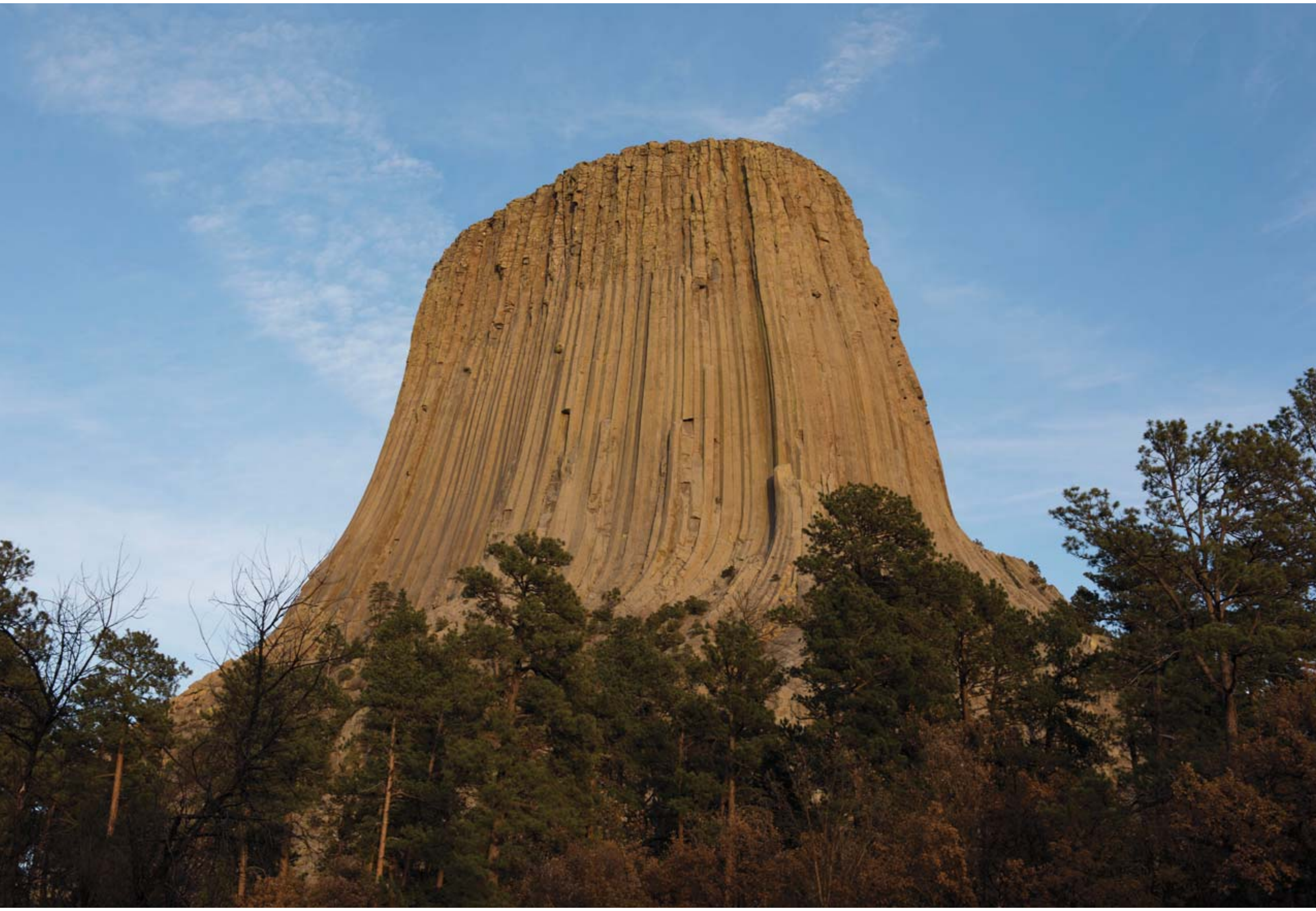
Intermountain Region
Resource Stewardship and Science

National Park Service
U.S. Department of the Interior

CROSSROADS IN SCIENCE

Where the Intermountain Region's Resource Stewardship and Science Programs and Centers Meet

Spring 2018



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—NATURAL RESOURCES—

"Age Of Reptiles": Uncovering the Mesozoic Fossil Record in Three Intermountain National Parks

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Introduction

The Mesozoic Era, commonly referred to as the "Age of Reptiles," is a period of Earth history known for tremendous changes in faunal and floral biodiversity and ecosystem evolution. Spanning approximately 185 million years, the Mesozoic is subdivided into three time periods: the Triassic (250-200 million years ago), the Jurassic (200-145 million years ago), and the Cretaceous (145-65 million years ago). The "Age of Reptiles" is widely recognized as the time when dinosaurs dominated the terrestrial environments and giant non-dinosaurian reptiles (ichthyosaurs, mosasaurs, plesiosaurs, etc.) inhabited the marine environments.

Three National Park Service areas (all within the Intermountain Region) are internationally recognized for their significant Mesozoic paleontological resources that contribute to our understanding of the Triassic (Petrified Forest National Park), Jurassic (Dinosaur National Monument), and Cretaceous (Big Bend National Park) (Figure 1). Collectively these parks preserve an extraordinary paleontological heritage available for scientific research and public education. From the dawn of the dinosaurs at Petrified Forest National Park through the terminal Cretaceous

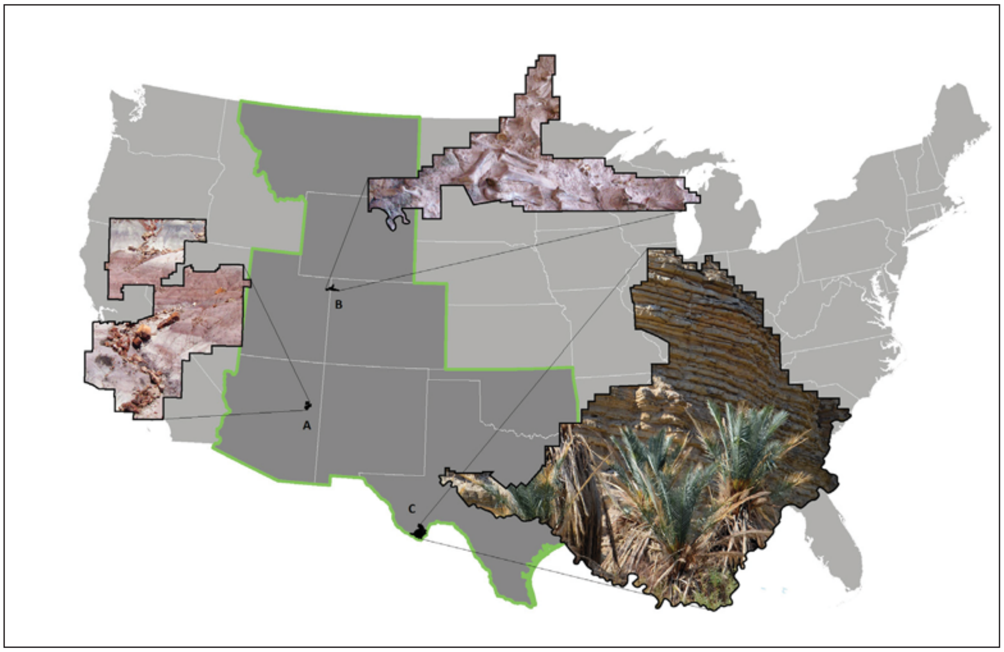

Figure 1. Map showing the location of three National Park Service areas which preserve outstanding fossils from the "Age of Reptiles" including: A) Petrified Forest National Park, Arizona; B) Dinosaur National Monument, Colorado and Utah; and, C) Big Bend National Park, Texas. (Graphic by Adam Marsh)

extinction event documented at Big Bend National Park, the fossils discovered in each park provides evidence for some of the most widely discussed scientific questions (Figure 2).

More than a century of paleontological field collecting and research has been undertaken in each of the park units. Museums across the United States and around the world display fossil specimens from Petrified Forest National Park, Dinosaur National Monument and Big Bend National Park. Remarkably, all three park units continue to attract researchers seeking to uncover new specimens and information to help expand our understanding of the "Age of Reptiles."

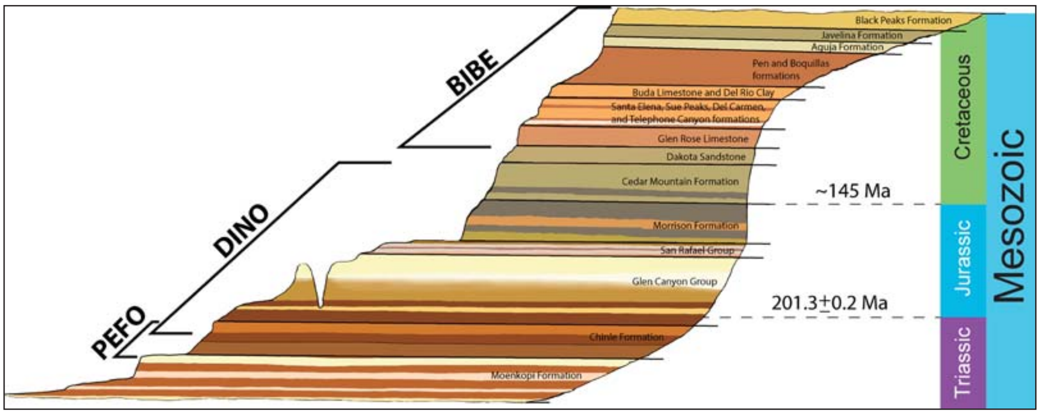

Figure 2. An idealized stratigraphic column showing the relationship of the various fossil producing geologic formations which span the "Age of Reptiles." Petrified Forest National Park (PEFO) preserves important Triassic rocks and fossils. Dinosaur National Monument (DINO) preserves important Jurassic rocks and fossils. Big Bend National Park (BIBE) preserves important Cretaceous rocks and fossils. (Graphic by Adam Marsh).

"Triassic Park" – Petrified Forest National Park

In western North America, the beginning of the Mesozoic Era is represented by the Moenkopi and Chinle formations. The geologic units were formed by a series of shallow marine carbonates and near-shore and fluvial mudstones, sandstones, and paleosols (fossil soils) of Early to Middle and Late Triassic age, respectively. The Chinle Formation is globally recognized for its vertebrate and plant fossils. Archosaurian reptiles such as phytosaurs, aetosaurs, and early dinosaurs make up the predominant fauna of the Chinle Formation (Figures 3 and 4). The abundant fossilized conifers, tree ferns, and cycads indicate a rich flora and diverse ancient ecosystem preserved at Petrified Forest National Park (PEFO) (Irmis, 2005; Ash, 2005). Established in 1906 through the authority of the Antiquities Act by President Theodore Roosevelt, Petrified Forest National Monument was set aside specifically to protect the *"scientific interest and value …[of] the mineralized remains of Mesozoic forests"* in the region (Proclamation No. 697). Because of this, fossil stewardship at Petrified Forest is identified within the park's enabling legislation.

Figure 3. A phytosaur skull found near Crystal Forest at Petrified Forest National Park. (NPS Photo)

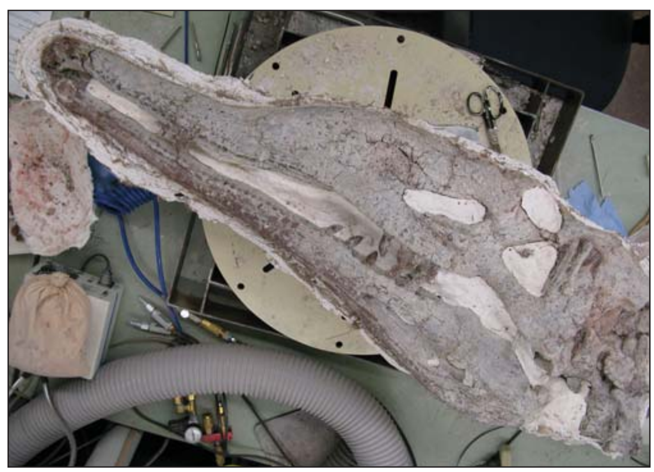

Figure 4. A portion of the snout from a new species of archosauriform reptile found at Petrified Forest National Park. (NPS Photo)

Paleontological field collecting at Petrified Forest National Park (PEFO) extends back over 100 years. Current research continues to uncover important new discoveries involving the geology and paleontology at the park (Parker, 2006; Parker and Martz, 2010). A recent research project in the park involved the drilling of a core through the entire geologic section at the park and confirmed that the Chinle Formation is almost 1,500 meters thick at the north end of the park (Olsen et al., 2014). The Triassic strata from the park consists of five subunits from top to bottom: the pink Owl Rock Member punctuated by thin limestone beds that are more prominent on the Navajo Nation to the north; the pastel red Petrified Forest Member of the Painted Desert; the sandier Sonsela Member; the dark blue and gray Blue Mesa Member; and the highly mottled Mesa Redondo Member (Martz and Parker, 2010; Martz et al., 2012). The recent emphasis on stratigraphy and geochronology has resulted in several high-resolution U-Pb detrital zircon dates throughout the section from around 208 Ma to 228 Ma (Riggs et al., 2003; Ramezani et al., 2011, 2014; Atchley et al., 2013; Nordt et al., 2015). These data indicate that the Chinle Formation at the park reflects more or less continuous deposition through almost 20 million years of the Late Triassic.

Figure 5. A histological thin section of a Late Triassic amphibian (metoposaur) intercentrum from Petrified Forest National Park. (Photo courtesy of B. Gee)

The current research focus at PEFO has been conducting a baseline fossil survey for new lands acquired in a boundary expansion. Student interns have been aiding this survey and have been publishing peer-reviewed papers on park topics like metoposaur bone histology (Gee et al., 2017) (Figure 5) and the first record of the actinopterygian fish *Saurichthys* in the Triassic of North America (Kligman et al., 2017). This fish specimen was discovered during an excavation in the boundary expansion-lands during a public field institute class. Additionally, a bonebed of a new species of archosauriform reptile was recently found and park paleontologists are preparing over 900 bones of the animal for publication and exhibition (Marsh et al., 2017). Of course, the origins of early dinosaurs remain an important part of the park story and researchers are discovering that PEFO's own dinosaur *Chindesaurus bryansmalli* was closely related to a meat-eating dinosaur found in Ghost Ranch, New Mexico, and not closely related to a group of more primitive South American herrerasaurids (Marsh et al., 2015).

Park paleontologists coordinate research within the park and continue working with institutions such as the Yale Peabody Museum, Los Angeles County Museum, and Burke Museum at the University of Washington to understand the wealth of fossil knowledge preserved at PEFO. While paleontological research in the area began over 100 years ago, the Chinle Formation at Petrified Forest National Park continues to be a rich source of information about the beginnings of the "Age of Reptiles" in North America.

Figure 6. Nearly lost amid a logjam of giant dinosaurs fossils on the face of the Carnegie Quarry, Geoscientist-In-Parks interns Nicole Ridgwell and Ben Otoo gather data for posting on the Carnegie Quarry website http://carnegiequarry.com/ (NPS Photo)

"Jurassic Park" – Dinosaur National Monument

The Carnegie Quarry, for which Dinosaur National Monument (DINO) was originally established in 1915, is one of the world's most famous fossil localities. Excavations from 1909-1924 resulted in the shipping of 800,000 pounds of fossils to the Carnegie Museum, the U.S. National Museum of Natural History, and the University of Utah. In 1958 the NPS took a radical new step in fossil resource stewardship by building the Quarry Visitor Center, an all glass building enclosing an unexcavated part of the quarry (Carpenter, 2013). Since then 1500 bones of 13 species of dinosaurs, turtles, and crocodiles have been excavated, exposed, and left in-place just as they were buried by an ancient river 150 million years ago (Chure and Englemann, 2013). Wildly popular with the public and the scientific community, this type of *in-situ* display has been copied at numerous fossil sites around the world. Because of the strong tilt of the fossil bearing sandstone, the Carnegie Quarry presents challenges for fossil preservation, curation, and stability not faced at other such fossil sites. Mitigating those threats has put DINO in the forefront of fossil conservation.

Figure 9. Three spectacular small crocodile skeletons, only 10 inches long, were found huddled together in the rocks of the Nugget Sandstone at Dinosaur National Monument. (NPS Photo)

Figure 7. This magnificent, uncrushed skull of the predatory dinosaur Allosaurus fragilis was found in the Carnegie Quarry and is now on exhibit in the Quarry Exhibit Hall at Dinosaur National Monument. (NPS Photo)

Figure 8. This tiny footprint, with four well preserved toe impressions, was made by a small reptile as it walked up the front of a sand dune in a 190 million year old desert now part of the Nugget Sandstone at Dinosaur National Monument. (NPS Photo)

The Carnegie Quarry has a rich historical record of excavation, study, resource management, and public education composed of photos, diaries, reports, correspondence, and publications (Figure 6). Launched in 2015, the Carnegie Quarry website http://carnegiequarry.com/ brings together the information from our archives and makes it freely available to the scientific community and the public.

Beyond the Carnegie Quarry, DINO contains 23 geologic formations preserving 1.1 billion years of earth history (Hansen et al., 1991). Ranging from ancient sea beds to fossilized desert sand dunes, on-going research and resource stewardship efforts focus on using paleontological and geological data to understand the evolution of each of the 23 ecosystems buried in those rocks. These projects have revealed an astounding fossil record.

The Carnegie Quarry is a gigantic fossil deposit which exhibits a strong bias in favor of the remains of large dinosaurs (Figure 7). However, that is only part of the picture. Excavation of quiet water lake deposits in the same formation has yielded a spectacular record of fragile fossil pollen, amphibians, reptiles, and mammals, including some of the most complete fossil frogs and salamanders known to science. As a result of this work, a more detailed picture and richer understanding of the Morrison Formation ecosystem has emerged, one which integrates the plants and animals into the varied environments of this ancient ecosystem (Figure 7).

The ancient desert deposits of the Nugget Sandstone are generally considered by paleontologists to be lacking in fossils. However, focused field work examining the Nugget Sandstone has revealed a harsh environment populated by spiders, scorpions, small reptiles, and dinosaurs (Figure 8 and 9). One Nugget Sandstone dinosaur trackway in DINO is about half a football field in size.

Figure 10. The Western Interior Seaway spanned North America during the Late Cretaceous. (Photo with permission from Scott D. Sampson, Mark A. Loewen, Andrew A. Farke, Eric M. Roberts, Catherine A. Forster, Joshua A. Smith, Alan L. Titus (http://creativecommons.org/licenses/by/3.0/nl/deed.en)], via Wikimedia Commons

This research and stewardship effort is sustained through the efforts of park staff, outside researchers, universities and museums across the country, graduate and undergraduate students, volunteers, Geoscientists-In-Parks interns, and many, many others. Thus DINO contributes not only the growth of paleontological knowledge regarding the “Age of Reptiles,” but nurtures the next generation of scientists who will continue to discover its fossil wonders and work for its preservation.

“Cretaceous Park”- Big Bend National Park

In many ways, the Cretaceous Period might be considered the beginning of our modern world. Although the ancient wildlife was dominated by reptiles such as dinosaurs, mosasaurs, and pterosaurs, many things that are familiar to us today evolved or were established during the Cretaceous.

Flowering plants (angiosperms) first appear in the Cretaceous fossil record, and, with them, bees, butterflies, and other pollinating insects. Grasses also first appear during the Cretaceous, leading to the rise of grazing animals. Africa split off from South America, and the continents moved more-or-less into the positions that we are familiar with today. Seasons began to grow more pronounced as the global climate became cooler. Forests began to look similar to present-day forests.

One big difference was a shallow trough that extended north-south through the center of North America, creating a seaway that geologists call the Western Interior Seaway (Hay et al., 1993) (Figure 10). From the Arctic Ocean to what is now the Gulf of Mexico, marine life thrived in the relatively shallow, sun-lit waters of the seaway (Everhart, 2005). Sediments deposited on the seaway floor would later harden into thick layers of limestone, preserving marine fossils such as mosasaurs in now-landlocked places like Kansas.

As the Cretaceous Period came to a close, the interior of the continent rose and the Western Interior Seaway narrowed. Eventually the seaway closed and the shoreline moved to its current location along the Gulf Coast.

The history of the Western Interior Seaway is crucial to understanding the geology and fossil record of Big Bend National Park (BIBE). Rocks exposed at Big Bend represent marine, coastal, and inland environments during the time that the seaway covered and then moved away from the Big Bend. The park preserves a relatively complete record of the past 130 million years and of the plant and animal life from that time (Turner et al., 2011).

Figure 11. Skull of Bravoceratops, a "new" species of ceratopsian dinosaur discovered at Big Bend National Park in 2013. (NPS Photo)

Figure 12. Strata deposited during the great terminal extinction event that ended the Cretaceous Period can be seen surrounding the Black Peaks landmarks in Big Bend National Park. (NPS Photo)

Over 1,200 taxa of fossils have been reported from BIBE (Schiebout, 1974; Rowe et al., 1992; Sankey, 2001). The park's fossil record is highly diverse and includes dinosaurs, mosasaurs, pterosaurs, crocodiles, turtles, lizards, birds, insects, frogs, toads, salamanders, boney fish, sharks, rays, sawfish, bivalves, ammonites, nautiloids, gastropods, sea urchins, corals, worms, sponges, plankton, saber-toothed cats, primitive dogs, early primates, early horses, camels, rhinoceroses, weasels, gophers, marsupials, tortoises, brontotheres, mammoths, and numerous plants, including many species of trees, ferns, leaves, algae, and fungi (Figure 11).

The park's fossil record includes numerous species that are new to science, and some that are found nowhere else in the world. For example, a new species of ceratopsian dinosaur, *Bravoceratops*, was discovered in 2013. The park's most famous fossil is *Quetzalcoatlus*, a giant pterosaur with a 35-foot wingspan, making it the largest known flying creature of all time (Lawson, 1975) (Figure 12).

BIBE is one of very few places in the world to have exposures of strata laid down during the terminal Cretaceous extinction, the asteroid impact event that wiped out the dinosaurs and three-quarters of species on Earth. The Cretaceous-Paleogene (K-Pg) strata in the park are unique, because they are the only known non-marine or continental deposits in the world that are in relatively close proximity to the asteroid impact site, bringing an end to the "Age of Reptiles" (Figure 13).

Figure 13. With its 35-foot wingspan, the pterosaur Quetzalcoatlus is the largest known flying creature of all time. (NPS Photo)

Conclusion

The Mesozoic fossil record connects three geographically-isolated national park units in the Intermountain Region. The strata and fossils exposed at Petrified Forest National Park, Dinosaur National Monument and Big Bend National Park conjoin to form a near-continuous record of Mesozoic geology and paleontology in North America. Scientists and visitors from around the world are offered the opportunity to journey through the "Age of Reptiles" while traveling to these world renowned fossil parks.

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