwin later roamed throughout northwestern New Mexico and collected and sold vertebrate fossils first to Othniel Charles Marsh of Yale University, and later, through the 1880s, to Marsh’s nemesis Edward Drinker Cope of Philadelphia. The rivalry and feud between Marsh and Cope, sometimes referred to as “The Bone Wars,” are legendary and sometimes are

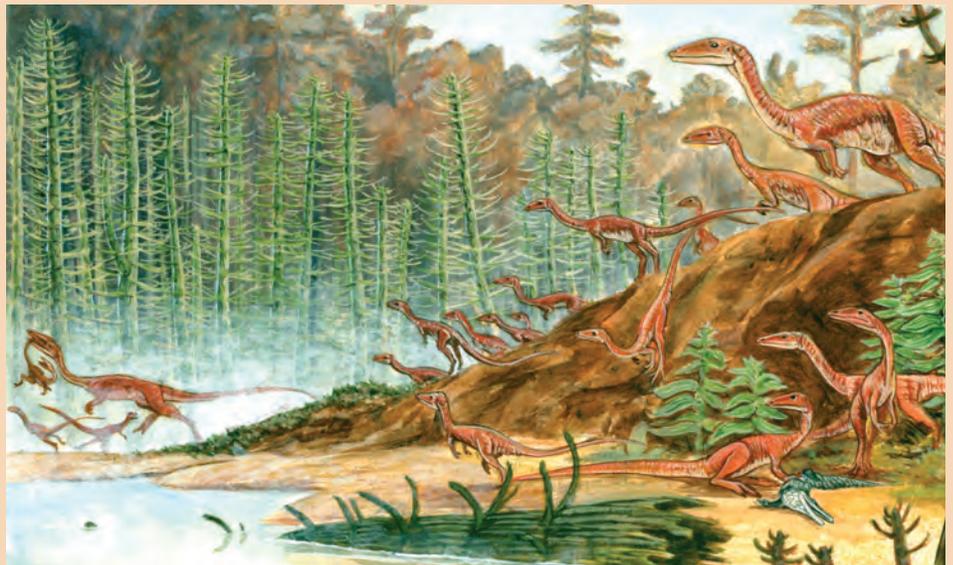
credited with jump-starting American science in the late 19th century.

In February 1881, while living in Abiquiu, Baldwin explored the Upper Triassic deposits of what is called the Chinle Formation a few miles north of town, in exposures along the Chama River at a locality he knew as Arroyo Seco. Baldwin often collected in winter, when a steady source of water was available as snow. He found a small concentration of delicate bones, which he picked up and placed in a sack. He included a note written in flowing black script, “*Contains Triassic or Jurassic bones all small and tender — Those marked little bones are many of them almost microscopic. All in this sack found together in same place. About four hundred feet below gypsum stratum Arroyo Seco Rio Arriba Co New Mexico February 1881. No feet — no head — only one tooth. D. Baldwin—Abiquiu.*”

He sent the sack, along with some additional specimens from near Gallina, to Cope in Philadelphia. Cope named them two species of a genus of small meat-eating dinosaur (theropod) previously named by Marsh; *Coelurus longicollis* and *Coelurus bauri*, writing that *Coelurus bauri* was “... about the size of a greyhound.” After further consideration, Cope moved both species to a different genus, first *Tanystrophaeus* and then the new genus *Coelophysis*. The name *Coelophysis* is derived from two Greek roots meaning “hollow form,” referring to the hollow bones of the small animal.

Ghost Ranch *Coelophysis* Quarry

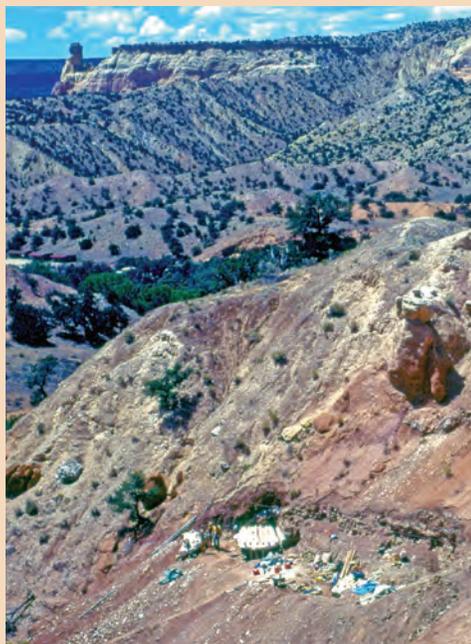
Several decades later, in 1947, Edwin Colbert, a curator of the American Museum of Natural History (AMNH), visited the Arroyo Seco area, which is near Ghost Ranch, while on his way to explore



A “flock” of *Coelophysis bauri* running across a Late Triassic landscape near what would become Ghost Ranch, New Mexico. Illustration by Matt Celaskey and Mary Sundstrom.

the Triassic in what is now the Petrified Forest National Park of Arizona. George Whitaker, a preparator on the American Museum's staff and part of Colbert's field crew, stumbled across a remarkable site in the Chinle Formation on Sunday, June 22, shortly before noon. Several days of careful excavation revealed what has become one of the most famous dinosaur localities in the world — the Ghost Ranch *Coelophysis* Quarry (also known as the Whitaker Quarry). Crews from the AMNH continued collecting through the next two summers, retrieving numerous blocks, some weighing several thousand pounds, containing complete skeletons of *Coelophysis* and other animals.

The Ghost Ranch *Coelophysis* Quarry was reopened in 1981 by crews from the Carnegie Museum of Natural History working cooperatively with several other institutions, including the then newly founded New Mexico Museum of Natural History, the Museum of Northern Arizona, and others. They recovered



Ghost Ranch *Coelophysis* Quarry undergoing excavation in late June, 1981. Photo courtesy of Timothy Rowe.

numerous additional blocks that have been widely distributed in museums across the United States for preparation and research. Several of the original blocks collected by the AMNH in the 1940s were opened only within the last ten years or so, and found to contain skeletons of animals other than *Coelophysis*, and several of the larger blocks collected by the Carnegie Museum continue to undergo preparation at the time of this writing.



Portion of a block from the Ghost Ranch *Coelophysis* Quarry collected in 1981 on display at the New Mexico Museum of Natural History and Science, showing a partial skeleton of *Coelophysis bauri* including the base of the tail, hind limbs and pelvic bones, dorsal vertebrae, and skull.

Some workers have estimated that about a thousand complete or nearly complete skeletons lie within the Ghost Ranch *Coelophysis* Quarry, a truly extraordinary accumulation of dinosaurs. *Coelophysis* is represented by young to old individuals, with bodies commonly intertwined and tangled. The quarry is overwhelmingly dominated by *Coelophysis*, but it also contains other animals including the small invertebrate conchostracans (clam shrimp) and ostracodes (seed shrimp), complete fish, a variety of archosaurs (archosaurs are a group of vertebrate animals that includes crocodiles, dinosaurs and birds, and their close relatives), including a crocodile-like phytosaur, long-limbed crocodile relatives (*Effigia* and *Vancleavea*), small reptiles like drepanosaurs and sphenodontids, and at least one other small, meat-eating dinosaur, *Daemonosaurus*.

What led to this accumulation of fossilized animals in a single location? Taphonomic studies (studies that look into what happens to organisms after death until their discovery as a fossil) of the quarry indicated that the bone bed is the result of transport of carcasses by running water and burial in silt, possibly in a small depression occupied by a pond. What killed the many hundreds of *Coelophysis* and other animals? That cannot yet be determined. Possibly the animals died in a drought. Perhaps animals congregated around a shrinking water source when flood waters overcame and drowned them and transported them to the *Coelophysis* Quarry site.

What's in a Name?

The name and identity of *Coelophysis* has been controversial. The original fossils collected by Baldwin, and described by Cope, are fragmentary and may not be complete enough to allow precise identification. In the early 1990s, a pair of New Mexican paleontologists therefore argued that *Coelophysis bauri* is a “*nomen dubium*” (doubtful name), and proposed a new name for the more complete Ghost Ranch specimens, *Rioarribasaurus colberti*. However, another team of paleontologists argued that since the name *Coelophysis bauri* has been applied to the Ghost Ranch specimens since 1947, it is best to designate one of the *Coelophysis* Quarry specimens a new type, or neotype, to maintain taxonomic stability. They petitioned the Commission of Zoological Nomenclature, which ruled in their favor in June 1996.

In the late 1990s, two paleontologists announced that they had discovered the area where Baldwin had collected the original type specimen of *Coelophysis bauri*, and named a new dinosaur from a partial skeleton that they had collected from the area, *Eucoelophysis baldwini* (meaning “Baldwin's true *Coelophysis*”). However, several years later, a pair of other studies demonstrated that *Eucoelophysis* is not a dinosaur, but rather a close dinosaur relative. Most paleontologists consider that the exact position of Baldwin's Arroyo Seco remains a mystery, although it likely was along the cliffs near Ghost Ranch.

Paleobiology

Coelophysis is a small dinosaur, belonging to the group Theropoda, that contains all meat-eating dinosaurs and birds. The many skeletons of *Coelophysis* provide for an incomparable knowledge of its skeletal anatomy. *Coelophysis* resembles other early dinosaurs in being bipedal (moved by means of its two rear legs) with a fully erect gait. Their bodies were long, with a relatively small head atop a long and sinuous neck. A long tail helped to balance their bodies over their hind legs. Early dinosaurs differed from other archosaurs in having a specialized hip-joint where the head of the femur bent at right angles and was securely socketed within a cartilage-lined hole within the pelvic bones. The ankle bones were tightly bound to the end of the distal hind limb bones, the tibia and fibula, thus preventing motion between the ankle and limb bones, but creating a hinge between the ankle bones and the bones of the hind feet. This allowed for very quick and steady motions of the long feet, but prevented flexibility. In other words, early dinosaurs were fleet-footed animals that sacrificed maneuverability for speed. *Coelophysis* had forelimbs that articulated with a backward-facing joint at the shoulder. The forelimbs ended in grasping hands with three functional, clawed fingers used for catching and holding prey. The teeth were small and blade-like, with serrated cutting edges, and were recurved—well-formed for biting and slicing small prey animals. All evidence points to *Coelophysis* being a swift predator that fed on smaller animals. The great number of animals buried together at the quarry suggests that the animals sometimes congregated in large “flocks.”

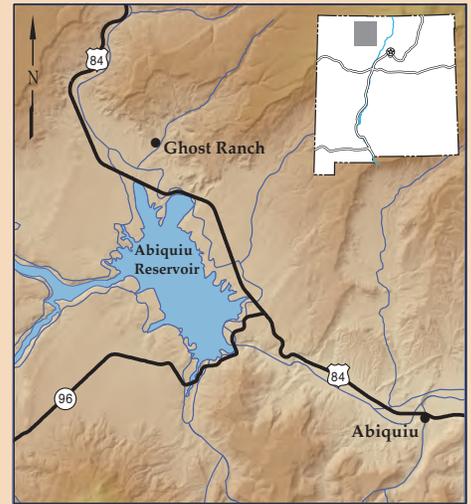
Many of the bones of *Coelophysis* are hollow with thin, delicate walls. This resulted in a very light-weight skeleton, like

that of birds. The neck vertebrae had side pockets that may have held air sacs tied to the respiratory system, such as are found in birds. Birds and many dinosaurs, including *Coelophysis*, had an ultra-efficient breathing system in which air is circulated in one direction across the lungs, enabled by the action of air sacs that were distributed throughout the body, and indeed even pervading many of the bones. These helped pump air through a rigid lung located within the chest cavity, and even allowed oxygen to pass across the lungs during both inhalation and exhalation.

Some specimens from the Ghost Ranch *Coelophysis* Quarry even preserve the extremely delicate, thin, plate-like bones that helped to support the eye, the sclerotic ring. These reveal the size and shape of the eye, indicating that *Coelophysis* was likely an animal that was active by day (diurnal), with excellent vision.

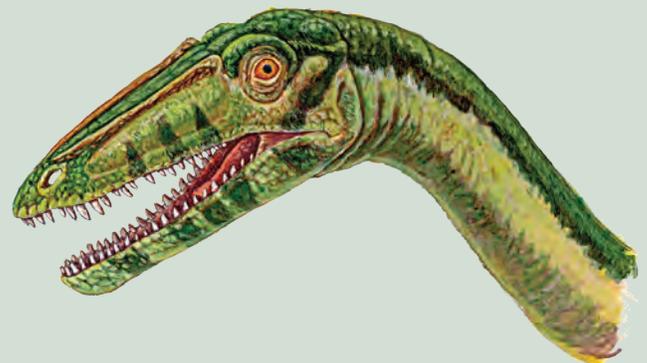
Based on studies published in 1989 and 1995, *Coelophysis* was deemed a cannibal based on the apparent existence of bones of juvenile *Coelophysis* within the gut of a larger adult. However, more recent examination of this specimen revealed that the alleged meal may not actually lie within the stomach area of the larger animal, but may be underneath it and showing through the ribs of the overlying body. Moreover, the smaller animal has also recently been identified as a small close relative of a crocodile, rather than a young *Coelophysis*. Intriguingly, in 2009, a group of scientists reported the bones of a small animal, possibly *Coelophysis*, in material that was regurgitated and excreted from a Ghost Ranch *Coelophysis* skeleton.

Dinosaur paleontologists have long worked to build a tree (known as a phylogeny) showing the evolutionary relationships among dinosaurs and

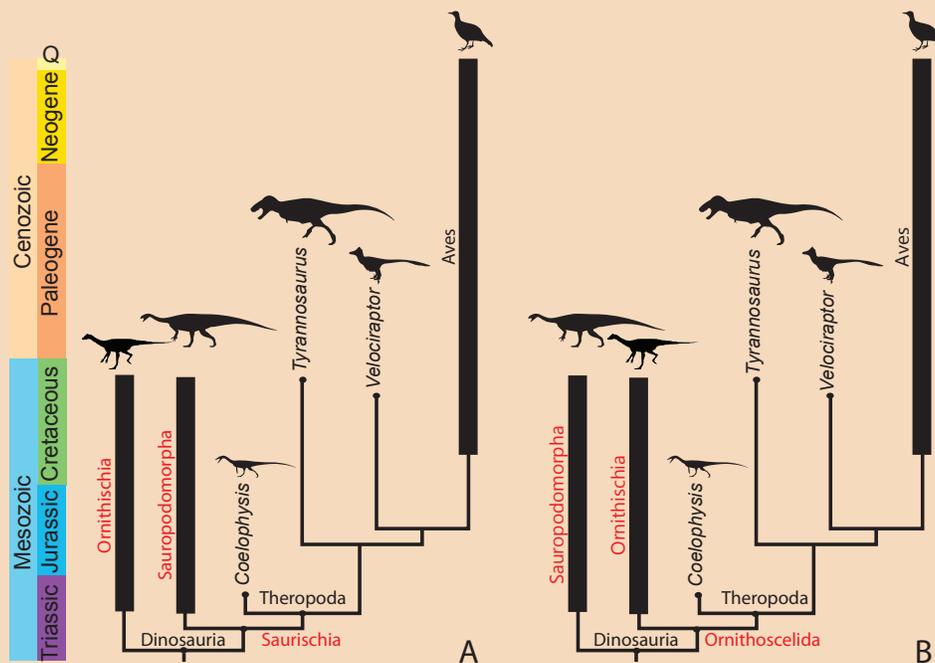


Location map of Ghost Ranch area.

their nearest relatives. A long-accepted phylogeny divides dinosaurs into two main branches or clades; the Saurischia (“lizard-hipped”) and Ornithischia (“bird-hipped”) dinosaurs. Theropod dinosaurs (including birds, ironically) are members of the Saurischia, along with sauropod dinosaurs and their closest relatives. However, a 2017 study shook up this long-standing hypothesis of dinosaur relationships, and posits a radically different phylogeny in which sauropod and their closest kin are lower on the tree, and theropod and ornithiscian dinosaurs are united in a more closely related group called the Ornithoscelida. This phylogenetic analysis, as well as others examining the relationships among early dinosaurs, typically rely heavily on data provided by the skeletons from the *Coelophysis* Quarry because of their completeness and excellent preservation. Time will tell if this recent and paradigm-shifting phylogeny is correct, but regardless, *Coelophysis* retains a similar position in both phylogenies near the base of Theropoda and demonstrates



Left: Close-up of the skull of *Coelophysis bauri* showing teeth and overlapping plates of the sclerotic ring that supported the eye. Right: Sketch of reconstructed head of *Coelophysis bauri*. Illustration by Matt Celeskey.



Two different time-calibrated dinosaur phylogenies. **A)** The long-accepted phylogeny with most dinosaurs placed within one of two main branches, the Saurischia (Sauropodomorpha and Theropoda) and Ornithischia. **B)** A recently proposed new phylogeny in which Sauropodomorpha are basal and Ornithischian dinosaurs are more closely related to Theropoda within the Ornithoscelida. Regardless, *Coelophysis* is a basal, early theropod dinosaur in both phylogenetic schemes.

just how quickly dinosaurs radiated into their primary divisions, after their Middle Triassic origin.

The large number of *Coelophysis* specimens provides not only a complete picture of the anatomy of an early dinosaur, but also important insights into the animal's ontogeny (growth and development) and variability within a species. While some studies have concluded that *Coelophysis* developed into a sexually dimorphic species with one sex larger and more robust than the other, another, more recent analysis, suggests that *Coelophysis* and other early members of Dinosauria show much higher levels of size variation than later dinosaurs, or even among close dinosaur relatives, the crocodylians.

Coelophysis' World

Dinosaurs were one group among many within the Archosauria, a group of reptiles that rose following "The Great Dying," the great mass extinction at the close of the Permian Period about 250 million years ago when over 95% of all marine species and 70% of terrestrial (land-based) vertebrate species became extinct. It was during a rapid evolutionary radiation following the extinction that many new groups of animals, including mammals, arose from the ashes in a dramatically new world. Interestingly, dinosaurs did not dominate the world of the Late Triassic. Instead, they were not particularly diverse or remarkable

compared to other archosaurs. Dinosaurs did not come into their own and reach dominance until after the next mass extinction at the end of the Triassic, about 200 million years ago, when most other major groups of archosaurs became extinct.

The Late Triassic Earth was still assembled into the supercontinent Pangaea, allowing animals to essentially walk between all the major continents, unimpeded by ocean barriers. This largely explains the rapid dispersal and appearance of dinosaurs throughout the Late Triassic world, soon after their first evolutionary appearance at or near the Middle Triassic. Late Triassic faunas tended to be nearly cosmopolitan (extending across all or most of the world). Indeed, a dinosaur very closely related to *Coelophysis bauri*, possibly even placed within the same genus, "*Syntarsus*" *rhodesiensis*, is represented by numerous skeletons from Zimbabwe, Africa. *Coelophysis* lived over a span of about 5 million years at the very end of the Triassic Period.

The Late Triassic world may have provided a particularly harsh climate with rapidly fluctuating extreme climatic conditions, at least at the lower latitudes occupied by New Mexico. This might explain why no herbivorous dinosaurs, but only a low diversity of meat-eating theropod dinosaurs, such as *Coelophysis*, have been found in Late Triassic tropical areas, and why

plant-eating dinosaurs appear to have been restricted to only higher latitudes. Indeed, it may be that the high variability observed in several, basal, Late Triassic theropods, including *Coelophysis*, was an adaptation to an unstable environment and contributed to their subsequent survival and success in the Early Jurassic.

—Tom Williamson

Tom Williamson is a Curator of Paleontology at the New Mexico Museum of Natural History and Science. He is engaged in research on Cretaceous and Paleogene vertebrates with a special interest in dinosaurs and mammals, and the recovery and evolution of mammals following the Cretaceous-Paleogene (K-Pg) extinction. He has conducted research on the K-Pg record in the San Juan Basin for over 25 years. He thanks Dr. Sterling Nesbitt and Dr. Stephen Brusatte for reviewing this paper.

For more information on Coelophysis, see the following websites:

The New Mexico Museum of Natural History and Science website on *Coelophysis*: <http://nmstatefossil.org>

The Ghost Ranch Museum of Paleontology website: www.ghost ranch.org/explore/museums/museum-of-paleontology/

BUREAU NEWS

Aquifer Mapping Program receives gift from Healy Foundation

The New Mexico Bureau of Geology and Mineral Resources (NMBGMR) at New Mexico Tech has received an important gift to support investigation of New Mexico's water resources. In July 2017, the Healy Foundation provided a generous gift in support of two ongoing, and one new, water-focused projects for the state. This gift allows the NMBGMR's Aquifer Mapping Program to continue its public-private partnership of hydrologic research with the New Mexico-based, charitable Healy Foundation.



NM Bureau of Geology hydrologist Sara Chudnoff, in center, shown here training rural water operators on techniques of groundwater level measurements and documentation.

The first of the three projects funded by this gift strongly focuses on groundwater level monitoring in small and rural communities. NMBGMR staff members are providing outreach and education to rural well operators, creating a population of trained citizen scientists, capturing important regional water level trends. These measurements, which can be uploaded by well owners through a web portal, will be publicly accessed through the NMBGMR's website.

The goal of the second project is to produce 3D visualizations and explanations of the geology and shape of several of New Mexico's important aquifers. Many of New Mexico's neighboring states have aquifer maps, and use these to build understanding of groundwater resources.

The third study funded by this gift will begin a new, regional-scale hydrogeological investigation of the Sunshine Valley, north of Questa, NM. The project will involve collection of geological and hydrological data that will be used to better understand the groundwater resources of this region.

Healy Foundation support has allowed us to help improve the state's working knowledge of groundwater resources, communicating to the public, and continuing detailed scientific study of specific areas. This is truly a public-private partnership investment in New Mexico's water future.

For more information visit the New Mexico Bureau of Geology's Aquifer Mapping Program at <http://geoinfo.nmt.edu/resources/water/amp/home.html>.



Rockin Around NM 2017, Socorro

This year, bureau geoscientists led teachers on field trips focused on the tectonic history and water resource management of the Socorro area. In the photo above, emeritus bureau geologist, Dr. David Love, leads a participant through a slot canyon out in the Quebradas area, east of Socorro, NM.



Polished petrified logs in place on bureau grounds

Have you noticed three large polished petrified stumps near the fountain in front of the New Mexico Bureau of Geology building? If not, come by and have a seat! Thanks to NM Tech Property, Facilities Management, and Brian Wheeler for moving the logs, and to Alan Perryman and others for polishing them!



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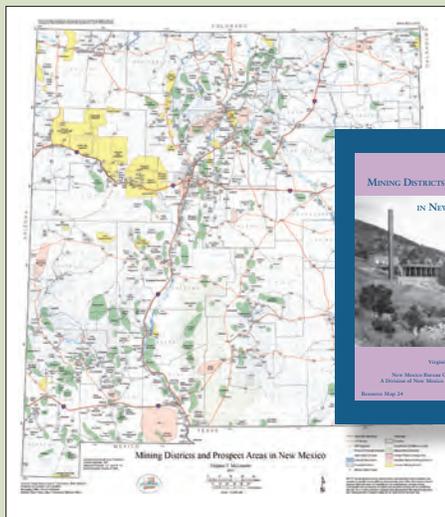
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Printed Map with booklet \$18.95.



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