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A Survey of the Paleontological Resources from the National Parks and Monuments in Utah

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ABSTRACT

The National Park Service (NPS) administers thirteen park units within the state of Utah. Most of these parks and monuments have been established and are recognized for their significant geologic features. Fossiliferous rocks of Paleozoic, Mesozoic, and Cenozoic age have been identified in all of the National Park System units in Utah. In 1998, the first comprehensive inventory of paleontological resources in the national parks and monuments of Utah was initiated. A wide diversity of fossilized plants, invertebrates, vertebrates, and trace fossils has been documented. Paleontological resources identified from within the parks and monuments have been assessed relative to their scientific significance, potential threats, and management as non-renewable resources. Considerable focus has been directed towards the *in situ* management of the abundant fossil vertebrate tracks identified throughout the Mesozoic formations within at least seven National Park Service areas in Utah. The baseline paleontological resource data obtained during this survey will assist park staff with improved management of their paleontological resources and protection of fossils within their park.

HISTORY OF PALEONTOLOGY IN UTAH NATIONAL PARKS

During five expeditions into Utah led by Captain John C. Fremont between 1842 and 1854 (Rolle, 1991), rock, mineral and fossil specimens were collected and sent to geologist and paleontologist James Hall in New York. Hall contributed descriptions of the Utah fossils as an appendix in Fremont's 1845 report (Fremont, 1845). This work represents the first scientific publication to document Utah's geologic resources (Willis, 1996).

Captain Howard Stansbury explored Utah in 1850, searching for a railroad route across the Wasatch Mountains. During this survey, Stansbury collected fossils that he sent to James Hall for identification. Hall described these fossils in Stansbury's published report (Stansbury, 1852).

In 1859, the remains of the first dinosaur from Utah Territory were discovered by John S. Newberry, a member of Captain John N. Macomb's survey party. This partial skeleton was later studied and described by paleontologist Edward D. Cope who named the specimen *Dystrophaeus viaemalae* (Cope, 1877; Gillette, 1996). The fossil is a Late Jurassic sauropod dinosaur collected in the Morrison Formation.

Figure 1. John Wesley Powell, circa 1870 (National Park Service photo collection).

After the American Civil War, there was renewed interest in westward expansion. Congress funded four great surveys of the western territories during the late 1860s and

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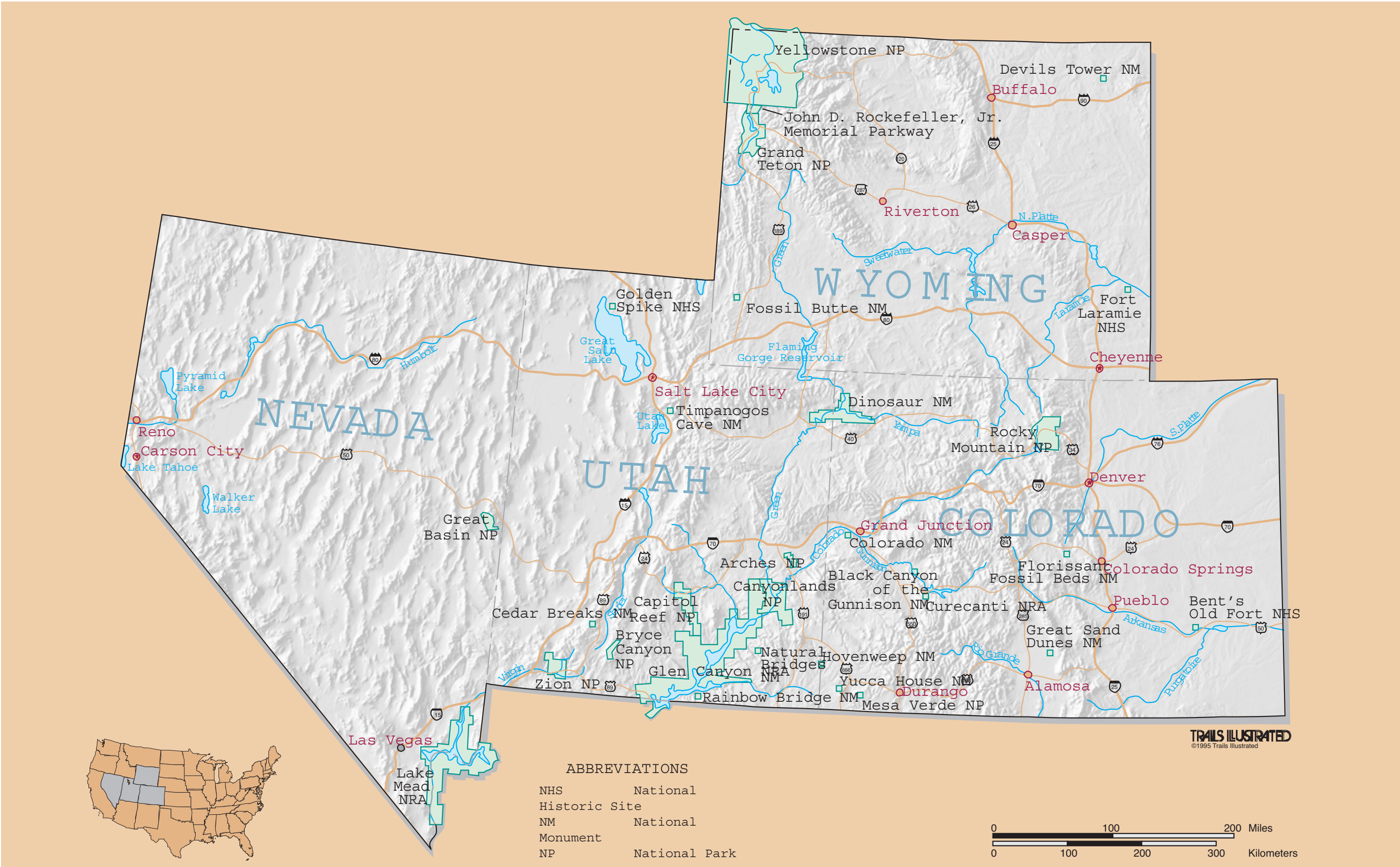

Figure 2. Map showing the locations of the National Park System units in Utah (copyright National Geographic Maps, Trails Illustrated).

1870s (Bartlett, 1962). Three scientific civilian surveys were organized under Ferdinand V. Hayden, Clarence E. King, and John Wesley Powell (figure 1). One military survey was formed and led by Lieutenant George M. Wheeler. All four of these surveys spent some time mapping and documenting geologic resources in Utah. Paleontologist F.B. Meeks participated in both the Hayden and King surveys and authored reports on fossils collected in Utah.

Yale paleontologist O.C. Marsh conducted field work in the Utah Territory during 1870. Marsh crossed the Uinta Mountains and traveled into the Uinta Basin where his field party discovered Eocene mammals, turtles, the rare Cretaceous crinoid *Uintacrinus*, and the second dinosaur specimen from Utah (Marsh, 1871). Marsh's dinosaur was the first theropod dinosaur known from Utah and was found near the current west boundary of Dinosaur National Monument (Bilbey and Hall, 1999).

A dinosaur bonebed (Carnegie Quarry) was discovered in northeastern Utah in 1909 by Carnegie Museum paleontologist Earl Douglass. Many significant dinosaur skeletons have been collected from the Upper Jurassic Morrison Formation in the Carnegie Quarry. One of the most complete sauropod skeletons ever found (*Apatosaurus louisae*) and a nearly complete specimen of *Allosaurus fragilis* were collected from the quarry (Holland, 1916a). In 1915, the site was established as Dinosaur National Monument through presidential proclamation. Carnegie Museum continued field excavations at the quarry between 1915 and 1922.

Over the past 150 years, Utah has been the focus of considerable interest by paleontologists. The 1939 Smithsonian Paleontological Expedition, the 1951 American Museum of Natural History field party led by Dr. Edwin Colbert, and other similar endeavors uncovered a great diversity of ancient plants and animals from Utah's national parks and monuments. During the 1990s, the Morrison Formation Extinct Ecosystem Project was a multi-disciplinary approach to understanding the geology and paleontology of the Upper Jurassic Morrison Formation. Many of the Utah national parks and monuments were assessed during this project. Although the Mesozoic strata and fossils have received the most attention in Utah, recent work in the Late Paleozoic and Early Cenozoic has led to some important paleontological discoveries. Fossil-rich deposits within the national parks and monuments of Utah yield specimens that contribute towards a better understanding of the history of life.

FOSSILIFEROUS UNITS IN THE UTAH NATIONAL PARK AREAS

Most of the National Park Service areas in Utah lie within the Colorado Plateau Province (figure 2). The plateau parks are dominated by a thick sequence of sedimentary rocks. The landscape is composed of colorful, eroded geologic features, punctuated by sparse vegetation in this semi-arid region. The Colorado, Green, and other rivers dissect the plateau rocks, forming canyons and mesas exposing the colorful layers of sedimentary strata that lend so much to the beauty of Utah. The scenic landforms that have formed naturally in Utah have gained the attention of the public and scientific community. Many of these outstanding geologic features of Utah are preserved within the National Park System.

The stratigraphic units vary between the eastern and western parts of the state and facies changes frequently reflect transgressive and regressive marine events. Between the Paleozoic and the Early Triassic, a sea on the western portion of Utah repeatedly advanced to the east. During the Cretaceous, a broad seaway that stretched northward from the Gulf of Mexico across the Great Plains and up to the Arctic Ocean, expanded and contracted intermittently, flooding eastern Utah from time to time. Tertiary and Quaternary fluvial and lacustrine deposits represent more recent geologic events. Stokes (1986), Hintze (1988), and the contributions included within this volume provide comprehensive overviews on the geologic history of Utah and the National Park Service areas within the state.

ARCHES NATIONAL PARK

Arches National Park was originally established as a national monument by presidential proclamation on April 12, 1929. The monument was redesignated as a national park on November 12, 1971, to preserve the extraordinary products of erosion including arches, windows, pinnacles, pedestals, and other landforms. For more detailed information on the geology and a stratigraphic section of Arches National Park see Doelling (this volume), Lohman (1975), and Doelling (1985).

The oldest fossils known from the Arches National Park area occur in the Middle Pennsylvanian Paradox Formation. The Paradox is a marine unit composed largely of limestone that contains the remains of algae, corals, bryozoans, brachiopods, crinoids, and other marine fossils. During the Late Pennsylvanian, cyclic sediments of the Honaker Trail Formation were deposited and are exposed on the western boundary of the park. Melton (1972) reports the following fossils from the Honaker Trail Formation in the Moab area: fusilinids, corals, bryozoans, brachiopods, gastropods, bivalves, crinoids, echinoids, and a variety of marine trace fossils (figure 3). In addition, Tidwell and others (1972) reported on a *Calamites*-like stem that was collected from the Honaker Trail Formation.

Fragmentary vertebrate remains occur in the Moenkopi and Chinle Formations in the Moab area. Just west of Arches National Park vertebrate bone, phytosaur teeth, and one theropod track have been reported from within the Upper Triassic Chinle Formation (S. Duffy, verbal communication, 1999).

Dinosaur tracks have been reported from in and around Arches National Park since the 1940's. Paleontologist Roland Bird is reported to have visited some track sites in the Arches area. Two theropod tracks have been identified in the Lower Jurassic Kayenta Formation in the "Petrified Dunes" area of the Arches National Park (S. Duffy, verbal communication, 1999). Tiny theropod tracks and a single quadrupedal trackway are reported from the Entrada Sandstone on the perimeter of the park (Fran Barnes, written communication, 1999). A dinosaur megatracksite, consisting of thousands of theropod tracks, weaves in and out of Arches National Park boundary. The track producing layer was originally identified as the Moab Tongue of the Entrada Sandstone (Lockley, 1990, 1991; Duffy, 1993), but more recent interpretation places the tracks into the basal sandstone bed of the Summerville Formation (Fred Peterson, written communication, 2000). Additional dinosaur track localities occur in the Morrison and Cedar Mountain Formations just outside of Arches National Park (Engelmann and Hasiotis, 1999). Several iguanodontid tracks in the collections at the College of Eastern Utah have been collected from the Cedar Mountain Formation just north of Arches National Park.

Figure 3. Marine invertebrates from the Pennsylvanian Honaker Trail Formation at Arches National Park.

The Upper Jurassic Morrison Formation is well exposed in and around Arches National Park. Petrified wood and a partial sauropod skeleton are reported from the Morrison within the park. Large petrified logs occur just west of the park at the contact between the base of the Morrison and the underlying Summerville. The Yellow Cat Flat area northeast of the park was administered as part of Arches National Park until 1971. The Lower Cretaceous Cedar Mountain Formation is capped by the Dakota Sandstone in the Yellow Cat Flat area. The area includes the Robert Gaston Quarry from which the first specimen of *Utahraptor* and the armored nodosaur *Gastonia* were collected along with other vertebrate remains referred to as the "Yellow Cat Fauna." Bodily (1969) reported on the most complete specimen of the nodosaur *Sauropelta* from the Poison Strip Sandstone of the Cedar Mountain Formation. This specimen was found just west of Arches Na-

Figure 4. A mammoth mandible collected from a rockshelter in Arches National Park.

tional Park in the Dalton Wells Quarry. Other specimens referred to as *Sauropelta* have been found along the north and west sides of the park (Carpenter and others, 1999). A variety of vertebrate tracks, including the first theropod tracks and possible pterosaur feeding traces, have been identified in the Cedar Mountain Formation from within and near Arches National Park (Lockley and others, 1999; J. Kirkland, verbal communication). Specimens of the cycadeoidales *Monanthesia* have been collected from the Cedar Mountain Formation near Arches National Park (Furniss and Tidwell, 1972).

The youngest Mesozoic unit in Arches National Park is the Upper Cretaceous Mancos Shale, which is exposed in the southern portion of Salt Valley. A few marine invertebrate fossils, including bivalves, occur in the Mancos Shale in the park. Plesiosaur and mosasaur remains have been discovered in the Mancos Shale about 35 miles outside of Arches National Park.

During the 1950's, Arches Chief Ranger Lloyd Pierson discovered the remains of a Columbian mammoth in the park. A partial mandible was collected from the site and was determined to be from a juvenile (figure 4). The specimen, nicknamed "Woody", may represent one of the youngest juvenile mammoths from the Colorado Plateau. The remains of a bighorn sheep (*Ovis canadensis*) and a bison (*Bison bison*) were found in rock shelters within Arches National Park (Mead and others, 1991). Packrat middens are common in the dry rock shelters and contain needles from Douglas fir (*Pseudotsuga menziesii*) and Limber Pine (*Pinus flexilis*). Radiocarbon dating of organic remains from the middens have yielded dates between 12,400 to 20,000 years B.P.

BRYCE CANYON NATIONAL PARK

Bryce Canyon National Park was originally established as a national monument on June 8, 1923. The area was designated and renamed Utah National Park on June 7, 1924. Finally, on February 25, 1928, the park was renamed Bryce Canyon National Park. Bryce Canyon National Park lies along the eastern margin of the Paunsaugunt Plateau in south-central Utah. The pink and white spires and cliffs have developed along an eroding fault escarpment within the early Tertiary Claron Formation. Underlying Upper Cretaceous rocks have produced a variety of paleontological resources from within and near Bryce Canyon National Park. For more information on the geology and a stratigraphic section of Bryce Canyon National Park, see Davis and Pollock, (this volume), Gregory (1951), and Bowers (1990).

The Dakota Formation is the oldest exposed unit within Bryce Canyon National Park. A large collection of vertebrate fossils, including the remains of fish, sharks, rays, lizards, crocodiles, turtles, dinosaurs, and early marsupial mammals, occur in the fluvial facies of the Dakota Formation near the park (Jeff Eaton, written communication, 1999). The last North American fossil lungfish is known from the Dakota just east of the park, which documents the last gasp of a largely Jurassic freshwater fish fauna that dies out at the end of the Cenomanian (Kirkland, 1987). Locally, *in situ* stumps, large fragments of silicified and coalified wood, and palynomorphs (spores and pollen) have been found at the top of the Dakota Formation (May and Traverse, 1973). The remains of the bivalve (oyster) *Exogyra* sp. commonly occur at the top of the Dakota Formation (Gayle Pollock, written communication, 1999).

The Tropic Shale and its equivalents are some of the most fossiliferous Upper Cretaceous (Upper Cenomanian to Middle Turonian) marine units in North America. The Tropic contains an abundance of marine invertebrates and the remains of a few marine vertebrates. The lower portion of the Tropic Shale contains the Late Cenomanian index fossil *Sciponoceras gracile* ("*Scip*" Zone) and the upper portion contains the middle Turonian index fossil *Collignoniceras woollgari* (Peterson and Waldrop, 1965). A small collection of invertebrate fossils has been recovered from within the park (Cobban and others, 1996). Gayle Pollock has collected fossil pearls from the Tropic Shale outside of the park near Tropic, Utah (W. Cobban, written communication, 2000). A few localized concentrations of fossil shark and ray teeth have been recovered from the upper portions of the Tropic Shale at nearby localities outside of the park.

The Straight Cliffs and Wahweap Formations contain significant terrestrial vertebrates (theropods and hadrosaurs). Eaton (1993, 1999) suggested that the fauna from the stratigraphically highest Cretaceous rocks of the plateau shows affinities to the Kaiparowits Formation (Judithian Land-Mammal Age). Eaton and his colleagues are continuing their research on the Wahweap and possible Kaiparowits sediments in an effort to refine the biostratigraphy of the uppermost Cretaceous from the Paunsaugunt Plateau. The vertebrate fauna from Bryce Canyon includes fish, dinosaurs, crocodiles, lizards, turtles, and mammals, including a partial upper molar from a marsupial (Eaton, 1994, 1995, 1999; Eaton, and others, 1993; Eaton, and others, 1998; Eaton and Morrow, 1990; Munk, 1998). Chris Shierup of Northern Illinois University surveyed the Wahweap? Formation in the western part of the Paunsaugunt Plateau, including one locality in the park, during 1999. Shierup recovered vertebrae, ribs, shoulder bones, and one theropod tooth that are currently under study.

The Claron Formation (Late Paleocene to Early Eocene) is composed of limestone, mudstone, sandstone, and conglomerate beds that form the scenic landforms of Bryce Canyon National Park. The strata were deposited in lacustrine fluvial and overbank floodplain environments, but have been altered considerably by massive calcretization of many of the beds. A few invertebrate fossils and palynomorphs have been documented from this formation (Eaton, and others, 1999b). A large number of invertebrate trace fossils were recently reported from the Claron Formation (Bown and others, 1997). The ichnofossils include hymenoptera nests, beetle burrows, and scorpion trails.

The Boat Mesa Conglomerate, inferred to be Oligocene in age, overlies the Claron Formation. Permian invertebrates are preserved within chert pebbles from this conglomerate, indicating that Permian age rocks were at least a partial source of the clasts. A single mammoth tooth (*Mammuthus*) is cataloged in the park collections and was allegedly collected from Pleistocene alluvium within Bryce Canyon National Park (Gayle Pollock, written communication, 1999).

CANYONLANDS NATIONAL PARK

Canyonlands National Park was established on September 12, 1964. The park consists of scenic geologic features including spires, mesas, and canyons formed by the downcutting of the Colorado and Green Rivers into the heart of the Colorado Plateau. For more information on the geology and a stratigraphic section of Canyonlands National Park, see Baars (this volume), Lohman (1974), and Huntoon and others (1982).

The Honaker Trail Formation is a very fossiliferous Pennsylvanian limestone exposed in Canyonlands National Park. This unit contains rugose corals, bryozoans, brachiopods, gastropods, a few trilobites, and crinoids.

A fossil-rich locality within the Permian Cedar Mesa Sandstone is reported from the Indian Creek drainage just east of Canyonlands National Park (Stanesco and Campbell, 1989; Sumida and others, 1999). Cranial and vertebral remains of the pelycosaur reptile *Sphenacodon* and fragments identified as the temnospondyl amphibian *Eryops* were collected from within a petrified log jam. The logs at this locality have been identified as conifers and reach nearly a meter in diameter. This site was completely destroyed by vandalism in 1995 (Sumida and others, 1999). There may also be some tracks in the Permian Cedar Mesa Sandstone in the park that are accessible by river (A. Hunt, verbal communication, 1998).

A few poorly preserved steinkerns and gastropod impressions were reported from the Lower Triassic Sinbad Limestone Member of the Moenkopi Formation in Canyonlands National Park (Lucas, 1995). These specimens were first reported by McKnight (1940) and are dominated by the following taxa: the brachiopod *Lingula* sp., *Monotis thaynesiana*, unidentified viviparoid gastropods, and the ammonite *Meekoceras* sp.

The Upper Triassic Chinle Formation is well exposed in Canyonlands National Park and contains diverse faunal, floral, and ichnofossil assemblages. Vertebrate body fossils reported from the park include the remains of semionotid and turseodid fish, metoposaurs, phytosaurs, and the aetosaur *Stagonolepis* (Hasiotis, 1993; Lucas and others, 1997; Heckert and others, 1999;). Fresh water gastropods, bivalves, conchostrachans, and the earliest known crayfish also occur within this unit. An abundance of fossil plants occur in the Owl Rock Member of the Chinle including: *Neocalamites* sp. and *Pagiophyllum* sp.

Burrows produced by lungfish, crayfish, worms, and insects are common in the Chinle Formation in Canyonlands National Park (Hasiotis and Mitchell, 1989; Hasiotis, 1993, 1995). Hasiotis (1993) also reported a horseshoe crab resting trace from the park. A single well-preserved impression of a tridactyl dinosaur footprint (*Grallator* sp.) was found in the Rock Point Member of the Chinle Formation near Upheaval Dome (Hunt and others, 1993b; Lucas and others, 1995). Another Chinle tracksite contains impressions of a tetrapod with a four-toed manus and a five-toed pes. These tracks have blunt toes, lack claw impressions, and have been identified as *Brachychirotherium* sp. There are also two types of large five-toed tracks. One set is associated with an aetosaur-like reptile and the other is attributed to a dicynodont reptile (Santucci and others, 1998).

Fossil vertebrate tracks are also known from the upper part of the Kayenta Formation just below the overlying Navajo Sandstone in Canyonlands National Park (Lockley and Hunt, 1993; Santucci and others, 1998).

CAPITOL REEF NATIONAL PARK

Capitol Reef was established as a national monument on August 2, 1937. The site was redesignated as a national park on December 18, 1971. The park preserves narrow, high-walled gorges cut through the 100-mile-long Water Pocket Fold. For more information on the geology and a stratigraphic section of Capitol Reef National Park, see Morris and others (this volume), Gregory and Anderson (1939), Smith and others (1963), Davidson (1967), Billingsley and others (1987), and Collier (1987).

John C. Fremont traveled through the northern portion of the Capitol Reef area in 1853, during his fifth and final expedition through Utah prior to the Civil War. Fremont's party may have been the first Europeans to enter the area. G.K. Gilbert was probably the first geologist to visit the area which is now within Capitol Reef National

Park. Fossil vertebrate tracks in the park received considerable attention by researchers after their discovery in 1945. A paleontological survey was conducted in 1994 along the GarKane Power Company's Right of Way through Capitol Reef National Park (Burres, 1994).

The Permian White Rim Sandstone (Cutler Group) which crops out locally within the park, is interpreted as a shoreface and coastal dune deposit in Capitol Reef National Park (Kamola and Chan, 1988). The marine trace fossils *Thalassinoides* and *Chondrites* are abundant in some parts of the cross-stratified sandstone facies. The Kaibab Limestone is a fossiliferous marine carbonate unit that interfingers with the White Rim Sandstone. The Kaibab Limestone contains fragmentary marine invertebrates including bryozoans, brachiopods, gastropods, bivalves, and crinoids.

The Triassic Sinbad Limestone Member of the Moenkopi Formation contains brachiopods, gastropods, bivalves, and ammonites. *Lingula* sp. is the only invertebrate fossil to be found outside of the Sinbad Limestone in the Moenkopi (Smith and others, 1963). Fossil vertebrate tracks were first reported from the Moenkopi in the Capitol Reef area by Charles Kelly in 1945. Paleontologist Charles Camp and Zion National Park naturalist Myrl Walker independently visited Capitol Reef in 1950 to survey for additional Moenkopi tracks after learning about Kelly's discovery. Peabody (1948, 1956) and Lammers (1964) published on the fossil vertebrate tracks, including *Chirotherium, Rotodactylus, Palaeophycus*, and *Diplidnites* from the Torrey Member of the Moenkopi Formation within Capitol Reef National Park. McAllister and Kirby (1998) reported on a variety of subaqueous reptile traces including: kick-off scours, z-traces, and buoyancy-size-mitigated, variably preserved traces.

In 1921, R.C. Moore, who was working with H.E. Gregory, collected some leaf impressions from the Upper Triassic Shinarump Formation in the Circle Cliffs area that is now within Capitol Reef National Park (Ash, 1975). These fossil plants were described by Berry (1927) and named *Zamites powelli*. Fossil plants were also collected in the Capitol Reef area by Roland Brown of the U.S. Geological Survey. Brown identified the fossil plants as *Palissya* sp., *Sphenozamites* sp., and an undetermined cycad leaf. The best preserved and most abundant stems of the fossil horsetail *Equisetites* occur in the Shinarump Member in the northern part of the park. *Phlebopteris, Cyneopteris, Cladophlebis, Pagiophyllum*, and *Araucarioxylon* are also known from this locality (Ash, 1975; 1993a). Leaves of a palmlike plant called *Sanmiguelia* cf. *S. lewisi* were reported from the Owl Rock Member of the Chinle Formation at Capitol Reef National Park (Ash, 1982). Petrified wood (figure 5), leaf impressions, bivalves, vertebrate bones, coprolites and trace fossils, including a few tridactyl tracks, have also been found within the Chinle at the park.

Large algal mounds are reported from interdunal playa deposits within the Jurassic Navajo Sandstone in Capitol Reef National Park (Len Eisenberg, verbal communication, 1999). The algal mounds occur within carbonate lenses that have been tentatively interpreted as "Oasis deposits."

Figure 5. Petrified wood from the Upper Triassic Chinle Formation at Capitol Reef National Park.

The Middle Jurassic Carmel Formation in central and southern Utah, including several localities in Capitol Reef National Park, contains a small but notable marine assemblage including *Ostrea* sp., *Trigonia* sp., *Camptonectes* sp. and the star-shaped columnals of the crinoid *Pentacrinus asteriscus* (Imlay, 1964; Sohl, 1965). Jurassic dinosaur bones and petrified logs occur in the upper portion of the Salt Wash Member of the Morrison Formation in and near Capitol Reef National Park. Turtle and dinosaur remains are reported from the Lower Cretaceous Cedar Mountain Formation just north of the park (J. Kirkland, verbal communication, 1999).

The Cretaceous Dakota Sandstone is locally fossiliferous at Capitol Reef and contains a dense oyster shell reef composed of *Pycnodonte* sp. and *Exogyra (Costagyra) olisiponensis* Marine fossils, including bivalves, gastropods, ammonites, and shark's teeth, have been recovered from the Tununk Shale Member and the Blue Gate Member of the Mancos Shale in and around Capitol Reef National Park (W. Cobban, written communication, 2000).

The Flagstaff Limestone is a fossiliferous unit of Late Paleocene or Early Eocene age in the park. Charophytes, ostracods, bivalves, and gastropods indicate a freshwater origin for the carbonate unit (Smith and others, 1963).

Over two dozen packrat middens from Capitol Reef National Park have been studied in order to assess local vegetational changes from the Pleistocene to the Recent (Cole, 1992; Cole and Henderson, 1993). The oldest midden is dated to somewhat older than 39,000 years B.P. The remains of a Pleistocene mammoth were found on Boulder Mountain, west of Capitol Reef National Park.

CEDAR BREAKS NATIONAL MONUMENT

Cedar Breaks National Monument was established through Presidential proclamation on August 22, 1933. The monument preserves a huge and colorful natural amphitheater eroded from a 2,000-foot-thick escarpment in upper Cretaceous and early Tertiary rocks. For more information on the geology and a stratigraphic section of Cedar Breaks National Monument see Hatfield and others (this volume).

The only reports of paleontological resources from within or near Cedar Breaks National Monument include some marine invertebrates from the Jurassic Carmel Formation just west of the monument (Imlay, 1964) and freshwater gastropods from the early Tertiary Claron Formation. Eaton (written communication, 1999; Eaton, and others, 1999a) reports on vertebrate fossils, including fish, turtles, and dinosaurs, from within the Straight Cliffs Formation in Cedar Canyon just west of the monument.

David Madsen (Utah Geological Survey, verbal communication, 1999) is examining Quaternary pond deposits from two localities that are adjacent to Cedar Breaks National Monument. The remains of insects, plant macrofossils, and palynomorphs (spores and pollen) have been recovered. Radiocarbon dates from these deposits range from 17,000 B.P. to the Recent.

DINOSAUR NATIONAL MONUMENT

Dinosaur National Monument was established by presidential proclamation on October 4, 1915. The site was originally established to protect the famous dinosaur quarry discovered in the Upper Jurassic Morrison Formation by Carnegie Museum paleontologist Earl Douglass. The monument was enlarged in 1938 to include the spectacular canyons cut by the Green and Yampa Rivers. For more information on the geology and a stratigraphic section of Dinosaur National Monument, see Gregson and Chure, (this volume), Untermann and Untermann (1954, 1969), Hansen and others (1983), and Hansen (1996).

The oldest sedimentary unit known from Dinosaur National Monument is the Precambrian Uinta Mountain Group. Hansen (1996) reported on fossilized algal globules *Chuaria* sp. from the Uinta Mountain Group near Manila, Utah, about 70 miles north of the monument.

The Upper Cambrian Lodore Formation consists of variegated, glauconitic shales, and sandstones that contain marine invertebrates and trace fossils. Brachiopods, gastropods, and trilobites have been identified from the Lodore Formation in Dinosaur National Monument (Herr, 1979; Herr and others, 1982; Hansen, 1996).

Corals, brachiopods, gastropods, and echinoderms are preserved, but rare, in the Lower Mississippian Madison Limestone (Hansen and others, 1983). Upper Mississippian brachiopods, fish, and coal beds are present in the Doughnut Formation (Hansen and others, 1983). The Lower Pennsylvanian Round Valley Limestone contains bryozoans, brachiopods, mollusks, and echinoderms (Hansen and others, 1983). Sponge spicules, corals, brachiopods, echinoid spines, crinoids, foraminifera, and conodonts are common in the marine facies of the Middle Pennsylvanian Morgan Formation (Driese, 1982).

The Permian Park City Formation (equivalent to the Phosphoria Formation farther north) consists of limestone, sandstone, and some chert layers. Marine invertebrates including brachiopods, bivalves, cephalopods, gastropods, and other invertebrates have been found in this unit (Hansen and others, 1983).

Peabody (1948) studied some unusual reptile tracks in the Lower Triassic Moenkopi Formation in the vicinity of Dinosaur National Monument. These include some swimming traces now in the collections of the Utah Field House Museum of Natural History in Vernal, Utah. *Scoyenia* traces have been reported from the Moenkopi at Dinosaur National Monument (Lockley and others, 1990).

In the 1960's an important vertebrate tracksite was discovered just northeast of Dinosaur National Monument. Today over two dozen tracksites have been identified within the monument. Numerous tracksites have been discovered in the Upper Triassic Popo Agie and Chinle Formations. Fossil tracks are diverse and include those identified from dinosaurs, mammal-like reptiles, phytosaurs, aetosaurs, lepidosaurs, ?trilophosaurs, and tanystropheids (Lockley and others, 1990, 1992a, 1992b, 1992c; Hunt and others, 1993a). Among these is a swimming trackway of *Gwyneddichnium* that shows webbing between the toes. In addition, there are examples of both walking and swimming types of these tracks. Horseshoe crab-like tracks are documented from the Chinle Formation at Dinosaur National Monument. There is also some petrified wood in the Chinle Formation in the monument.

Tridactyl theropod tracks and a rich *Otozoum* tracksite are known from the Lower Jurassic Glen Canyon Sandstone, which is equivalent to the Navajo Sandstone farther south and the Nugget Sandstone farther west and north (Lockley and others, 1992a; Santucci and others, 1998). The Middle Jurassic Carmel Formation is a shallow marine deposit that locally contains gypsiferous beds. Bivalves, gastropods, echinoderms, and a few rare tridactyl vertebrate tracks have been reported from the Carmel Formation in nearby areas adjacent to Dinosaur National Monument.

Chure (1993) reported on three plesiosaur specimens that may have been collected from the Redwater Member of the Stump Formation (Middle to Upper Jurassic) near the western boundary of Dinosaur National Monument. Belemnites, ammonites, gastropods, and bivalves occur in the Middle Jurassic Curtis Member of the Stump Formation in the Dinosaur National Monument area.

The Upper Jurassic Morrison Formation is widely recognized as one of the most prolific dinosaur-bearing units in the world. In addition to the dinosaurs, the Morrison Formation has produced important collections of Jurassic mammals and other vertebrates (Chure and Engelmann,

Figure 6. Paleontologist Earl Douglass during the excavation of a Diplodocus skeleton in the Douglass Quarry at Dinosaur National Monument, circa 1923 (National Park Service photo collection).

1989). The Morrison Formation at Dinosaur National Monument contains four members including, from oldest to youngest, the Windy Hill, Tidwell, Salt Wash, and Brushy Basin Members (Turner and Peterson, 1999).

Utah's first theropod dinosaur (also recognized as the second dinosaur discovered in Utah) was found in 1870 near what is today Dinosaur National Monument (Marsh, 1871; Bilbey and Hall, 1999). Earl Douglass made his famous discovery of the dinosaur bonebed in 1909. Under Douglass' direction the Carnegie Museum worked the site until 1922. During 1923, the U.S. National Museum collected a specimen of *Diplodocus*, which was mounted for display in that museum (figure 6). In 1924, the University of Utah collected a skeleton of *Androdemus* (now *Allosaurus*) from the quarry. Holland (1912, 1915, 1916b, and 1924) and Gilmore (1924, 1925a, 1925b, 1926, 1932, 1936a, and 1936b) published extensively on the dinosaur discoveries from Dinosaur National Monument.

Theodore White was hired as the monument's first paleontologist in 1953. White focused his attention on the preparation of the *in situ* bone-bearing layer and talking with the public about the world of dinosaurs. He hired and trained two maintenance men, Tobe Wilkins and Jim Adams, to relief the bones on the Carnegie Quarry cliff face. White published both scientific and popular articles about the fossils at Dinosaur National Monument (White, 1958, 1964, 1967). White liked to call himself the "Chief Ramrod of the Hammers and Chisels" until his retirement in 1973 (Ann Elder, written communication, 1999). Russ King, Dan Chure, Ann Elder, and Scott Madsen have recently worked as staff paleontologists at Dinosaur National Monument (Chure, 1987, 1992; Chure and McIntosh, 1990). Elder (1999) provides an historical overview of the Carnegie Quarry at Dinosaur National Monument..

Between 1989 and 1992, George Engelmann conducted a comprehensive paleontological survey of the Morrison Formation at Dinosaur National Monument (Engelmann, 1992). More than 270 fossil sites were recorded during the survey. Most of the sites were dinosaur bone localities, but sites containing plant remains, invertebrates, and small vertebrates were also reported.

A number of new dinosaurs have been collected in recent years from Dinosaur National Monument. In 1990, the first large carnivorous theropod dinosaur was collected from the Salt Wash Member of the Morrison Formation (Chure and Madsen, 1993; Chure and others, 1993). Chure (1994) reported on the oldest troodontid dinosaur which was recovered from the monument. A partial skeleton of a hatchling dinosaur, identified as *Camptosaurus*, was discovered at the monument in 1991 (Chure and others, 1992). This is the only hatchling of *Camptosaurus* sp. known from the fossil record.

Chure and others (1989) reported on non-mammalian vertebrates collected from the Brushy Basin Member of the Morrison in Dinosaur National Monument. Evans and Chure (1999) reported on lizards from the Morrison Formation that were collected in the monument. The remains of the turtle *Glyptops* sp. and the crocodile *Hoplosuchus kayi* (Gilmore, 1926) and *Goniopholis* sp. have been collected from the monument. Several tiny frog skeletons and many isolated frog bones have been collected from a Brushy Basin microvertebrate locality in the park. Some of the frog remains have recently been described and represent a new pipoid anuran named *Rhadinosteus* (Henrici, 1992, 1993, 1998).

Engelmann and others (1989) reported on microvertebrates, including mammals, that have been collected from quarries in Dinosaur National Monument. The quarries are in the Brushy Basin Member of the Morrison and have yielded hundreds of isolated teeth and a few partial jaws. The skull of a new multituberculate *Glirodon grandis* was also found at the monument (Engelmann and Callison, 1999). Other mammals identified include a triconodont, a symmetrodont, at least two species of dryolestids, and a paurodontid.

Yen and Reeside (1950) described freshwater mollusks from the Morrison Formation. Sohn and Peck (1963) identified the ostracod *Theriosynoecum wyomingense* as a guide fossil for the Salt Wash Member of the Morrison Formation.

Ash (1993b, 1994) reported on an unusual leaf *Czechanowskia* sp. from the Brushy Basin Member of the Morrison Formation in the monument. This plant is considered by some as an indicator of humid paleoclimates. The discovery of this plant in deposits of an alkaline-saline lake farther south brings this interpretation into question (Turner and Fishman, 1991). A ginkgo leaf locality occurs in the middle of the Brushy Basin Member of the Morrison Formation. Tidwell (1990) reported on a plant locality in Orchid Draw in the western part of Dinosaur National Monument. A palynological (fossil pollen) assessment of the Morrison Formation, including several sites within the monument, was conducted by Litwin and others (1998).

Recent evidence shows that dermestid beetle larvae (Coleoptera: Dermestidae) borings are preserved in dinosaur bones collected from the Carnegie Quarry (Hastiotis, and others, 1999). These trace fossils suggest subaerial exposure of the dinosaur carcasses prior to burial and represent the earliest evidence of dermestids in the paleontological record.

Recent work in the Lower Cretaceous Cedar Mountain Formation has produced some spectacular fossil specimens. One site in particular, a river-deposited bonebed, has yielded a nearly complete articulated sauropod skull, elements of a second disarticulated sauropod skull, numerous sauropod post-cranial elements, and a few isolated theropod bones. Though only a preliminary analysis of these fossils has been completed, the cranial material appears to be some of the most complete Cretaceous sauropod specimens found in North America (Ann Elder, written communication, 1999).

The Dakota Formation of Late Early or Early Late Cretaceous age consists of shoreface and terrestrial strata deposited along the western margin of the western interior seaway. Petrified wood and fragmentary invertebrate remains have been found in this formation. Fish scales and bones are locally abundant in the Mowry Shale of Late Cretaceous age. Bivalves, ammonites, and shark teeth are also known from the Mowry Shale in the Dinosaur National Monument area. The Upper Cretaceous Frontier Formation contains bivalves, gastropods, ammonites, petrified wood, and some thin coal beds. The Mancos Shale is not well exposed in the monument, but locally this unit is very fossiliferous and preserves a high diversity of marine invertebrates. Ammonites are reported from the Mancos at Ashley Creek and Brush Creek near the monument (Kennedy and Cobban, 1991).

Sharpe (1991) reported on the Quaternary and Holocene flora in Dinosaur National Monument collected to assess vegetation changes.

GLEN CANYON NATIONAL RECREATION AREA

Initially administered under a cooperative agreement with the Bureau of Reclamation that was signed on April 18, 1958, Glen Canyon National Recreation Area was established as a unit of the National Park Service on October 27, 1972. The recreation area includes the 186-mile-long Lake Powell, which was formed by one of the world's highest concrete dams. For more information on the geology and a stratigraphic section of Glen Canyon National Recreation Area see Anderson and others (this volume).

John Wesley Powell led expeditions down the Colorado River, passing through Glen Canyon in 1869 and 1871. Powell and his survey team traveled the Colorado River by boat and collected a few paleontological specimens. The Geographic and Geologic Survey of the Colorado Plateau was established soon thereafter and was under the direction of Powell until 1879, when all of the geographical and geological surveys of the western United States were abolished and their work was incorporated into the newly formed United States Geological Survey. Construction of the Glen Canyon Dam was initiated in 1957 and completed in 1963. Lake Powell was finally filled approximately 17 years after completion of the dam. A systematic paleontological survey was never conducted along the Colorado River in Glen Canyon prior to construction of the dam. Fossils along the lake shoreline experience periods of submergence and periods of emergence due to fluctuations in the lake's water levels. A popular publication by Crampton (1994) provides photos of the natural and cultural resources within the Glen Canyon area prior to the flooding by Lake Powell.

A species of the rare temnospondyl amphibian *Platyhystrix* was collected from the Upper Pennsylvanian Halgaito Shale at a site called the Cedar Point Locality (Sumida and others, 1999). A nearly complete dorsal "sail" from this animal was recovered from the Cedar Point Locality that overlooks the San Juan River Canyon where it winds through the upper part of Glen Canyon National Recreation Area. The fossil was recovered from a conglomeratic stream channel (Vaughn, 1962; Berman and others, 1981). In a locality east of the Cedar Point Locality, just north of Mexican Hat, Utah, Vaughn (1962) documented so many specimens of this amphibian that he designated the site the "*Platyhystrix* Pocket."

Three Permian vertebrate tracksites are known from the Cedar Mesa Sandstone within Glen Canyon National Recreation Area. One of the tracksites documented evidence of a predator attacking a prey, however, only photographs and replicas of this trackway are available for study since the original site is now under the waters of Lake Powell. This tracksite was named the "Dirty Devil Tracksite" and has been interpreted as a "Permian Murder Scene" because *Anomalopus* sp. tracks converge on the smaller *Stenichus* sp. trackway (Lockley and Madsen, 1993). The two other Permian track localities are named "Steer Gulch" and "Grand Gulch" tracksites.

Three types of subaqueous traces, including both vertebrate and invertebrate swim traces, were found at two tracksites in the Middle Triassic Moenkopi Formation within Glen Canyon National Recreation Area (Schultz and others, 1995). The vertebrate traces are preserved as parallel scrape marks, thought to have been formed when a buoyant animal's manus touched the substrate during a swimming stroke. The invertebrate traces are small, crescent-shaped swim traces attributed to limulids. There are also Triassic Moenkopi tracks discovered near Hite on the shores of Lake Powell.

Vertebrate tracks occur in the Upper Triassic Chinle Formation along the northern shores of Lake Powell (Lockley and others, 1992d). These tracks are identified as *Atreipus milfordensis*, which represent the first discovery of these tracks in the western United States. Hunt (A.P.

Figure 7. Eubrontes dinosaur tracks from the Jurassic Kayenta Formation at Glen Canyon National Recreation Area.

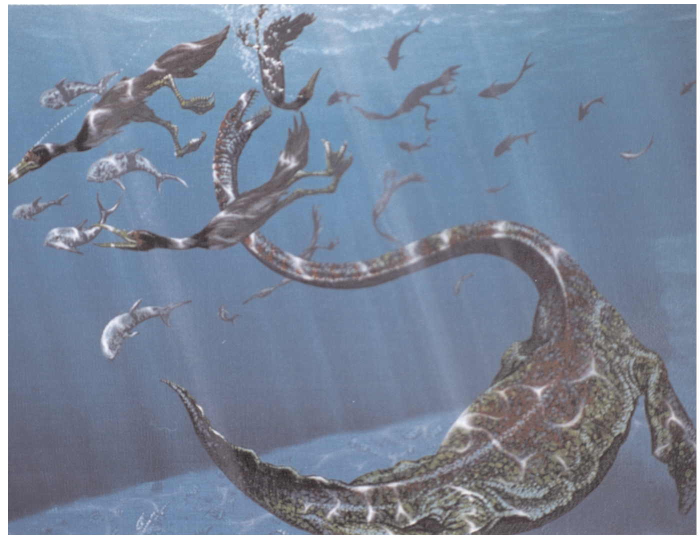

Figure 8. Painting of a Cretaceous plesiosaur by artist Rich Penny (copyright 1998).

Hunt, verbal communication, 1998) reported that fossil vertebrate bones, including a fish, were recovered from the Rock Point Member of the Chinle Formation in the recreation area. Gregory and Moore (1931) also reported on some Chinle vertebrate remains from the Lee's Ferry area. Vertebrate bones are also reported from the Chinle in The Rincon area (Tom Chidsey, written communication, 2000). Petrified wood from the Chinle Formation has been reported from a number of localities within Glen Canyon National Recreation Area including The Rincon, Blue Notch Canyon, and from Neskahi Wash.

At least three tracksites occur in the Wingate Sandstone (basal formation of the Glen Canyon Group) at Glen Canyon National Recreation Area. The three sites are at Lee's Ferry (Riggs, 1904), North Wash, and The Rincon. All the Wingate specimens represent the ichnogenus *Grallator*.

Tracks are known from the upper part of the Kayenta Formation just below the Navajo Sandstone. Large theropod tracks (*Eubrontes* sp.) were removed from the Kayenta in Explorer Canyon and are on display at the Page Visitor Center (figure 7). The Explorer Canyon tracksite was featured in a 1967 National Geographic Magazine (Edwards, 1967). *Eubrontes* sp. represents the first large theropod track type in the fossil record.

There are at least ten tracksites known from the Navajo Sandstone in Glen Canyon National Recreation Area (Lockley and others, 1998). All of these sites are on the west end of the recreation area. A number of theropod dinosaur tracks from the lower portion of the Navajo were discovered and then destroyed during the construction of Glen Canyon Dam (Stokes, 1978). One tracksite from the upper portion of the Navajo has been under water for over a decade. An *Otozoum* sp. "giant animal" tracksite, consisting of at least 28 criss-crossing trackways, has been documented from the Navajo Sandstone (Lockley and others, 1998). There are very small theropod tracks in association with the *Otozoum* sp. tracks. Another impressive tracksite occurs in the Navajo on an overhang, about 150 feet above lake level at Tapestry Wall north of Bullfrog. This tracksite contains at least 14 large theropod (*Eubrontes* sp.) tracks on the underside of a long overhanging exposure. A partial reptile skeleton was discovered from a laminated pond limestone in the Navajo Sandstone in Navajo Nation portion of Glen Canyon National Recreation Area (P. Buchheim, verbal communication, 1999).

There are several sauropod footprints with preserved skin impressions found near Lake Powell. These tracks occur near the contact between the Summerville Formation and the Morrison Formation. This site is near Bullfrog, on the north side of Lake Powell. There is also a site just outside of the boundaries of Glen Canyon National Recreation Area that contains possible pterosaur tracks (Lockley and others, 1998). At one Morrison locality in the recreation area, termite nests are preserved by preferential cementation. Therefore, the fossilized nests appeared as cylindrical concretions about 20 cm in diameter that stand 30 to 40 cm above the sandstone surface (Hasiotis and Demko, 1996; Engelmann, 1999).

The bivalve *Exogyra* occurs in the Cretaceous Dakota Sandstone in Glen Canyon National Recreation Area. At least three plesiosaur localities have been reported in the Upper Cretaceous Tropic Shale from within the Glen Canyon area (Gillette and others, 1999). The skeletal material assessed from these sites indicates all of the specimens are associated with adult plesiosaurs (figure 8). Teeth from the extinct skate *Ptychodus* sp., a few unidentified shark teeth, and a variety of marine invertebrates have also been recovered from the Tropic Shale in the national recreation area.

In 1982, a survey team in Glen Canyon National Recreation Area entered a large, dry sandstone cave known as Bechan Cave. The survey team found an organic layer of Pleistocene age preserved in the cave that consists of more than 300 m^3 of plant debris, herbivore dung, and dried animal remains. Radiocarbon dates from the cave deposits range from 11,670 to 12,900 years B.P. (Davis and others, 1984, 1985; Mead and Agenbroad, 1992). Analysis of the dung identified the source of the fecal material came from the megaherbivores *Mammuthus* sp., *Euceratherium collinum, Nothrotheriops shastensis, Bison* sp., and cf. *Oreamnos harringtoni*. Coprolites of rabbits, rodents, and possibly mountain sheep or deer (*Ovis canadensis* or *Odocoileus* sp.) were also recovered from the dung deposits. Preliminary analysis of the hair samples indicated the sources to be from mammoths and two types of ground sloths. A *Euceratherium* lower molar and metapodial were also recovered from Bechan Cave. Microfaunal remains from the cave included: *Scaphiopus intermontanus, S.* cf. *S. bombifrons, Pituophis melanoleucus, Crotalus* cf. *C. viridis*, a grouse-sized bird, *Brachylagus idahoensis, Marmota flaviventris, Spermophilus* sp., *Thomomys* sp., *Lagurus curtatus, Microtus* sp., and *Neotoma cinerea* (Mead and Agenbroad, 1992; Mead and others, 1993b). Pollen analysis of the dung blanket indicated that, away from the riparian area, the predominant plant community may have been sagebrush steppe rather than blackbrush (*Coleogyne* sp.), which is the dominant shrub today (Mead, and others, 1984). In an effort to locate additional Pleistocene remains, a helicopter survey was conducted in 1983 at Glen Canyon, however, no new significant paleontological resources were discovered.

GOLDEN SPIKE NATIONAL HISTORIC SITE

Golden Spike National Historic Site was established on April 2, 1957, in north-central Utah, to commemorate the completion of the first transcontinental railroad in the United States. The site is located at the point where the Central Pacific and Union Pacific Railroads met in 1869.

Late Paleozoic miogeoclinal rocks are exposed in uplifted areas in and around Golden Spike National Historic Site. The Pennsylvanian–Permian Oquirrh Formation is exposed in the nearby Promontory Mountains. The basal limestone member consists of coarse bioclastic beds that contain fusulinids, horn corals, bryozoans, brachiopods, gastropods, and crinoids that have been reported to be Early to Middle Pennsylvanian in age (Miller and others, 1991).

A fossilized mandible from an extinct marmot, *Paenemarmota* cf. *P. sawrockensis*, was collected from an early Pliocene colluvium locality near Golden Spike (Nelson and Miller, 1990).

Fine-grained lacustrine deposits associated with the Late Pleistocene Lake Bonneville Alloformation contain pockets of ostracods, bivalves, and gastropods (Don Currey, verbal communication, 1999).

GRAND STAIRCASE-ESCALANTE NATIONAL MONUMENT

The Grand Staircase-Escalante National Monument was established in south-central Utah on September 18, 1996. Paleontological resources are specifically addressed by President Clinton in the proclamation establishing the monument. Grand Staircase-Escalante National Monument is administered by the Bureau of Land Management. Therefore the monument is not included in this paleontological resource inventory of National Park Service areas in Utah. A preliminary inventory of paleontological resources within the Grand Staircase-Escalante National Monument has been conducted by Gillette and Hayden (1997).

HOVENWEEP NATIONAL MONUMENT

Hovenweep National Monument in southeastern Utah was established on March 2, 1923, to preserve a concentration of Pre-Columbian cliff dwellings, pueblos, and towers. Sedimentary rocks exposed in the monument include the Upper Jurassic Morrison Formation, the Lower Cretaceous Burro Canyon Formation, and the Upper Cretaceous Dakota Sandstone. The only report of paleontological resources from the monument is an unidentified bone found by a Utah Geological Survey geologist (Martha Hayden, written communication, 1999). Although there are not many reports of fossils from within the monument, judging from their known presence nearby, invertebrate fossils most likely are present in Hovenweep National Monument.

NATURAL BRIDGES NATIONAL MONUMENT

Natural Bridges National Monument in southeastern Utah, was established on April 16, 1908 to preserve three spectacular natural bridges. The monument was the first National Park Service unit established in Utah. The natural bridges are formed in the Permian Cedar Mesa Sandstone, which is the oldest geologic unit exposed in the monument. Stratigraphically, the rocks near the monument range from Permian to Jurassic in age. Although a paleontological survey has not been undertaken at the monument, a few isolated fossils have been reported. For more information on the geology and a stratigraphic section of Natural Bridges National Monument see Huntoon and others (this volume).

The Permian Cutler Formation in southeastern Utah was originally divided into five members (Baker and Reeside, 1929). More recent work by Condon (1997) recognized the Cutler as a Group in southeastern Utah and identified the following subdivisions in and near Natural Bridges: lower Cutler beds, Halgaito Formation, Cedar Mesa Sandstone, and Organ Rock Formation. The Cedar Mesa Sandstone is primarily a light-colored, cross-bedded sandstone unit that locally contains pink arkosic sandstone and mudstone beds as well as scarce grey-green limestone lenses. The unit has been interpreted as largely eolian in origin because of the abundant cross-bedded sandstone. However minute fragments of marine invertebrate fossils locally occur within the sandstone. Baars (1975) suggested that the fossils indicate a marine origin of the beds whereas Stanesco and Campbell (1989) concluded that the marine fossils were transported into the eolian sands by wind. Duffy (1998) reported on *in situ* fossilized plant roots or rhizoliths preserved in the Cedar Mesa Sandstone at Natural Bridges National Monument. Poorly preserved horizontal and vertical burrows are also preserved in the fine-grained, green-gray, interdunal sandstone beds (Jackie Huntoon, written communication, 1999).

The Upper Triassic Chinle Formation is exposed near the monument and some isolated petrified wood specimens have been reported from this formation (S. Duffy, verbal communication, 1999). Dubiel (1983, 1987) reported ostracods, conchostracans, unionid bivalves, and various trace fossils from the Chinle Formation nearby in White Canyon.

A large, flat-floored dry rock shelter in the Cedar Mesa Sandstone contains a wealth of indurated late Pleistocene (Rancholabrean) packrat middens and a 100-cm stratigraphic profile that contains skeletal and plant remains. Dung pellets from the shelter were radiocarbon dated and range in age between 39,000 to 9660 years B.P. (Mead and Agenbroad, 1992; Mead and others, 1993b). Two metapodials, identified as those belonging to the extinct mountain goat *Oreamnos harringtoni*, were recovered from the shelter and represent the oldest dated remains of this mountain goat. Plant microfossils indicate that Engelmann spruce (*Picea engelmannii*), limber pine (*Pinus flexilis*), and Douglas fir (*Pseudotsuga menziesii*) grew nearby during the late Pleistocene, whereas a riparian willow (*Salix* sp.) and cottonwood (*Populus* sp.) is now present in the bottom of the canyon and a pinyon-juniper (*Pinus edulis*-*Juniperus osteosperma*) community now predominates higher up on the canyon walls and in the benchlands above the canyon (Mead and others, 1987).

RAINBOW BRIDGE NATIONAL MONUMENT

Rainbow Bridge in south-central Utah was proclaimed a national monument on May 30, 1910, to preserve the world's largest natural bridge. The bridge is 309 ft (94 m) above the floor of Bridge Canyon and spans 278 ft (85 m) (Hansen, 1959). The bridge is carved in the Lower Jurassic Navajo Sandstone which forms vertical cliffs in the area. The floor of Rainbow Bridge consists of the Lower Jurassic Kayenta Formation. The Kayenta is a reddish-orange fluvial sandstone unit. For more information on the geology and a stratigraphic section of Rainbow Bridge National Monument see Chidsey and others (this volume).

Hall (1934) was the first to report dinosaur tracks near Rainbow Bridge. The tracks were discovered during the University of California's Rainbow Bridge Expedition of 1933. These poorly preserved tracks are named *Eubrontes* sp. and are in the Kayenta Formation.

TIMPANOGOS CAVE NATIONAL MONUMENT

Timpanogos Cave was proclaimed a national monument on October 14, 1922. However, it was administered by the U.S. Forest Service until it was transferred to the jurisdiction of the National Park Service on August 10, 1933. The monument was established to protect a colorful limestone cavern and associated karst features on the north side of Mount Timpanogos near the American Fork River in north-central Utah. For more information on the geology and a stratigraphic section of Timpanogos Cave National Monument see Mayo and others (this volume), Baker and Crittenden (1961), and White and Van Gundy (1974).

The oldest fossils in the monument are trace fossils found within the Precambrian Mutual Formation. Invertebrate fossils are preserved in the Cambrian Maxfield Limestone, Ophir Shale, and the Devonian/Mississippian Fitchville Formation. Walcott reported Early and Middle Cambrian trilobites (*Olenellus*) from the Ophir Shale. Worm burrows and brachiopods also occur within the Ophir (Baker and Crittenden, 1961). The limestone caves in the national monument are developed in the Mississippian Deseret Formation. A variety of fossilized marine invertebrates, including syringoporoid corals and brachiopods, have been found in the formation.

Packrat middens have been found at several localities within the national monument including the Timpanogos Cave System and Hidden Cave Mine. In 1939, Tom Walker found mammal bones in a rockshelter known as the Grotto, which was known to be the den for a mountain lion until 1880. Bones were collected from packrat nests found in the Organ Pipe Room of Hansen Cave. During 1998, George (1999) initiated an assessment of packrat middens from three cave areas within Timpanogos Cave National Monument. Eleven species of mammals were collected and identified from the middens. A partial bison skeleton was found in the gravels at the mouth of Swinging Bridge Canyon in the monument (Rod Horrocks, written communication, 1999).

ZION NATIONAL PARK

The area that is now Zion National Park was originally proclaimed Mukuntuweap National Monument on July 31, 1909. The area was renamed Zion National Monument on March 18, 1918. The site was redesignated as Zion National Park on November 19, 1919. For more information on the geology and a stratigraphic section of Zion National Park see Biek and others (this volume), Gregory (1939, 1945, 1950), and Hamilton (1978, 1984).

Several important expeditions by Europeans came into or near Zion Canyon during the 18th and 19th centuries. The earliest description of the area is in the diaries of the Dominguez-Escalante Expedition of 1776. The federal government initiated scientific surveys into southwestern Utah during 1853, some of which passed into and near Zion Canyon. Some of the more notable surveys were led by George Wheeler and John Wesley Powell. These two surveys mapped and interpreted the geographic and geologic features in a region that covered more than 50,000 square miles.

The Wheeler Survey, also referred to as the U.S. Geographic Surveys West of the One Hundredth Meridian, was a series of military and scientific expeditions undertaken by the U.S. Army. The survey was led by Captain George M. Wheeler. Although field surveys were conducted in 1869 and 1871, Wheeler did not receive funding to organize a regional scientific survey until 1872. The Wheeler Survey continued field work until 1879. Geologists G.K. Gilbert and Edwin E. Howell joined the Wheeler Survey and were involved in geologic field work in Zion Canyon and the surrounding area during 1872. The results of the survey, including descriptions of the geology and paleontology, were published in a series of volumes by the U.S. government.

The following quote is found within the Wheeler Geological Report (1886) in reference to southwestern Utah. "Clambering along the cliff, and while securing a large haul of fossils, the crisp edge of coal crops was noticed, and prospecting which a 12-foot vein of dense bituminous coal, having both above and below a bed of shale 15 to 18 inches thick, was found, with petrified wood strewn in many directions. Fossils were found in sandstones..."

John Wesley Powell followed the Virgin River Valley northward into Zion Canyon during 1871 (Powell, 1875). Powell did not focus much attention on the geology until he employed Howell in 1874 and Gilbert and Dutton in 1875. William Henry Holmes produced several outstanding line drawings of the area that are well known for their geological and topographical accuracy as well as their artistic beauty.

The rocks exposed in and around Zion National Park range from Permian through Cretaceous in age. During this interval, the Zion area was repeatedly covered by marine transgressions from seaways that lay largely to the west, north, or east. The oldest unit exposed in Zion National Park is the Lower Permian Toroweap Formation. The Kaibab Limestone of Late Early Permian age is a marine limestone unit, overlying the Toroweap, exposed in two small areas in the northwest corner of the park along the escarpment produced by the Hurricane fault. Brachiopods, bryozoans, corals, crinoids, and sea urchins have been recovered in the Zion area (McKee, 1952) although fossil preservation generally is poor.

The Moenkopi Formation (Early to Middle Triassic) represents both shallow marine and nearshore terrestrial environments in and near the Zion region. Fossilized marine bivalves, snails, and ammonites (*Meekoceras* sp.) are known from the formation. A few pieces of fossil wood and bone have been found in this unit. The Virgin Limestone Member contains fossilized asteroid starfish and abundant internal molds of mollusks. This unit is well exposed in the northwest and southwest corners of the park. The terrestrial component of the Moenkopi Formation increases upsection, reflecting gradual transgressions and regressions of the early Triassic sea.

The Chinle Formation (Late Triassic) includes petrified wood that was originally transported by streams from the east and southeast. The logs are found in the basal Shinarump Conglomerate Member and has been identified as *Araucarioxylon* sp. and *Woodworthia* sp. Fossilized bones from the labyrinthodont *Metoposaurus* sp. have been collected from freshwater mudstone beds near Cougar Mountain.

The Lower Jurassic Moenave Formation includes, from oldest to youngest, the Dinosaur Canyon, Whitmore Point, and Springdale Sandstone Members. The Dinosaur Canyon Member consists of red mudstone, siltstone, and some sandstone deposited in mudflat, fluvial, and overbank environments. The Whitemore Point Member is a gray mudstone and shale unit deposited primarily in lacustrine environments. Palynomorphs recovered from this member are especially important as they provided the most reliable dating of this formation. The Springdale Sandstone Member is composed largely of red sandstone deposited by high energy streams that originated in a highland source region in the ancestral Rockies of western Colorado. Pond and stream deposits from the Moenave Formation contain the remains of the fish *Semionotus kanabensis* (Hesse, 1935; Day, 1967). Fossil vertebrate tracks have been found in both the Whitmore Point and Springdale Members of the Moenave (Smith and Santucci, 1999).

The Lower Jurassic Kayenta Formation in the Zion region consists primarily of siltstone and sandstone deposited in sabkhas downwind (south) of extensive eolian dune deposits that are included in the Navajo Sandstone. This unit contains several thin limestone beds that preserve fossil trails of aquatic snails or worms. The first vertebrate tracks reported from Zion National Park were tridactyl dinosaur prints in the Kayenta (Stokes and Bruhn, 1960). Additional vertebrate tracksites were discovered in the Kayenta during a paleontological survey in Zion during 1998 and 1999 (Santucci and others, 1998; Smith and Santucci, 1999).

Although the Navajo Sandstone is one of the most easily recognized units in the southwest, the unit appears to be largely devoid of body fossils in Zion National Park, although a few tridactyl dinosaur footprints have been found along the trail to Observation Point (Fred Peterson, written communication, 2000). The large-scale cross-bedding that is so pronounced in the park reflects stratification produced in windblown sand deposits. In an unpub-

Figure 9. Large artiodactyl track from Zion National Park.

Figure 10. Heron-like bird track from Zion National Park.

lished report found in the Zion National Park files, John Bradbury claims that during 1962 poorly preserved fossil wood was found within a shale lens of the Navajo Formation.

The Middle Jurassic Carmel Formation includes several light tan to gray limestone beds that contain marine fossils, including crinoids, pectens, oysters, and other bivalves (Gregory and Williams, 1947). The crinoids are identified as *Isocrinus* sp. An oolitic limestone bed containing algal balls, bivalves, and gastropods is present along Wildcat Canyon Trail.

A small exposure of the Cretaceous Dakota Sandstone is exposed in the northwest corner of the park on top of Horse Ranch Mountain. The formation contains a basal conglomerate overlain by a series of sandstone and mudstone beds, some of which contain freshwater bivalves and plant impressions. A few undescribed vertebrate fossils are reported from the Dakota just east of Zion National Park (Eaton, written communication, 1999; Kirkland, written communication, 1999).

The remains of a plesiosaur were excavated from the Upper Cretaceous Tropic Shale near the eastern boundary of Zion National Park (Gillette and others, 1999).

A large artiodactyl track (figure 9) and a bird track (figure 10) resembling those of herons were collected from Quaternary lacustrine deposits in the Coalpits Wash area (Santucci and others, 1998). The remains of a bison (*Bison antiquus*) were collected in the park many years ago (Wayne Hamilton, verbal communication, 1998). Hevly (1979) analyzed pollen and spore samples taken from Quaternary lacustrine sediments in Zion National Park.

PALEONTOLOGICAL RESOURCE MANAGEMENT AND PROTECTION

The paleontological resources in the national parks and monuments of Utah provide valuable information about ancient plants and animals. The National Park Service manages fossils along with other natural and cultural resources for the benefit of the public. Fossils are recognized as non-renewable resources that possess both scientific and educational values. All fossils are protected under federal law and their collection is prohibited except under the terms of a research permit.

Paleontological resources are placed on exhibit in many of the national parks and monuments in Utah. The Quarry Visitor Center at Dinosaur National Monument provides visitors with the opportunity to view the world famous dinosaur bone-bearing rock wall as an *in situ* exhibit. Glen Canyon National Recreation Area has a sandstone slab of dinosaur tracks on display outside of the Visitor Center and mammoth dung and bones are on exhibit within the Visitor Center.

Comprehensive paleontological resource inventories are underway in a number of National Parks Service units in Utah. These surveys are designed to identify the scope, significance, and distribution of the paleontological resources and to assess any natural or human-related threats to the paleontological resources. Fossils reported from areas adjacent to the parks and monuments are also considered in order to assess the potential for stratigraphically equivalent resources within park boundaries. This baseline data will better enable park staff to plan strategies that increase the management, protection, research, and interpretation of park fossils.

Ongoing and future paleontological research in the various National Park Service units within the state of Utah will not only enlarge our knowledge of the fossil record but, more importantly, will expand our understanding of the ancient environments in which the fossils lived.

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