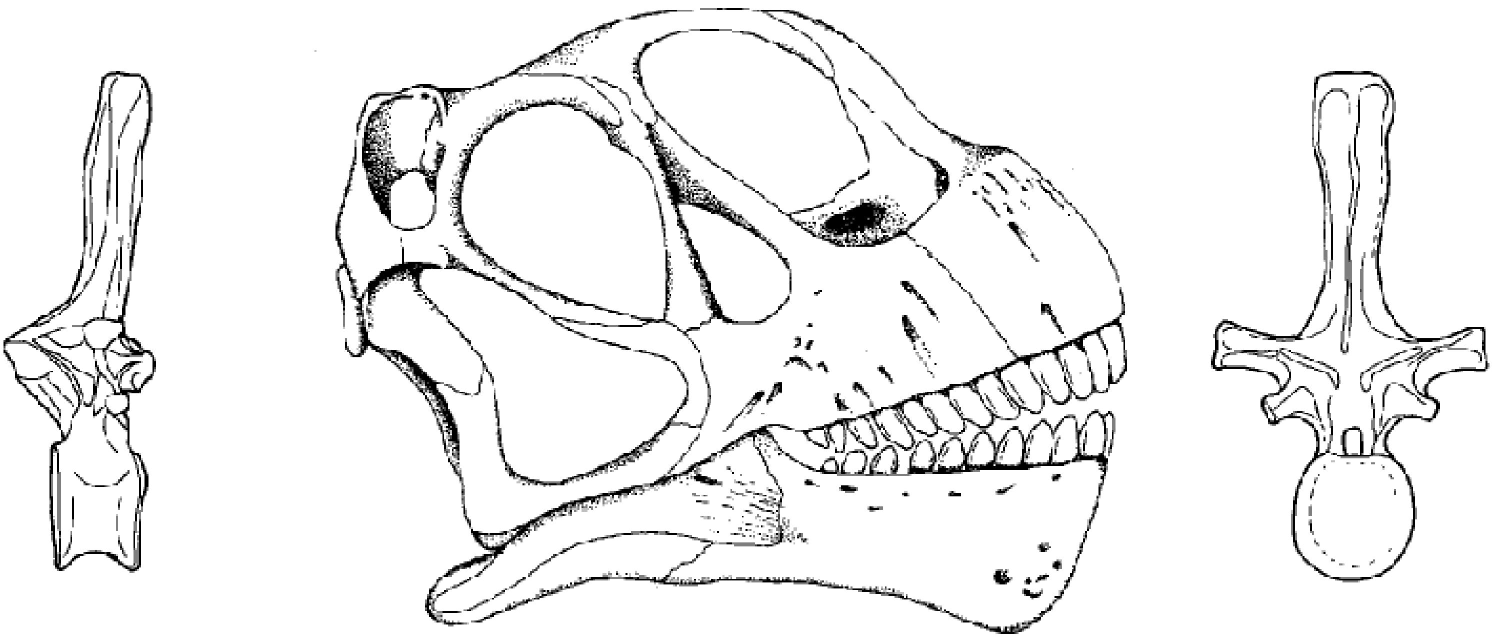
ARCHES NATIONAL PARK PALEONTOLOGICAL SURVEY

Brooke A. Swanson, Vincent L. Santucci, Scott K. Madsen, Ann S. Elder, and Jason P. Kenworthy

Technical Report NPS/NRGRD/GRDTR-05/01



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Geologic Resources Division
12795 West Alameda Parkway
Lakewood, CO 80227
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On the cover:
Drawing of sauropod dinosaur skull and vertebrae typical of those found with Jurassic-aged sediments of the Colorado Plateau.

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BY

Brooke A. Swanson
University of Wisconsin Geology Musuem
1215 West Dayton Street
Madison, WI 53706

Vincent L. Santucci
George Washington Memorial Parkway
Turkey Run Park
McLean, VA 22101

Scott K. Madsen
Dinosaur National Monument
4545 E. Highway 40
Dinosaur, CO 81610

Ann S. Elder
Dinosaur National Monument
4545 E. Highway 40
Dinosaur, CO 81610

Jason P. Kenworthy
George Washington Memorial Parkway
Turkey Run Park
McLean, VA 22101

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DEDICATION

Fran Barnes and his wife Terby, residents of Moab who lived in the area for over 30 years, were in the unique position of having a more comprehensive understanding of the region's potential paleontologic resources than many, if not all, scientists who venture here for research purposes. Fran and Terby explored the canyon country extensively and were extremely knowledgeable of historical, prehistorical, and paleontological resources within the region as well as trail systems. Fran's unflagging efforts to alert scientists to his discoveries as well as his own initiative in reporting localities and his interpretations thereof through his own publications were exceptional. His vitality and enthusiasm still lured him into the field twice weekly, despite being over 80 years old (in 2002). In recognition of his contributions to the scientific intrigue of canyon country, we dedicate this volume to Fran Barnes, who passed away in 2003. He will be sorely missed.

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INTRODUCTION

In a collaborative effort to protect and manage the fossil resources at Arches National Park in southeastern Utah, a formal survey of the paleontology of the park was initiated in 1995. In 2000, with the support of the staff at Arches, the Geological Resources Division, and the Geological Society of America, field and literature surveys were conducted in order to construct a reasonably complete record of the resources known within and adjacent to the park boundaries.

The significance of the fossil record in canyon country is widely recognized. The staff at Arches National Park serve a multifaceted role as protectors, managers, and interpreters of the fossils within Arches' boundaries. This survey is intended primarily as a tool for them. It is hoped that the information within will assist in future decisions pertaining to paleontological resources whether it is for law enforcement rangers or interpretive staff.

It has been our pleasure producing this document. The cooperation of park service permanent and seasonal staff, research scientists, and members of the Moab community has contributed a wider breadth and greater authority to the survey.

Historical Background

Established in 1929, Arches National Monument was granted park status on November 16, 1971. Prior to its recognition as a national park, however, the area had a record of inhabitants and visitors ranging from Native Americans to miners and ranchers. The Ute, Fremont, and ancestral Pueblo people are reputed to have inhabited the region, especially farther south towards what is now Canyonlands National Park (Lohman, 1975). Evidence of their presence remains primarily as pictographs and petroglyphs that can be found throughout the area.

The first Anglo-American inhabitants within the present boundaries of Arches National Park were John and Fred Wolfe, a father and son who relocated from Ohio in 1898 for the advantages the drier climate could provide the father. A few years later John Wolfe persuaded his daughter to bring her husband and two children west to live at the ranch, where they lived until 1910, when they returned to Ohio. The first geologic mapping effort by the United States Geological Survey (Dane, 1935) marks the location of their homestead which has now been incorporated into the park and lies along the trail to Delicate Arch.

Many more people followed the Wolfes, homesteading and in search of wealth within the rock formations of the west. A prospector, Alexander Ringhoffer, began publicizing the beauty of the area around Moab and started the effort to create a national park to protect the unique geologic features found there. President Herbert Hoover created Arches National Monument in 1929 and it became Arches National Park in 1971 through an act of Congress.

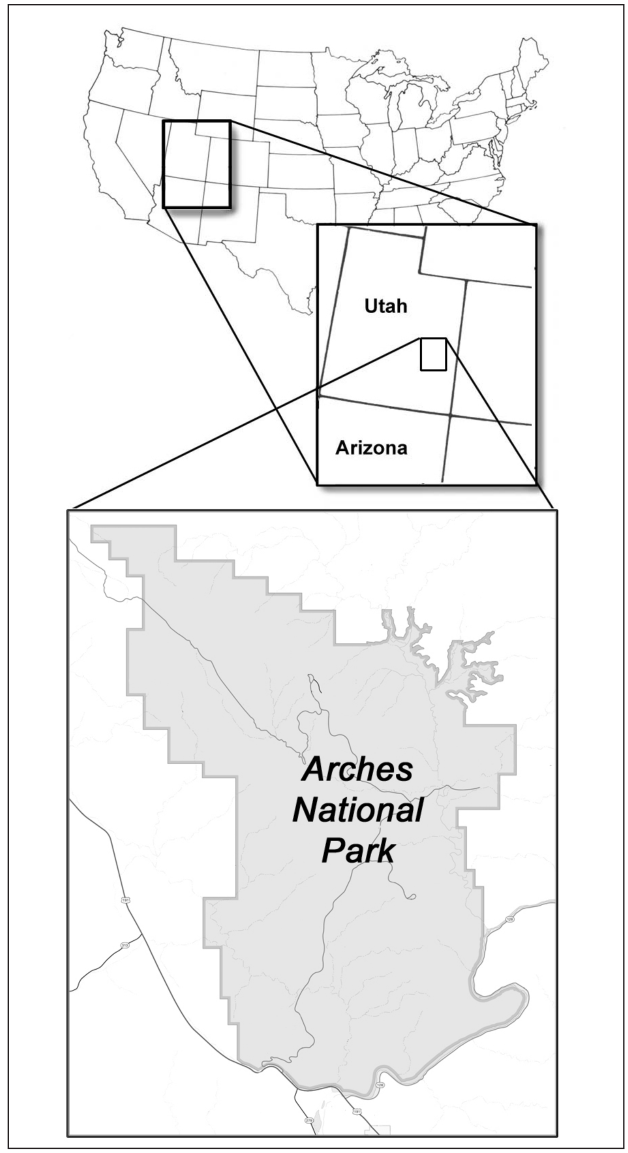

Figure 1: Location of Arches National Park

Primarily recognized for preserving over 2,000 natural arches, Arches National Park attracts 750,000 visitors annually. The park provides public education on cultural and natural resources as well as the management and protection of non-renewable resources such as fossils. The boundaries of the park have fluctuated over the years with the most recent change being the addition of 3,140 acres in the Lost Spring Canyon Addition on the northeastern side of the park. This parcel of land brings the current total area of Arches National Park to 76,359 acres.

History Of Paleontologic Research

Little formal research has focused specifically on the paleontologic resources within Arches National Park. Doelling has thoroughly examined the stratigraphy and structure of the salt anticline region in a number of publications (1985a; 1985b; 1988; 2003) and has proposed mechanisms for the formation of natural arches. The first mention of the vertebrate paleontological resources of the area was by McKnight (1940) who briefly describes the trackways of a tridactyl, bipedal animal in the top of the Moab Member of the Curtis Formation near Courthouse Spring, west of Arches. Within the same strata, and not too geographically distant, Lockley (1991) reported the presence of potentially millions of theropod tracks. Named the Moab Dinosaur Megatracksite, these tracks extend from Moab to Crescent Junction and can be found within Arches (Duffy, 1993). Holocene bison and bighorn sheep remains have been recovered from packrat middens (Mead *et al.*, 1991) as well as Pleistocene mastodon remains located in a rock shelter in lower Courthouse Wash (Figure 5).

Geologic Setting

Arches National Park is located in east-central Utah, five miles north of Moab, well within the boundaries of the Colorado Plateau (Figure 1). Arches lies within the Paleozoic Paradox Basin, which served as a depositional center accumulating layers of clastic, carbonate, and evaporite (salt) sediments throughout the Paleozoic. Sedimentation continued residually through the Mesozoic and into the early Tertiary. These sediments were deposited in environments that alternated from terrestrial to near shore and marine regimes. Each of these environments hosted a variety of prehistoric life and provide the basis for the paleontologic resources found within and around Arches National Park.

For the last 45 million years the area of Arches National Park has ceased receiving sediment. The Colorado Plateau owes its existence to an uplift that has shifted the region from an area of deposition to one of erosion over the past 15 million years. Ranging between 4,000-7,000 feet in elevation, the Colorado Plateau has been carved out by the continued down-cutting by the Colorado River and its tributaries creating the canyons for which the region is famous (Baars, 1983).

All of the arches, windows, and monuments within the park are located stratigraphically within the Entrada Formation, a Jurassic sandstone. Arches and windows in the park are the consequence of the erosional forces, though some of the specific mechanisms are unknown. The standing hypothesis of arch formation begins with long sandstone fins that correspond to fractures on the crests of anticline folds along the shoulders of a salt valley. These fins are subsequently exposed to acidic rainwater coupled with groundwater which eat horizontally through weak horizons in the fins. Growth of a newly formed arch is aided by gravity which allows blocks to drop from the roofs of arches, enlarging the openings (Doelling, 1985a; Stevens and McCarrick, 1988).

Aside from the arches, the Salt Valley anticline is located in Arches National Park and represents an excellent example of salt deformation and dissolution features. When fresh water reaches the Paradox Formation the salt dissolves out in the subsurface, collapsing the rocks above it into the developing cavity. Here, salt deformation is not visible as rockfall or other collapse-like features but rather as U-shaped anticlines and synclines (Doelling, 1985a).

The Significance Of Arches National Park Paleontological Resources

Although primarily known for its geologic features - the arches, windows, and pinnacles that give the park its name - Arches National Park has a diverse and scientifically significant fossil record. In the past, many fossils have been retrieved from relatively near but outside the park boundaries, within stratigraphic units that can be traced into the park (Figure 2). These specimens serve as indicators of the potential paleontological wealth that lies within the park.

The basal Yellow Cat Member of the Cedar Mountain Formation in the area around Arches National Park has been yielding the oldest Cretaceous dinosaur fauna in North America. In quarries no more than a few miles

Figure 2: (top) Historic tracksite from outside park boundaries; (bottom) Fossil vertebrae found within the park, location unknown.

from Arches, dinosaur species known nowhere else in the world have been excavated (Britt and Stadtman, 1997; Kirkland, 1997; Kirkland *et al.*, 1997; 1998b; 1999; 2005). Most notable of these sites are the Dalton Wells Quarry to the west of the park and the Gaston Quarry to the northeast (Kirkland *et al.*, 2005). The Gaston Quarry has yielded *Utahraptor*, a large dromaeosaur "raptor" whose large size was anticipated by the Steven Spielberg film, *Jurassic Park* (Kirkland *et al.*, 1993). This theropod is also present at the Dalton Wells Quarry. The Gaston Quarry is dominated by the spiny ankylosaur *Gastonia* (Kirkland, 1998a), while the Dalton Wells Quarry is dominated by sauropod dinosaurs and in particular a new, undescribed titanosaur (Britt *et al.*, 1996). A number of other critical sites are known to occur in the Cedar Mountain Formation just to the northeast of the park (Kirkland *et al.*, 1998a; Dicroce and Carpenter, 2001; Tidwell *et al.*, 1999; 2001). Also, west of the park and extending into Arches at the top of the Moab Member of the Curtis Formation there are estimated millions of theropod dinosaur tracks. This geographic and stratigraphic concentration of footprints is referenced as the Moab Dinosaur Megatracksite (Lockley, 1991).

Within the park, the most significant discoveries have occurred recently. Historically, dinosaur bones have been noted as being found in the park, however no intensive study or pursuit of localities has been undertaken. In 1933, the Arches National Monument Scientific Expedition announced the discovery of dinosaur bones in the Moab newspaper. There are a number of similar reports in historical literature, with no accompanying photographs or site information.

Recently, a new sauropod specimen was discovered in May 2000 and has been identified as *Apatosaurus*. Other sauropod bones, ankylosaur bones, oyster beds, and a number of trackway sites were also found during the survey including those of small theropods and a possible pterosaur trackway with feeding traces.

A very significant dinosaur tracksite was discovered in 2000 near the Delicate Arch viewpoint in rocks of the Ruby Ranch Member of the Cedar Mountain Formation (Lockley *et al.*, 2004). The site is the largest yet known from the Cedar Mountain Formation with at least 50 sauropod, theropod, ornithopod, and ankylosaur tracks in two different assemblages. Nearly all of the track types known from other track sites are found at this new site, in addition to some track types previously unknown in the formation. The site also is the first of the known Cedar Mountain Formation tracksites to display trackway sequences, in which are multiple tracks created in sequence by one individual (Lockley *et al.*, 2004).

A number of strata garnered the attention of the survey and deserve further study. The significance of playa deposits within the Navajo Formation is beginning to be explored. While there have not been any significant discoveries in the Navajo within the park, petrified wood and possible fossilized spring deposits have the potential to contribute to the understanding of this formation. Also, the Chinle Formation yielded a number of vertebrate and invertebrate trace fossil sites along with a plant locality all of which could be helpful in paleoenvironmental reconstructions.

ACKNOWLEDGMENTS

The staff at Arches National Park were invaluable to the completion of this survey. Specifically, Laura Joss, Superintendent; Karyl Yeston, Park Ranger (now at Grand Canyon National Park); Jim Webster, former Chief Ranger (now retired); Gary Salamacha, Park Ranger; Karen McKinlay-Jones, Park Ranger; Diane Allen, Chief Interpreter; Murray Shoemaker, Interpreter; Gary Haynes, Park Ranger; Eve Stocks and Marilyn Hawks, administrative assistants; Denise D'Agnese, Southeast Utah Group (SEUG) librarian. Aside from fielding a wide range of questions, their collective and individual humor and support were greatly appreciated.

At the headquarters for the Southeast Utah Group thanks go to Bruce Rodgers, former Chief, Resource Management Division (now retired); Jeff Troutman, Chief, Resource Mangement Division; Vicki Webster, Curator; Gery Wakefield, GIS extraordinaire; Gary Gurtler, computer guru; Steve Budelier, Scott Goldberg, and Jesse Abrams of the weed-spraying crew for taking BAS across the Colorado River; and Craig Hauke, for taking BAS up the Colorado River.

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STRATIGRAPHY AND GEOLOGIC HISTORY

Geologic History

The geology of Arches National Park and the surrounding region provide a unique chapter on the geology of the Colorado Plateau (Figure 3). The largest concentration of natural arches in the United States can be found within park boundaries and owe their genesis in part to salts deposited 300 million years ago with subsequent deformation continuing periodically into the Early Cretaceous (Doelling, 1988). For a more thorough discussion of the sedimentology and stratigraphy of Arches National Park, please refer to Doelling (2003).

Precambrian basement rocks in the region consist of gneiss, schist, quartzite, and granite that are cut by large faults. Precambrian through Mississippian strata do not outcrop in the Salt Valley/Arches National Park region. However, nearby deep drilling indicates the underlying strata are alternating layers of dolomite, limestone, shales, and sandstones deposited in an ancient inland sea.

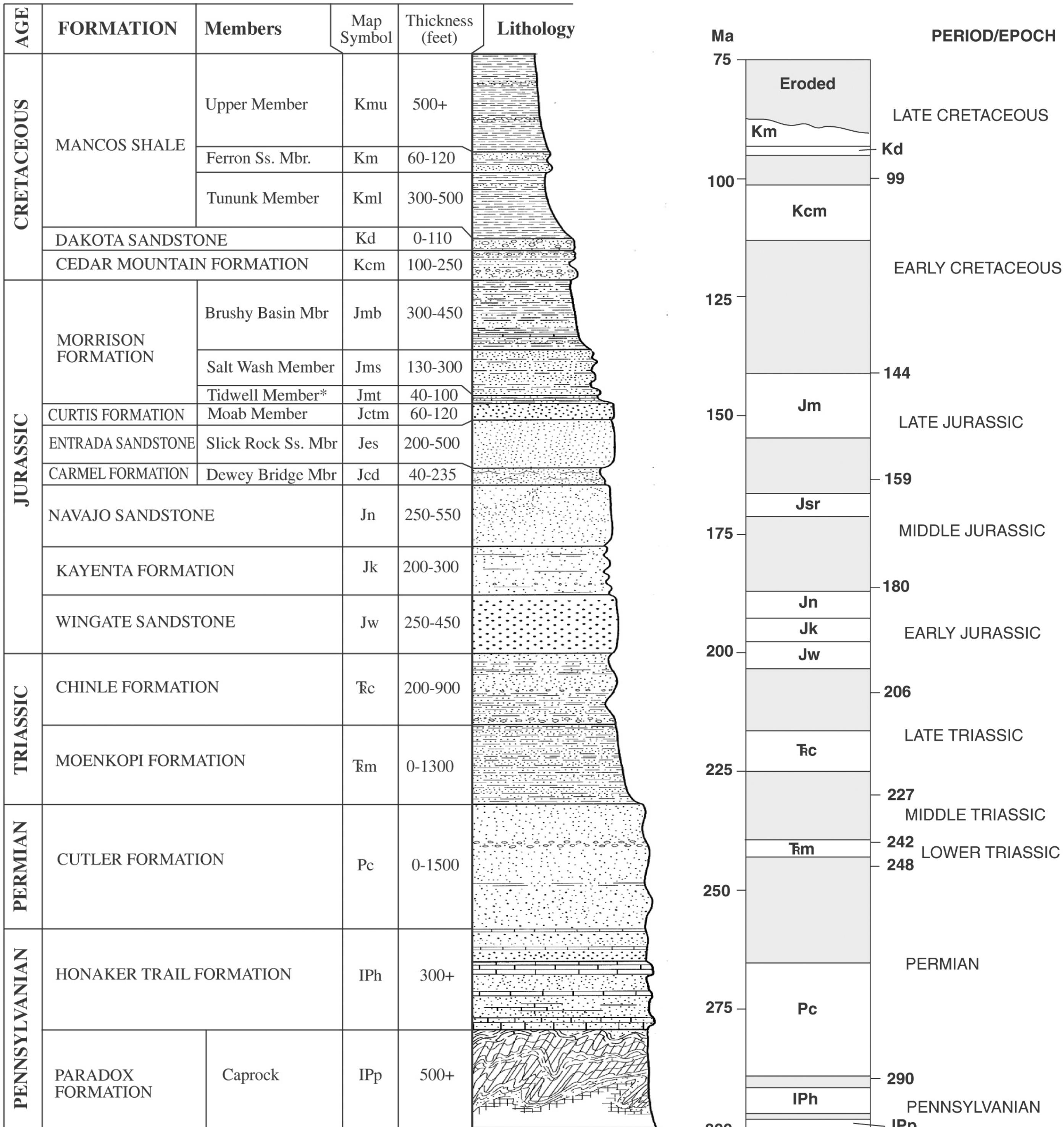
During the late Paleozoic (Pennsylvanian), a fault-block mountain range (the ancestral Uncompahgre Mountains) rose along the Utah/Colorado border to the east. At the same time, a basin developed to the southwest and included the Arches area. The boundary between the mountain range and basin was a Precambrian normal fault that was reactivated in Pennsylvanian time and remained active until the Triassic period (early Mesozoic Era). Periodically, the sea that occupied the Paradox Basin was restricted by fluctuating sea-level from an open ocean which lay to the west. A warm and dry climate caused excessive evaporation in the basin creating a rise in the concentration in the salinity. As the concentrations rose, increasingly salty sediments precipitated out of the water column and are recorded in the rock record as limestone, dolomite, gypsum and halite (salt) (Doelling, 1985a). Global sea-level changes episodically allowed sea water to “freshen” the basin, normalizing salinity until the basin became restricted again and the concentration cycle would begin again, depositing more layers of progressively saline lithologies. Hite (1960) has identified 29 of these cycles within the Paradox Basin. The subsidence of the basin accompanied the uplift of the Uncompahgre Mountains to the east. During the Permian, erosion off this high mountain escarpment led to the deposition of thousands of feet of sediment into the Arches region and the restricted sea that occupied it. Thus salt interfingers with the clastics of the alluvial fans; the clastic beds beneath the salt are known as marker beds and separate the individual salt cycles.

Eventually, clastic deposition dominated and pushed the Paradox shorelines southwestward. Alluvial fans thousands of feet thick extended into the Arches region and eventually buried the salt. The weight of these sediments and those that were deposited in Triassic time pushed the plastic salt into weakened linear areas along the alignment of the old Precambrian faults, which were also active during Pennsylvanian to Triassic time. The salt thickened along these linear faults, forming walls of salt as much as three miles wide and 14,000 feet high. One such salt wall is present under Salt Valley in Arches National Park. Another lies under Moab Valley to the southwest.

The Paradox Formation consists of 75-90% sodium chloride (table salt) within the Salt Valley anticline and is approximately 10,000 feet thick (almost two miles high). Salt is not exposed at the surface anywhere in the Paradox Basin, but is found about 900-1200 feet beneath the surface (Doelling, 1988). Salt has unique properties (plasticity, solubility, low density) which have ultimately directed the cosmetic character of the Arches and southeastern Utah region. With increasing pressure from the accumulation of overlying sediments, the salt of the Paradox Formation deformed and migrated to areas of lesser pressure, influencing the thickness of overlying layers and forming the salt walls (Doelling, 1988).

As the Cutler Formation deposits pushed the sea southwestward, sand dunes appeared along the coast. During this time the region was situated south of the equator in the southern arid belt. The end of the Permian was marked by several million years of nondeposition and erosion as the sea retreated from the Arches region.

During the Early and Middle Triassic, the sediments of the Moenkopi Formation were deposited in a floodplain environment bounded by a vast sea to the west and the Uncompahgre Mountains to the east (Blakey *et al.*, 1993). After a lengthy period of erosion or non-deposition, the braided stream environment that deposited the basal Chinle Formation was followed by a fluvial floodplain environment. Unconformities developed in both the Moenkopi and Chinle Formations in the vicinity of the rising salt walls and are related to Triassic episodes of salt movement. During the Triassic, North America was moving rapidly northward from the southern arid belt through the equatorial region and into the northern arid belt. The Petrified Forest Member of the Chinle Formation probably represents the short time interval that the southwestern United States straddled the equatorial rainy belt. The intertonguing of river and sand dune deposits that characterizes the Chinle/Wingate contact marks the time when North America entered the northern arid belt and resumed sand dune deposition across the region. During this time, a vast,



* Includes a thin section of the Summerville Formation at the base, that is generally less than 10 feet thick.

Figure 3: Stratigraphic column and nomenclature of sedimentary units in Arches National Park (from Doelling, 2003; used with permission of the Utah Geological Association). Note: "Jsr" indicates the Middle Jurassic San Rafael Group, which includes the Carmel, Entrada, and Curtis formations.

Sahara-scale sand sea expanded over a plain crossed by rivers and lakes.

The transition from the Triassic to Jurassic can be placed within the Wingate Sandstone. Rivers draining the Uncompahgre Mountains extended westward across the region as reflected by the Kayenta Formation only to be buried by a second, even more extensive field of Navajo Sandstone sand dunes. These sand dunes covered the region until the end of the Early Jurassic and included isolated, interdunal playa lakes (Lutrell, 1993; Peterson, 1994). Although the seas expanded and contracted just to the east of Arches during the Middle Jurassic, at Arches sand dunes were preserved as the Entrada Sandstone and continued to dominate the landscape until the end of Middle Jurassic time when tidal flat conditions briefly overstepped these deserts and deposited the sediments of the Summerville Formation (Lutrell, 1993; Peterson, 1994; Doelling, 2003).

Late Jurassic floodplain environments of the Morrison Formation overrode the Middle Jurassic marginal seas. These rocks are the most famous dinosaur beds in all of Utah and preserve the second most diverse dinosaur fauna of any geological formation in the world (Chure *et al.*, 1998). These strata have not been studied in the area around Arches to the degree they have in other parts of the region, but are still well documented as having significant fossils at all stratigraphic levels in this area. As many as 30 million years of erosion and nondeposition at the end of Morrison time is represented by a regional pediment surface, indicated by a significant paleosol or chert pebble lag at the top of the Morrison Formation.

Deposition of sediments did not resume in the region until about the middle of the Early Cretaceous with deposition of the Cedar Mountain Formation, which continued periodically until the end of the Early Cretaceous over a period of nearly 30 million years. Over the past decade, the Cedar Mountain Formation of eastern Utah has been the focus of investigation by researchers from many institutions resulting in the discovery of dozens of significant vertebrate fossil localities from throughout the stratigraphic section. To date, approximately ten dinosaur taxa have been described and as many as thirty more have been recognized on less complete material. Preliminary conclusions resulting from these studies demonstrate that the Cedar Mountain Formation spans the last 25-30 million years of the Early Cretaceous. This is contemporaneous with the evolution and dominance of flowering plants, the shifting of North American climates from dry to wet, and the dramatic disconnection of North America from Europe and subsequent connection of North America with Asia via the Bering Land Bridge in Alaska (Kirkland *et al.*, 1997; 1999).

Unconformably overlying the Cedar Mountain Formation are Upper Cretaceous fluvial and coastal sediments of the Dakota Formation, recording the initial incursion of the Late Cretaceous Western Interior Seaway into the region from the east. Marine muds of the Mancos Shale were deposited over the next ten million years and reached a thickness of greater than 2000 feet. During this time, the Western Interior Seaway connected the ancestral Gulf of Mexico with the ancestral Arctic Ocean, effectively dividing the continent into western volcanic mountains and a larger stable continent in the east. The marine Mancos Shale in turn was overlain by the Mesaverde Group, deposited as the seas retreated to the east. These rocks are currently being exploited for their extensive coal reserves in the Book Cliffs area, north of Arches. Rocks deposited during the very last part of the Cretaceous were probably removed by erosion although they are preserved west of the San Rafael Swell within the lower part of the North Horn Formation (Elder and Kirkland, 1993; 1994).

Regional compression associated with the Laramide orogeny in the early to mid Tertiary gently folded the entire rock column and reactivated the old Precambrian normal faults for a second time. The middle Tertiary was an interval of tectonic quiescence which ended with the intrusion of vast masses of igneous rock into the Mancos Shale south of Arches (30 million years ago). The Colorado Plateau uplift, which commenced about 15 million years ago, caused erosion of the rocks that had accumulated after Triassic time. The erosion has worked its way down to the vulnerable salt walls along which the old normal faults were aligned. Fresh water (rainfall to ground water) reaches the salt walls through the fault fractures and through new ones generated as collapse ensued. The erosion also exposed the resistant intrusive masses which were emplaced during the mid-Tertiary which now form the La Sal Mountains seen to the southeast of the park.

ROCK FORMATIONS EXPOSED AND FOSSILS FOUND IN ARCHES NATIONAL PARK

(Note: Age ranges are estimates, see Figure 3. Ma= millions of years)

Paradox Formation (Pennsylvanian: 297-300+ Ma)

Lithology: 75-90% halite (table salt) and potash salts in the Salt Valley anticline with marker beds of more resistant anhydrite (a de-watered variety of gypsum), dolomite, and clastics (Doelling, 1988).
Fossils: Rugose corals, lacy and branched bryozoans, productid brachiopods, crinoid stems, and trilobites have been found within an exposure in a newly blasted drainage.

Honaker Trail Formation (Upper Pennsylvanian: 291-295 Ma)

Lithology: Limestone, dolomite, and sandstone deposited in an open, shallow sea.
Fossils: Corals, bryozoans, brachiopods, crinoids, echinoids, fusulinids, gastropods, pelecypods, trilobites, and a variety of marine trace fossils (Melton, 1972) (Figure 4). Tidwell *et al.*, (1972) describes a *Calamites*-like stem from this formation and Baars (1962) mentions fusulinids. Ottinger (personal communication, 1995) reported finding cladodont and bradyodont shark teeth across from the Arches entrance. Invertebrate fossils have dated the uppermost Honaker Trail Formation as Virgilian (Doelling, 2003).

Cutler Formation (Permian: 265-289 Ma)

Lithology: A large alluvial fan complex shed from the Uncompahgre Uplift that interfingers with the upper Honaker Trail Formation. Lithologies include arkose sandstone, gritstone, and conglomeratic sandstone, all of which are micaceous and range from reds to purples (Doelling, 1985a).
Fossils: The Cutler Formation is only exposed within the park directly adjacent to Highway 191 north of the park entrance. No fossils have been found within the park.

Moenkopi Formation (Lower Triassic: 241-245 Ma)

Lithology: Chocolate brown sandstone and siltstone from tidal flats of a receding sea. Generally thin, evenly-bedded siltstones containing some conglomerate, gypsum, and claystone with ripple marks and mudcracks (Doelling, 1988).
Fossils: Tracks are common in this formation from the Wyoming border, south into Arizona (Mickleson, personal communication, 2002) however, none have been reported from within the park. Shoemaker and Newman (1959) report juvenile ammonites and gastropods from this formation in the Salt Valley, but these fossils now are recognized as freshwater snails and ostracodes from the Cedar Mountain Formation (Lucas *et al.*, 1997a; 1997b).

Chinle Formation (Upper Triassic: 215-225 Ma)

Lithology: Primarily fine-grained stream floodplain deposits of interbedded siltstone, sandstone, and multicolored shale with a basal conglomerate (Doelling, 1988).
Fossils: Dinosaur tracks, numerous vertebrate and invertebrate burrows, and layers yielding plant seeds, stems, and leaves (Figure 6h, g, f). The uppermost Chinle in the entire area is loaded with tracks representing the most abundant track fauna in the Triassic of North America. The base of the Chinle preserves paleosols ("fossil" soils with root casts) in the park.

Wingate Sandstone (Lower Jurassic: 198-204 Ma)

Lithology: Very uniform, fine-grained, well-sorted crossbedded sandstone ranging from orange-brown to pink-gray in color (Doelling, 1988). This eolian sandstone had its source to the northwest.
Fossils: No Wingate fossils have been reported from within the park, however it is known to yield tracks on parting surfaces and include *Brachychirotherium* (aetosaur) indicating a good portion of the formation is Triassic. Also tritylodont (*Brasilichnium*) tracks have been found higher up in the section.

Kayenta Formation (Lower Jurassic: 192-198 Ma)

Lithology: Stream-deposited sandstone with subordinate conglomerate and shale layers, primarily reddish

but can vary in its coloration (Doelling, 1988). Lenticular, crossbedded playa/oases deposits of thin gray limestones and dolomites.
Fossils: Playa deposits preserve tree stumps and abundant trace fossils including theropod tracks and invertebrate burrows that can be found within the park.

Navajo Sandstone (Lower Jurassic: 181-192 Ma)

Lithology: Large eolian, dune-sized crossbeds dominate this pale orange sandstone (Doelling, 1988). Oases deposits (limestone lenses), similar to those in the underlying Kayenta Formation, are found within the sandstone.
Fossils: The Navajo was formerly thought to be devoid of fossils but recent discoveries of vertical burrows, fossilized conifer stumps and theropod, prosauropod, and tritylodont tracks within the oases deposits prove otherwise. However, only invertebrate traces have been found associated with these playa deposits within the park.

Carmel Formation (Middle Jurassic: 165-170 Ma)

Lithology: Contains limestone, gypsum, chert, and sandstone interpreted to have been deposited on tidal flats of a inland sea that laid to the west.
Fossils: None reported from the park.

Dewey Bridge Member

Lithology: Soft, muddy sandstone, irregularly contorted bedding throughout originally deposited horizontally on the broad tidal flats of the westward-lying sea (Doelling, 1988).
Fossils: No fossils reported from within the park

Entrada Formation (Middle Jurassic: 165-170 Ma)

Lithology: Previously, the Dewey Bridge, Slick Rock and Moab Members were all included within the Entrada Formation. However, Doelling (2003) revised the stratigraphy of the Entrada Formation. His revisions consist of separating the Dewey Bridge Member into the Carmel Formation and the Moab Member into the Curtis Formation. See Doelling (2003) for explanations of the revised stratigraphy.
Fossils: Widely thought to be devoid of vertebrate fossils, however trace fossils have been found. Ekdale and Piccard (1985) describe invertebrate ichnofossils from this formation. Also two types of vertebrate tracks are reported: 1. *Eubrontes*-like, larger and more robust (probably *Megalosauripus*) and 2. *Grallator*-like, smaller and more gracile with middle digit much longer than other two.

Slick Rock Sandstone Member

Lithology: A massive, reddish-orange to brown unit with alternating cross- and planar bedding signifying a fluctuating beach and fluvial depositional environment (Doelling, 1988).
Fossils: No fossils reported from within the park.

Curtis Formation (Middle Jurassic: 165-170 Ma)

Lithology: Brown, thin-bedded, silty, fine-grained, slope or recess-forming sandstone marine-deposited sediments. The Curtis sea did not extend into the Arches region, however the Moab Member sediments are the subaerial equivalent to the Curtis facies.
Fossils: Many tracks are found at the top of the Moab Member.

Moab Member

Lithology: Very pale orange to light-gray massive calcareous sandstone (Doelling, 1988). Large eolian crossbeds are seen with the uppermost few feet containing rip-up clasts as well as current and wave ripples which represent the reintroduction of water to the desert sands of the Moab (Lockley, 1991). The Moab Member is also known as the Moab Tongue Member. Historical stratigraphic nomenclature frequently includes the Moab Member within the underlying Entrada Formation. Recent work, however, has placed with Moab Member within the Curtis Formation (Doelling, 2003; Kirkland *et al.*, 2005)
Fossils: The Moab Member hosts the oldest known megatracksite that extends through the park and to the northwest. Made by a theropod, *Allosaurus*-like track-maker, the tracks are found right at the contact of the Moab Member and the overlying finer-grained sediments (Summerville) (Lockley, 1991). Other sites within the Moab Member display a variety of small tridactyl tracks and burrows ranging from 3-7 cm in diameter

(Figure 6b, c). At the upper contact there are also horizontal burrows ranging from 3-7 cm in diameter. Other sites documented during this survey are found within the Moab Member. At these sites there are two distinct tridactyl traces, one larger and with fleshy digits and the other small with slender digits (Figure 6d).

Summerville Formation (Middle Jurassic: 165 Ma)

Lithology: Doelling (2003) describes a thin layer of Summerville which exists between the Entrada and Morrison Formations within Arches National Park. This formation is made of light-tan to brown sandstone and red siltstone from deltaic deposits with isolated hypersaline marine zones (salt hoppers). This formation can be confused with the Tidwell Member of the Morrison. However, the Tidwell Member has a higher carbonate content (Lockley, personal communication, 2000).

Fossils: Dinosaur footprints have been reported (Lockley, 1991).

Morrison Formation (Upper Jurassic: 144-154 Ma)

Lithology: Deposited in stream channels and floodplains; the Morrison Formation is divided into three members in the park and consists of siltstones, sandstones, and claystones (Doelling, 1985). Doelling (2000) proposed revisions to the stratigraphy of Arches National Park and recommended the Tidwell Member be differentiated from the underlying Summerville Formation.

Fossils: The Morrison Formation yields the majority of the dinosaur material found in local rock shops. Outside the park to the west there is a turning sauropod trackway on Bureau of Land Management (BLM) land as well as three parallel sauropod trackways west of Highway 191. Emily Bray (personal communication, 2000) reported dinosaur eggshell from south of the airport which turned out to be from the Cedar Mountain Formation.

TIDWELL MEMBER

Lithology: Thin-bedded red sandstones and shale showing ripple marks deposited in shallow water or a sloping floodplain. At the base of the member is a thin lacustrine limestone containing large, white, chert concretions (Doelling, personal communication, 2002)

Fossils: No fossils reported from within the park. However, west of the park on State land the Tidwell has produced the only associated pterosaur skeleton known from the Jurassic of North America as well as a number of sauropod dinosaur bones. (Czerkas and Mickelson, 2002; UGS data base).

SALT WASH MEMBER

Lithology: Primarily a river-deposited unit comprised of sandstone, mudstone, siltstone, shale, limestone and conglomerate (Doelling, 1988), with the conglomerate being particularly sparse within Arches (Engelmann, 1995).

Fossils: Petrified wood and dinosaur bone (Doelling, 1985). There are limb cavities found within this member, indicating where fossils used to be. Ant (Hymenoptera: Formicidae) ichnofossils (galleries and chambers) represent the earliest known fossil evidence of ants (Hasiotis and Demko, 1996). Outside the park there is a tracksite within the Salt Wash Member with a sauropod turning and a limping theropod.

BRUSHY BASIN MEMBER

Lithology: Whereas the Salt Wash Member is primarily river sediments, the overlying Brushy Basin Member is made of floodplain and lacustrine deposits, muddier siltstone and claystone. Green mudstones contain zeolite minerals and were formed subaqueously in a lacustrine environment while purple mudstones were deposited in floodplain environments (Doelling, personal communication, 2002).

Fossils: This unit contains many petrified wood and bone fragments. The remains of a sauropod skeleton have been found and removed illegally from near Wolfe Ranch. Ant (Hymenoptera: Formicidae) ichnofossils (galleries and chambers) contribute to the earliest known fossil evidence of ants (Hasiotis and Demko, 1996). An *Apatosaurus* skeleton was found recently in a pediment paleosol at the contact of the Morrison Formation and the Cedar Mountain Formation, suggesting a Jurassic age for this unit.

Cedar Mountain Formation (Lower Cretaceous: 100-112 Ma)

Lithology: This formation is divided into three members within the park and consists of a thin continental unit of sandstone, conglomerate and limestone (Doelling, 1988a).

Fossils: Ostracodes, protistids, snails and abundant white petrified wood can be found (Doelling, 1988). Shawn Duffy (personal communication, 2000) found a dinosaur rib near Wolfe Ranch. Plant material of cycads (*Cycadeoidea* sp. and *Monanthesia* sp.) and ferns (*Tempskya* sp.) have been identified. Many discoveries of dinosaur eggs and bone have been made outside the park within this formation. Within the park, the Delicate Arch Viewpoint tracksite recently has been found. Also, at the contact between the Cedar Mountain and Morrison Formations associated sauropod caudal vertebrae have been found, as well as a new *Apatosaurus* skeleton.

Yellow Cat Member

Lithology: Ledge-forming sandstone, silty mudstone floodplain and lacustrine deposits (Doelling, 1988).
Fossils: No fossils are reported from within the park, though the Yellow Cat Member is known to yield an extensive vertebrate fauna unique to the area around Arches.

Poison Strip Member

Lithology: Silty, shaly mudstone with ledges of sandstone, quartzite, or nodular-weathering brown muddy limestone (Doelling, 1988). Gravelly sandstone sequence that forms an important regional marker bed hogback (Kirkland *et al.*, 1997). This unit resembles the Brushy Basin Member of the Morrison Formation with more subtle coloring (Doelling, 2003).
Fossils: A log 30 feet long and 3 feet across with another, smaller log have been found beneath a heavily burrowed sand layer and may be partially burnt. A number of dinosaur remains have been found outside the park in this member.

Ruby Ranch Member

Lithology: Channel sandstones and carbonate paleosols from floodplain deposits (Kirkland *et al.*, 1997).
Fossils: Within this exfoliated sandstone unit, a large significant tracksite was discovered containing over 50 sauropod, theropod, ornithopod, and ankylosaur tracks, and for the first time in the Cedar Mountain Formation, a sequential trackway (Lockley *et al.*, 2004). An solitary tridactyl ornithopod track has also been found (Lockley *et al.*, 1999). No vertebrate fossil material has been found. However ant, crayfish, termite, small and medium-sized theropod, and subaqueous crocodile tracks, as well as a trampled surface with iguanodontid, sauropod, dromaeosaurid tracks and some possible feeding traces have been found (Figure 6a, e).

Dakota Formation (Upper Cretaceous: 94-96 Ma)

Lithology: A shaly unit with conglomerates and overall yellow-gray to brown sandstone (Doelling, 1988).
Fossils: Stokes (1952) found a *Tempskya* trunk and McKnight (1940) reports *Halymenites* (?) plant material, mostly unidentifiable stem fragment impressions. *Tempskya* (ferns) and *Pycnadonte newberryi* (bivalve shells) are found in a bed a few meters above the Dakota in basal Mancos. Sporadic fossil leaves are also found within this formation (Doelling, 1988).

Mancos Shale (Upper Cretaceous: 87-94 Ma)

Lithology: Separated into three members in the park, the upper and lower units are fissile shales with a bed of more resistant sandstone sandwiched between. The sediments were deposited by a gently sloping, shallow sea (Doelling, 1988). The upper shale member is more fossiliferous than the lower and the most resistant sandstone is the most fossiliferous (Doelling, personal communication, 2002)
Fossils: Pelecypods, gastropods, ammonites, oysters and other marine invertebrate fossils.

Tununk Member

Lithology: Fissile shale
Fossils: Pelecypods, gastropods, ammonites, oysters and other marine invertebrate fossils, as well as shark teeth.

Juana Lopez Member
(mapped as Ferron Sandstone)

Lithology: Platy, thin-bedded brown-gray, calcrete and very fine-grained sandstone with more fossils in the upper units (Molenaar and Cobban, 1991; Franczyk *et al.*, 1991).
Fossils: Oysters and cephalopods (Doelling, 1985a). More fossils appear higher in this section with oysters, gastropods, cephalopods, and shark teeth being found by Molenaar (1975) outside of the park.

Main Body Mancos

Lithology: Fissile shale
Fossils: Pelecypods, gastropods, ammonites (*Baculites*), oysters and other marine invertebrate fossils.

Tertiary Rocks (1.8-65 Ma)

Within the collapsed core of the Salt Valley Anticline, Tertiary rocks have been identified as probable Green River Formation (Eocene) clasts as well as tuffaceous sandstones containing diatoms that have been dated as Miocene (Dyer, 1983).

Pleistocene Deposits (0.01-1.8 Ma)

Columbian Mammoth (*Mammuthus columbi*): "Woody" from Lower Courthouse Wash area. A juvenile partial mandible tusk was collected and bone fragments can still be seen at the site. The columbian mammoth was a hairless mammoth similar to modern elephants (Santucci *et al.*, 2001) (Figure 5).

Bighorn Sheep (*Ovis canadensis*): Found at Bison Alcove. The remains of at least two individuals were found as well as a horncore with the sheath. Some of the bones show signs of burning and other human impact (Mead *et al.*, 1991; Santucci *et al.*, 2001).

Bison (*Bison bison*): Found at Bison Alcove. The remains of one individual, most likely a young adult, as well as a hornsheath. None of the artifacts show evidence of butchering. The artifacts have been dated to either A.D. 1405-1420 or A.D. 1535-1605 (Mead *et al.*, 1991; Santucci *et al.*, 2001). Wild bison were present in the late Pleistocene but were displaced and/or killed when white settlers entered the area.

Packrat (*Neotoma*): Middens containing needles from Douglas fir (*Pseudotsuga menziesii*), Winterfat (*Ceratoides lanata*) and Limber pine (*Pinus flexilis*). Winterfat is the only one of these three that still can be found in Arches National Park (Sharpe, 1991; Santucci *et al.*, 2001; D. Allen, personal communication, 2002).

PALEONTOLOGICAL RESOURCES INVENTORY

This section provides a taxonomic inventory of paleontological resources from localities within Arches National Park. A more detailed listing can be found in Appendix A.

Paleobotany

Cedar Mountain Formation (Cretaceous) Microfossils of *Metacypris angularis*, *Cypridea* cf. *Cypridea brevicornis*, *Cypridea wyomingensis*, and *Clavator harrisi* were collected by Stokes (1952). Additionally, Katitch (1956) found *Eupera* cf. *Eupera onestae* from the same locality within the park.

Pleistocene Deposits (Pleistocene - 12,400-20,000 ybp) *Ambronia*, *Ambrosia*, *Amelanchier utahensis*, *Amsinkia/Cryptantha*, *Argemone*, *Artemisia*, *Artemisia ludoviciana*, *Artemisia/Chrysothamnus*, *Astragalus*, *Atriplex*, *Atriplex canescens*, *Atriplex confertifolia*, *Bouteloua*, *Ceratoides lanata* (winterfat), *Celtis reticulata*, *Cercocarpus* cf. *montanus*, *Chaenactis*, *Chenopodium*, *Chrysopsis*, *Chrysothamnus*, *Cirsium*, *Coleogyne ramosissima*, *Commandra umbellata*, *Cornus sericea*, *Cryptantha*, *Cryptantha* cf. *Cinerea*, *Cycloma atriplicifolia*, *Dicoria*, *Dithyrea wislizenii*, *Dyssodia acerosa*, *Ephedra*, *Fraxinus anomala*, *Gutierrezia*, *Gutierrezia* cf. *microcephala*, *Gutierrezia sarothrae*, *Heteropogon*, *Juniperus osteosperma*, *Lepidium*, *Lithosperium* cf. *incisum*, *Mentzelia*, *Oenothera pallida*, *Opuntia*, *Opuntia polyacantha*, *Osmorhiza depauperata*, *Pinus edulis*, *Pinus flexilis* (Limber pine), *Populus*, *Pseudotsuga menziesii* (Douglas fir), *Quercus*, *Quercus gambelii*, *Rhus*, *Rhus aromatica*, *Ribes montigenum*, *Rosa* sp., *Senecio*, *Solidago*, *Sphaeralcea*, *Stipa hymenoides*, *Symphoricarpos*, *Tiquilia*, *Yucca*, *Yucca* cf. *angustissima* (Sharpe, 1991).

Fossil Invertebrates

Kingdom Protista

Honaker Trail Formation (Pennsylvanian) Fusulinids have been found near the Visitor's Center (Melton, 1972).

Kingdom Animalia

Phylum Cnidaria

Honaker Trail Formation (Pennsylvanian) The corals *Syringopora* sp., *Caninia torquia*, and *Lophophyllidium profundum* have been found in limestones near the Visitor Center (Melton, 1972).

Phylum Arthropoda

Honaker Trail Formation (Pennsylvanian) Two pygidia of the trilobite *Ditomopyge* were recovered near the Visitor Center (Melton, 1972).

Phylum Mollusca

Gastropods

Honaker Trail Formation (Pennsylvanian) *Anomphalus rotuius*, *Bellerphon* sp., *Bellerphontid* sp., *Euphemites carbonarius*, *Knightites montfortianus*, *Pharkidonotus percarinatus*, *Straparollus* sp., and *Worthenia* sp. have been found in upright positions within silty shales near the Visitor Center (Melton, 1972).

Pelecypods

Honaker Trail Formation (Pennsylvanian) *Acanthopecten carboniferus*, *Aviculopecten* sp., *Chaenomya* sp., *Erimondia* sp., *Lima* sp., *Limapecten* sp., *Limatula* sp., *Mylania* sp., *Nuculana bellistriata*, *Parallelodon*, *Permophorus occidentalis*, ?*Pseudomonotis*, *Pseudomonotis equistriata*, *Pseudomonotis kansasensis*, *Pteronites* sp., *Ptychomphalus* sp., *Schizodus* sp., *Septimyalina burmi*?, and *Wilkingia* sp. have been found in limestones near the Visitor's Center often in close association with twiggy and sheeting bryozoans (Melton, 1972).

Phylum Brachiopoda

Honaker Trail Formation (Pennsylvanian) Brachiopods *Chonetes granulifer*, *Chonetina flemingi*, *Composita* sp., *Composita subtilita*, *Derbyia* sp., *Derbyia bennetti*, *Derbyia crassa*, *Derbyia wabashensis*, *Dictyoclostus americanus*, *Echinoconchus* sp., *Echinoconchus semipunctatus*, *Juresania nebrascensis*, *Linoproductus* sp., *Linoproductus meniscus*, *Linoproductus prattenianus*, *Marginifera lasallensis*, *Marginifera wabashensis*, *Neospirifer kansasensis*, *Neospirifer triplicatus*, *Orbiculoidea* sp., *Phricodothyris perplexa*, *Punctospirifer kentuckyensis*, *Wellerella osagensis*, and *Wollerella tetrahedra* are found in a range of lithologies from shales to limestones near the Visitor's Center (Melton, 1972).

Phylum Bryozoa

Honaker Trail Formation (Pennsylvanian) Branching, massive, sheeting, and twiggy bryzoans have also been collected in this formation (Melton, 1972).

Fossil Vertebrates

Kingdom Animalia

Phylum Chordata

Class Reptilia

Subclass Dinosauria

Morrison Formation (Upper Jurassic) Fragments of dinosaur bone are found widely within this formation. Ankylosaur and general sauropod bones have been reported as well as a newly discovered *Apatasaurus* skeleton from the Brushy Basin Member.

Cedar Mountain Formation (Lower Cretaceous) Dinosaur bone fragments and sauropod caudal vertebrae have been found in Yellow Cat Member.

Class Mammalia

Order Rodentia

Pleistocene cave deposits *Neotoma* (packrat) middens

Order Artiodactyla (deer, cattle, pigs)

Bison Alcove (Pleistocene) Fragments of *Ovis canadensis* (bighorn sheep) and *Bison bison* (bison) found in a packrat midden.

Order Proboscidea

Lower Courthouse Wash (Pleistocene) *Mammuthus columbi*, the columbian mammoth

Invertebrate Trace Fossils

Honaker Trail Formation (Pennsylvanian) Melton (1972) reports trace fossils to be the most abundant fossils from the locality he studied near the Visitor Center. The site yields domichnia (possibly *Ophiomorpha*), fodinichnid, pascichnid, and repichnid traces (according to the terminology of Seilacher, 1964).

Chinle Formation (Triassic) Horizontal burrows and troughs in Salt Wash exposures as well as along the southern margin of the park (this survey). *Octopodichnus* found within Salt Valley.

Navajo Formation (Triassic-Jurassic) Assorted horizontal invertebrate burrows found within or near playa limestone deposits.

Morrison Formation (Upper Jurassic) Ant galleries and chambers found by Hasiotis and Demko (1996)

Figure 4: Corals from within the Honaker Trail Formation.

Figure 5: Mastodon mandible from a cave in Lower Courthouse Wash.

found within the Salt Wash Member.

Vertebrate Trace Fossils

Chinle Formation (Triassic) Tridactyl tracks come out of this formation from the southern margin of the park along the highway. Isolated reptile track (*Dromopus*?) in Salt Wash (this survey).

Kayenta Formation (Jurassic) Shawn Duffy found two theropod tracks and many other tracks have been found in oases deposits.

Curtis Formation (Jurassic) Ekdale and Piccard (1985) report invertebrate fossils. Two types, one *Eubrontes*-like, the other, *Grallator*-like, of vertebrate tracks were found. Lockley's (1991) mega-tracksite is found within the Moab Member. Small isolated tridactyl prints within the member (this survey). *Megalobrontes* tracks and trackways (maximum 12 tracks) representing a variety of different sized animals (Britt, 1996)

Cedar Mountain Formation (Early Cretaceous) A small theropod trackway, unusual feeding traces, subaqueous crocodile tracks are also found within the Ruby Ranch Member. Lockley *et al.* (2004) discovered a significant tracksite with over 50 sauropod and theropod tracks during field work for the Arches National Park Paleontological Survey. This tracksite included two track bearing surfaces. The upper, more complex, track surface displayed tridactyl theropod tracks, didactyle theropod tracks and sauropod tracks as well as tracks from ornithischian dinosuaurs (Lockley *et al.* 2004). Some of the tridactyl tracks may have been made by the coelurosaur theropod *Nedcolbertia* . The didactyl tracks may be attributable to dromeosaurs (*Deinonychus*?). The sauropod (possibly *Pleurocoelus* or *Venenosaurus*) trackways are similar to the classic "wide-gauge" sauropod trackway *Brontopodus*. The two types of ornithischian tracks were likely made by an ornithopod (potentially cf. *Tennontosaurs*) and an ankylosaur (possibly *Sauropelta*), respectively. The lower track-bearing surface contains a much less complex assemblage of theropod tracks and what may be sauropod track underprints (Lockley *et al.* 2004). Theropod tracks on this surface display two morphologies, one narrow-footed and the other, a more common morphology suggesting a medium-sized theropod.

LOCALITIES

Arches National Park has been divided into re gions defined geographically based upon geomorphic features, landmarks, and park roads, for the purposes of this report. Specific paleontological localities are organized within each region (see Arches Regional Map, Figure 7).

Salt Valley Region

This region runs diagonally through the park from the northwest perimeter to the Salt Valley Overlook where it narrows and heads east across the main park road and along the extension toward the Delicate Arch Viewpoint. It is accessible to the northwest via a gravel and sand road which meets the main park road near Sand Dune Arch and the eastern extension is easily available by the main park road and extension towards the Delicate Arch Viewpoint. This region includes Cache Valley.

The western extent of Salt Valley consists of a wide plain of alluvium, sand, and talus deposits bordered on each valley wall by the Wingate, Chinle, and Kayenta Formations. In the narrower, more accessible region of Salt Valley to the east many dinosaur body fossil and track localities as well as plant localities have been found within the Morrison Formation. In addition, oyster beds are located within the Mancos Shale.

Petrified Dunes Region

The Petrified Dunes Region is bordered on the south by the Colorado River. The park boundary follows the river from the bridge for Highway 191 upriver around the Big Bend to Salt Wash. The Petrified Dunes Region boundary then heads west towards and just north of the Windows Section of the park. The western border of this region is the main park road and the eastern cliffs of Courthouse Wash. The only access to this region is on foot, preferably from the Windows Section or any pull off along the main park road.

Beds of the Navajo Sandstone are the dominant strata of the Petrified Dunes Region; however they are largely devoid of fossils. The major exceptions are playa deposits preserved as limestone lenses within the eolian sandstone. Within and around these playas tracks, plants, and body fossils are often found (Figure 9).

Courthouse Wash Region

This is the southwestern-most region of the park including the park entrance extending northward to the intersection of Courthouse Wash and the western park boundary. The eastern extent of this region includes the eastern cliffs of Courthouse Wash adjacent to the Petrified Dunes and Willow Flats regions. Courthouse Wash can be accessed from the south along Highway 191 or within the park approximately 5 miles from the park entrance along the main park road.

Courthouse Wash itself is the primary focus for paleontological resources from this region of the park. The Kayenta Formation outcrops near the mouth of the wash and yields invertebrate burrows and dinosaur tracks. Pleistocene deposits within the wash contain mastodon remains and more recent pack rat middens have coyote, desert bighorn sheep, deer and rabbit bones as well as seeds and other plant remains which can assist in the

Figure 6: Composite of fossils from Arches National Park. Clockwise from top left: A. Isolated dinosaur tracks from the Ruby Ranch Member of the Cedar Mountain Formation; B. Two tridactyl tracks (facing one another) from within the Moab Tongue Member of the Curtis Formation. C. Tridactyl tracks from within the Moab Tongue Member; D. Two distinctive track types from within the Moab Tongue Member.

Figure 6 (continued): Composite of fossils from Arches National Park. Clockwise from top left: E. Possible feeding traces from the Ruby Ranch Member of the Cedar Mountain Formation; F. Plant fossils from the Chinle Formation; G. Invertebrate burrows from the Chinle Formation; H. *Octopodichnus* tracks from the Chinle Formation reconstruction of previous ecological systems and local climates (Sharpe, 1991).

Devils Garden Region

This region extends along the northern border of the park southeast to the campground and then loops around and heads northwest along the margin of the Salt Valley back to the park boundary. The Devils Garden loop trail can offer some access to this region, but entry from the Yellow Cat area to the north via four-wheel drive trails may be preferable.

There are extensive exposures of the contact between the Moab Member of the Curtis Formation and the Tidwell Member of the Morrison, a contact that yields plentiful theropod dinosaur tracks associated with the Moab Megatracksite (Lockley, 1991).

Klondike Bluffs Region

This region consists of a small slice of land between the western border of the park and Salt Valley. Two roads can be used to gain access of this region, both of which can be reached from within the park.

The Klondike Bluffs Region hosts exposures of the Entrada/Curtis and Morrison Formations which have extensions of the Moab Megatracksite at the contact. Nothing has been found in this region within the park, however just west of the boundary many theropod dinosaur tracks are well exposed (Figure 8, 10).

Salt Wash Region

The Salt Wash Region consists most of the drainage of Salt Wash divided by the Salt Valley Region. The southern part includes a wedge of land bordered by the eastern park boundary, the Windows Section to the south and Salt Valley to the north. Salt Wash can be entered from the Delicate Arch Road area of the park or from the south at the confluence of the wash and the Colorado. However, a boat is required to cross the Colorado in order to reach the mouth of Salt Wash.

The mouth of Salt Wash cuts through a large exposure of the Chinle Formation in which burrows, plant fossils, and tracks can be found. In the northern part of this region burrows and tracks can be found at the Entrada/Curtis-Morrison contact.

Willow Flats Region

The Great Wall along the main park road borders this region in the southeast, the Salt Valley Region to the north, the park boundary and Klondike Bluffs Region to the west and the Courthouse Wash Region in the south. Willow Flats is accessible via two four-wheel drive roads from within the park as well as from Highway 191 outside and to the west of the park.

The Willow Flats region hosts some of the Entrada/Curtis-Morrison contact where burrows and dinosaur tracks can be found.

INTERPRETATION

Long-Range Interpretive Plan

The Long-Range Interpretive Plan (LRIP) is in place, but does not address paleontology as an interpretive theme at Arches National Park. However, there are relevant considerations made by the Comprehensive Interpretive Plan (CIP), which includes the LRIP, that can be extended to apply towards the fossil resources of the park. For example, the exhibits within the Visitor Center are more than 40 years old and the information is antiquated; the dinosaur diorama sports a classic Mesozoic jungle scene with a tail-dragging *Tyrannosaurus rex*. The CIP calls for entirely new exhibits with the construction of a new Visitor Center in the near future. Fossil resources should be covered in this change.

As it stands, there is no mention of the paleontological resources found within Arches' park boundaries in publications, exhibits, or programs. The one exception is found inside the Visitor Center where there is a diorama with some associated specimens of invertebrate, plant, and dinosaur fossils. In the future, with the construction of the new Visitor Center, there is the distinct potential for the introduction of paleontology into the interpretive program at Arches.

Currently, paleontology is mentioned in the interpretive staff training briefly during the introduction to the regional geology; interpreters are welcome to gather more information individually. An assortment of videos, professional papers and theses, and a collection of books at variable levels of digestibility are available in the Arches library. Some slides and photographs are also housed within the library for use in interpretation.

As a method of resource protection, the interpretive staff is discouraged from discussing fossil resources within the park with visitors (Allen, personal communication. 2000). This raises the inherent question posed by the presentation of paleontological resources via interpretive programs to the public. Is the park willing to risk the resources in order to educate the public about them? With the popularity of paleontology evident by the glut of dinosaur movies and paraphernalia on the market, advertising the resources found within and around Arches places them in implied danger at the least from naive enthusiasts, but more likely by fossil hunters with more economic motivations. The park's experience with archaeological thefts related to the disclosure of information has demonstrated that loss from unauthorized collecting will occur if the public is informed of the resource. Such considerations must be taken into serious account with any change in the current interpretive program such as those mentioned below.

Interpretive Themes

The primary interpretive themes for Arches consist

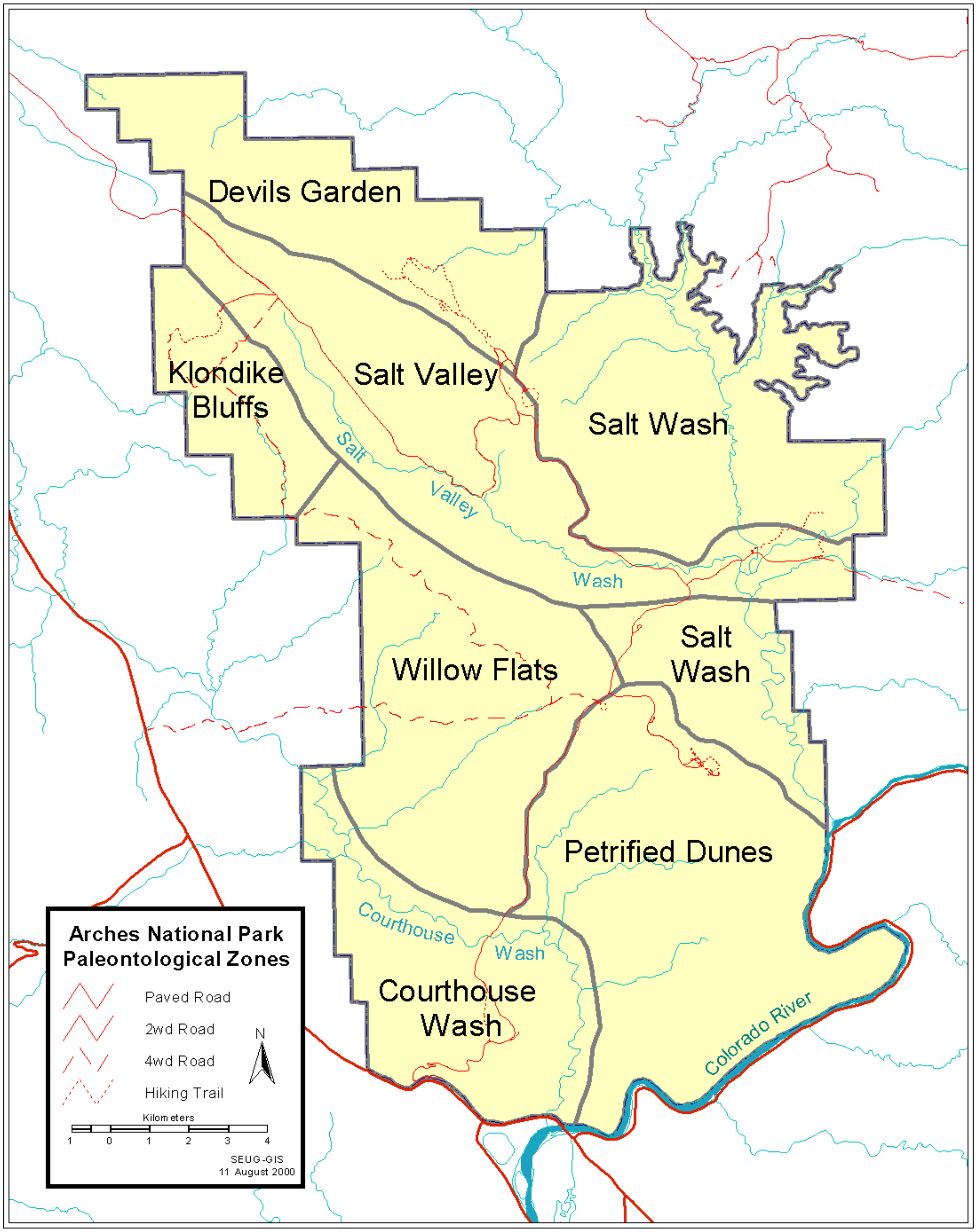


Figure 7: Arches National Park regional map identifying regions with paleontological resources.

of geology; desert ecology; protection and stewardship; and archeology and local human history (Arches Comprehensive Interpretive Plan, May 2001). In practice, the interpretive program is divided nearly equally between biological and geological components addressing, fore example, desert ecology and arch formation respectively.

Similar to the problem faced at other parks that have but are not known for paleontological resources is the one faced by Arches: if the resource is advertised there is greater demand for interpretation and protection thus requiring more staff-hours. At parks known for their fossil resources there are many considerations that are made in order to present the resource accurately to an audience who are perpetually exposed to conflicting scientific and popular conceptions of paleontology. Specific staff-training that addresses these problems is often offered at these fossil parks. A simplified version of this type of training, perhaps as an evening workshop or brown-bag lunches could address these issues at Arches.

There are many ways in which paleontology could be interpreted at Arches in a pamphlet, wayside exhibit, or guided walk. Examples include:

• Using fossils as a means by which to interpret the paleoecology of the region and compare environments of the past to the one we live in today.

• An animal adaptation program could discuss adaptations dinosaurs and other animals might have had to live the desert environment represented by the Wingate, Navajo, and Entrada Formations. How might those adaptations differ from the ones seen at Arches today?

• The living soil includes a lot more than the cryptobiotic crust. There are a plethora of invertebrates, and vertebrates even, who make their homes beneath our feet. Examples of their ancestors' preserved homes are abundant in the Chinle Formation. A program could discuss the difficulties in matching up a trace fossil to its maker and how modern animals can be useful tools for making more accurate guesses as to who lived in what.

Additionally, with education of staff and visitors the issue must be raised as to whether specific locality information should be provided to visitors of the park. With advertising of the park's paleontology, protection and surveillance of fossil localities would need to be incorporated into staff duties. Naturally, the manageability of adding fossil protection into staff responsibilities should be evaluated prior to implementation.

Interpretive Resources

There are a variety of resources available for the interpretive staff at Arches National Park. The library has an expanding section of paleontology-related books for children and adults alike, most of which focus on dinosaurs. Also there are a over a dozen videos, most of which are taped slide presentations given at the Moab Information Center (sponsored in part by the Dan O'Laurie Museum as well as the Canyonlands Natural History Association) in Moab by scientists who have been doing research and field work in the region. Slides, photographs, and a teaching collection of specimens are also available at Arches as tools that can be used to augment interpretive programs relating to the paleontological resources of Arches National Park and the surrounding area.

Small additions which could significantly aid the interpretive resources at Arches include more "touch and feel" specimens which could be used in programs or an interactive temporary or permanent display in the Visitor Center. These could include latex molds of trackways (relatively simple and inexpensive) and fossils (body and trace) collected from within the park which do not have particular scientific value, but would serve as tangible, "show-and-tell" educational tools.

Recommended Interpretive Actions

Currently the public has no access or information pertaining to Arches paleontological resources aside from the antiquated diorama in the Visitor Center. While this may be a solution providing the most protection for the resource and least investment by the park, it also compromises a visitor's understanding of the complete story of Arches, beyond those topics addressed by the interpretive themes.

Solutions that stress proper management of and respect for paleontological resources and simultaneously release information to the public should be sought. Programs that address time and the geologic processes within Arches can use dinosaurs as a guidepost to the Mesozoic (many people have a sense of where dinosaurs fit into the geologic time scale). Paleoecology is another subject that could supplement current ranger programs, especially those addressing the environment and change through time.

The park could begin implementing a paleontological disclosure policy similar to the one currently used for archaeological sites. Rangers are often approached by visitors for locality information. Ranking known paleontological sites by their scientific value and only advertising those which are well known can serve as a means for preserving less known and more significant sites.

Also with a new Visitor Center facility there can be a definitive make-over of the paleontology diorama as well as additional information relayed through movies and publications.

RECOMMENDED INTERPRETIVE ACTIONS

- Revise display in Visitor Center (most likely when the new VC is built).
- Introduce a paleontology disclosure policy similar to the one used for archaeological sites.
- Encourage paleontology-themed interpretive programs.
- Ensure that all paleontology-themed interpretive programs include a resource protection and stewardship message.
- Boost interpretive fossil collection (latex track molds, petrified wood, dinosaur bone scraps) in order to provide more hands on material for programs.
- Reintroduce paleontology into volunteer training and/or provide workshops for interpretive staff in order to keep them aware of the park's resources.

PALEONTOLOGICAL RESOURCE MANAGEMENT

National Park Service Policy

Fossils are nonrenewable resources that require specific actions for appropriate management. Paleontological resource management on federal lands has gained considerable attention over the past decade and has gained recognition as an independent discipline by the scientific community and land management agencies. This report is meant as a preliminary survey, assessing the potential for significant paleontologic resources to be found in the park.

National Park Service Management Policies state "Management actions will be taken to prevent illegal collecting [of fossil resources] and may be taken to prevent damage from natural processes such as erosion. Protection may include construction of shelters over specimens for interpretation *in situ*, stabilization in the field or collection, preparation, and placement of specimens in museum collections. The locality and geologic data associated with a specimen will be adequately documented at the time of specimen collection. Protection may also include, where necessary, the salvage collection of threatened specimens that are scientifically significant."

Within the National Park Service, paleontological resource management has received initial direction through the Natural Resources Management Reference Manual (NPS Director's Order (DO) 77). The National Park Service Geological Resources Division provides service-wide support to assist parks with achieving some of the objectives outlined in NPS DO-77. Special management actions that are recommended in NPS DO-77 for paleontological resource sites include:

MONITORING

Periodic re-examination of known fossil localities should be conducted to assess site stability and the need for management action. Photo-documentation of the site is essential to monitor any changes. For example, near the Klondike Bluffs area are a number of known tracksites that have been encircled with stones so that mountain bikers avoid riding over them (Figure 8). Sites like these should be revisited in order to monitor impact. Additionally, the Cedar Mountain Formation Tracksite includes many tracks in highly fragile condition.

CYCLIC PROSPECTING

In areas of high rates of erosion, periodic surveys should be undertaken to identify the exposure of any new fossil material at the surface and the loss of previous exposed material.

STABILIZATION/REBURIAL

The management of *in situ* paleontological resources can be accomplished through a wide range of techniques and methodologies. In situations where the excavation of fossil material is not feasible, reburial of the material may be the appropriate interim management action. Reburial can stabilize or slow down the destructive forces of weathering and erosion lengthening the time available to make management decisions.

EXCAVATION

The removal and collection of a fossil from a geologic context may be the appropriate action for management of *in situ* paleontological resources. Depending upon the scientific significance, immediate threats, or other variables, the careful collection of fossil specimens may be warranted. Appropriate collecting permits must be secured in advance for any excavation, collection and curation of paleontological resources.

CLOSURE

A fossil locality may be best managed through closure or restricted access to the area. Closed areas may be completely withdrawn from public use, restricted to ranger-led activities, or require special permit for entry (i.e., research).

files and made available only to protection staff and scientific researchers.

Natural erosion is a major threat to all paleontological resources. Fossils exposed at the surface and near-surface area subjected to physical, biological and chemical forces that can often be destructive. Continued inventory and monitoring of fossil areas subject to significant erosion is recommended.

Construction and visitor use may generate increased levels of erosion. In some cases, however, these activities may also lead to the exposure of subsurface fossil material.

Patrols

Significant or well known fossil sites require periodic monitoring by park staff. Patrols may be important in preventing or reducing paleontological resource theft and vandalism.

Alarm Systems

Arches has been using seismic monitoring systems to alert rangers to any disturbances of sensitive paleontological localities. When the alarm is triggered at the site, a ranger is dispatched to investigate. Arches has been cooperating with other land management agencies and permitted institutions who run quarries outside of the park, providing monitoring and surveillance when the site is unattended.

Management of paleontological resources should be distinct from the management of archeological resources. Paleontological resources are typically recognized as natural resources and should be managed accordingly. The Archeological Resources Protection Act (1979) and the NPS Cultural Resources Management Guidelines (NPS DO-28) provide guidance for cases when paleontological resources occur in an archeological context.

Baseline Paleontologic Resource Data Inventories

The inventory and monitoring of paleontological resources serves as the foundation of any paleontological resources management program. Without the baseline data available from a paleontological survey, any further actions or management decisions would be based upon insufficient information.

To complete a paleontological survey of Arches National Park, the following information is needed:

Geographic data on fossil localities, including topographic coordinates, Universal Transverse Mercator coordinates (UTMs) the geographic extent of each locality, maps, GPS measurements, etc.;

Stratigraphic data related to the geology at each locality, including the formations or subunits and the age of the units;

Paleontological data related to the identification of paleo taxa present within park localities;

Geologic data related to the lithology and depositional environment of the fossiliferous units.

All fossil localities should be documented using both ground and aerial photographs whenever possible. Ground photos should include close-up details showing the fossils, sedimentary structures, and general setting of the locality. Aerial photos should be at a scale appropriate to the physical characteristics of the locality. All locality information must be maintained in locked

RECOMMENDED MANAGEMENT ACTIONS

Continue updating/revising paleontology resource inventory documentation and locality maps.

Train all staff in paleontological resource management addressing such themes as: How to identify a fossil. What to do with one once you've found it. Or what to do with it when some visitor hands it to you. What questions to ask.

Monitor known paleontological sites for human impact and erosion, keep a file of the status of each locality.

Additional focused field survey for paleontological resources.

PALEONTOLOGIC RESOURCE PROTECTION

The protection of fossil resources not only from the elements but also from looting is integral to preserving the scientific value associated with a specimen. To remove a fossil from its geographic and/or stratigraphic context without documentation is equal to discarding volumes of information that can aid in the understanding of a fossil's place in time and space.

The protection of paleontological resources within and outside of the boundaries of Arches National Park has been a cooperative effort between the park rangers and the workers at specific quarries. There are a number of well-known, significant, and productive quarries that lie just beyond the boundary of the park and have been subject to vandalism and looting in the past.

Perhaps the most efficient means of protecting these resources is inclusion of fossil-rich areas within the formal boundaries of Arches. There are a number of potential regions which could profit from the additional protection that the park service would provide.

RECOMMENDATIONS FOR FOSSIL PROTECTION

- Regular patrols of known sites
- Establish site alarms
- Continued cooperation between NPS, BLM, the state of Utah, and universities.
- Expand park boundaries to include productive areas outside the park (e.g. Gaston and Dalton Wells quarries, more of the Moab Megatracksite)
- Develop PMIS statement for paleontology resource protection.

RESEARCH

The National Park Service Natural Resources Management Reference Manual (NPS DO-77) states, "paleontological research by the academic community will be encouraged and facilitated under the terms of a permit…" Arches National Park has been the host to a number of specific research projects, generally directly affiliated with a university.

A Special Use Permit (Form 10-114) is required for any other research. The Special Park Uses Guidelines (NPS DO-53) provide details on the issuance of permits, was recently revised and can be found online.

Current Research

Allen Shaw is studying the taphonomy of ankylosaur bonebed "Lorries Site" (DMNS). Martin Lockley and Jim Kirkland are working on the Cedar Mountain Formation Tracksite. John Foster is excavating a new *Apatosaurus* specimen at the top of the Morrison Formation.

Suggested Research

Navajo Paleoecology – The Navajo Sandstone dominates the surface of the southern part of Arches National Park. This "Petrified Dunes" region has the potential to yield a plethora of interesting fossils if Navajo exposures outside of the park are any indication of what can be found within. The Navajo Sandstone has limestone lenses thought to be playa deposits hosting *in situ* conifer trunks and vertebrate and invertebrate traces (Figure 9).

Chinle Study - A study of invertebrate and vertebrate trace fossils and body fossils within the Chinle Formation is needed. The potential for a project identifying and analyzing these and additional localities would yield more information as to the paleoenvironment of the Triassic (Figure 6f,g,h).

Morrison Formation – A more thorough study/examination of the dinosaur and plant localities that have been found in Salt Valley should be conducted.

Permit System

A research permit serves as an administrative tool to help ensure resource protection by defining limitations on and responsibilities of researchers working in the park. Park management should ensure that information gained through research is obtained by the park (field notes and photographs), and that any specimens collected under a permit remain accessible and properly cataloged into a museum collection, the park's or otherwise.

Funding

Funding for paleontological research has traditionally been difficult to secure within the National Park Service. Fossils lack specific legislation for appropriation of funds to support paleontological resource projects. Most of the financial support for paleontological resource projects has come from park cooperating associations, park donation accounts, or from academic institutions. With limited funding for paleontological resource projects, the training and utilization of volunteers can be a valuable way to accomplish management objectives.

The National Park Service has moved toward a greater recognition of paleontological resources within the last few years. A staff position in Washington was created to oversee geologic and paleontologic resource issues. The newly created Geologic Resources Division in Denver, Colorado, is working towards securing sources of funding to support paleontological research in the national parks.

Literature Survey

As a part of the Arches Paleontological Survey, background searches into existing geologic and paleontologic publications were conducted with the purpose of finding all information pertaining to Arches known paleontological resources. The cooperation of Weber State University in Ogden, Utah was much appreciated in this effort as well as the Lincoln County Library in Kemmerer, Wyoming. Also, the library at Arches National Park was useful in providing park-specific information.

There is not a wealth of publications focused solely on the resources within Arches boundaries. The majority of papers mention vague site or specimen information, necessary for the protection of the fossil but largely unusable for garnering specific data.

COLLECTIONS AND CURATION

Museum Collections

Arches National Park's paleontological collections fall under the jurisdiction of the Southeast Utah Group (SEUG) with headquarters in Moab, Utah, approximately 10 miles south of the park. There are currently 136 catalogued specimens in the Arches National Park museum collection. All of the collections within the National Park Service are catalogued and tracked using the Automated National Catalog System (ANCS+) program. Northern Arizona University (NAU) has more than 900 specimens from Quaternary packrat middens collected within Arches. The collection described in Lucas *et al.*, 1997, is reposited at the New Mexico Museum of Natural History and Science. These are classified as paleontologic resources of Arches as they serve as a resource that should logically be addressed within the management of Arches paleontologic resources.

Currently, fossils collected within Arches National Park are either stored at SEUG headquarters, or held in outside repositories. There are no displays or exhibits within the park utilizing specimens collected from the park. However, there is a Mesozoic diorama and "touch-and-feel" exhibit in the Arches Visitor Center with invertebrates (Hermosa Formation), a petrified tree trunk, a cross-section of dinosaur bone, and a single theropod dinosaur track. Because these items are not known to have been collected within the park, they are not accessioned into the park's museum collection. Further, only the track has any sort of collection location information associated with it.

Scope Of Collections

The scope of the Arches paleontology collections aptly reflects the lack of information known about the park's fossil resources. There are large gaps in the collections at SEUG headquarters. Many specimens are the consequence of serendipity instead of systematic or intentional collection efforts. This is understandable, primarily because of the focus of the park is arches, not fossils. Additionally, the "Scope of Collection Statement" (SOCS) states four themes that "establish which resources should be collected and curated from Arches." Paleontological resources are not included in these themes, however a note is made that increasing knowledge and focus on fossils from Arches is raising the urgency of their addition to the SEUG collection.

The SOCS also addresses the physical collection of paleontological resources stating, "fossil remains may be collected by an approved and permitted paleontologist only if leaving the remains in place would expose them to unacceptable wear, deterioration, destruction, or the possibility of breakage, loss, or theft." It is the opinion of the authors that significant scientific specimens should also be closely considered for immediate removal as they could shed light onto currently shady areas of paleontological knowledge.

Collections at Arches could benefit from establishing representative collections of the known paleoflora and fauna from within the park. However, the SOCS sets a policy of only incorporating endangered resources. Also, space is limited at current local NPS facilities, mak-

Figure 8: Stone circles marking dinosaur tracks located in the Klondike Bluffs Region of the park. These circles deter mountain bikers and hikers from riding and walking over the tracks.

Figure 9: Limestone lenses within the Navajo Sandstone represent oases deposits, a potential research topic.

ing it impossible to curate a representative collection. Prudent additions to the collections can be made, but an outside repository should be sought for any major excavations from within the park.

Security

Locality information is kept secure within the computer database (ANCS+) as the locality fields are inaccessible via the public search function. All of the computer files are kept on one computer with back-ups sent to Harpers Ferry, West Virginia. Only the curator has access to these files. Field notes and maps are kept in a locked cabinet with restricted access to certain Arches National Park employees.

All of the SEUG collections are maintained with restricted access. The building in which the collections are housed hosts a security system, with an alarm dedicated specifically for the collections room. In a review of the facility conducted in April 2002 by a Museum Management Planning Team, the security of this room was deemed adequate for the specimens stored within.

Relatively minor maintenance upgrades may further benefit the fossil collections. For example, the temperature of the collections room can be controlled but the humidity cannot. Also the collections room's smoke detector has malfunctioned in the past. It should be noted that these problems have been acknowledged by the staff and remedies have been sought; however, the current building in which SEUG headquarters is housed is privately owned, thus there are some limits on what upgrades the National Park Service, as tenants, can perform.

Considering the health and safety of the curatorial staff, the installation of a proper ventilation system should be evaluated as many of the fossils measure above acceptable levels for radioactivity. The strata in which many of the specimens are found contains uranium, of which the radon daughters are known to cause cancer. The level of radon in the storage room and in the Arches paleontology cabinet has been measured and found to be above acceptable levels. Removal of specimens from the cabinet with storage on open shelving could alleviate the problem with adequate ventilation to the room. However, the storage of these specimens in an offsite facility would be preferable. This has been the recommendation of the Museum Management Planning Team as well.

Organization

Due to the small number of items within the paleontology collections at Arches, organization is not a large problem. The current system organizes the specimens generally by type, instead of strict taxonomic or stratigraphic placement. With expansion of the collections a more rigid system should be considered.

Photographic Archives

HISTORIC PHOTOS

There is only one known historic photograph related to the paleontology in Arches National Park. The photograph is of a sequence of six dinosaur vertebrae found in the Morrison Formation in Cache Valley. The status of the fossil as well as the photographer was unrecorded with the photograph. Also found within the Arches photographic archives was a photograph of a fallen block of Chinle (?) containing theropod dinosaur tracks. This photograph was taken from Williams Bottom along the Colorado River southwest of Moab.

MUSEUM SPECIMENS

In 1996 photographs were taken of the specimens in the collection. These photographs are held at the SEUG headquarters by the curator.

SLIDE COLLECTION

The interpretive staff has expressed an interest in expanding the slide collection at Arches. Until recently many of the slides were antiquated and not very representative of the resources in the park. A number of slides have been produced in relation to this survey. These are in the process of being added to the interpretive collection.

Fossil Collections In Outside Repositories

Northern Arizona University (NAU)
New Mexico Museum of Natural History and Science (NMMNH)
Denver Dinosaur Tracks Museum Library

Fossil Collections From Lands Adjacent to Arches In Outside Repositories

RECOMMENDATIONS FOR PHOTO ARCHIVES

Develop paleontology portion of slide collection.

Create more slides from illustrations.

Museum of Western Colorado

Moab Megatrackway/dinoturbated seds (Entrada/Curtis/Summerville/Morrison) MWC 185.1-187.5 (Lockley, 1991)

College of Eastern Utah

Iguanodontid tracks (Cedar Mountain Fm) (Thompson Park) (Santucci, *et al.*, 1998)

Denver Museum of Natural History

Cedar Mountain and Morrison fossils

Brigham Young University

Cedar Mountain and Morrison fossils

Oklahoma Museum of Natural History

Utah Museum of Natural History

Various Cedar Mountain Formation fossils

PALEONTOLOGICAL RESOURCES NEAR ARCHES

North Of Arches

The Yellow Cat Flat area, to the northeast of Arches, was incorporated within Arches National Park between 1969 and 1971. However, subsequent boundary changes excluded the Yellow Cat Flat area from the park. Fossiliferous rocks of the 125-120 million year old Cedar Mountain Formation are exposed in the Yellow Cat Flat area and the sites mentioned below. Kirkland *et al.* (2005) summarizes much information regarding paleontological resources surrounding Arches National Park.

The Robert Gaston Quarry is located just north of Arches National Park in rocks of the Yellow Cat Member of the Cedar Mountain Formation (Kirkland *et al.*, 1993; 1997; 1998; 2005). The quarry has yielded dinosaurian material including the type specimens of the dromeosaur *Utahraptor ostrommaysorum* (Kirkland *et al.* 1993) and the armored nodosaur *Gastonia burgei* (Kirkland 1998), as well as other members of the "Yellow cat fauna" were collected here (Santucci, 2000). There also is a trampled surface recording tracks resembling those of a sauropod or another large dinosaur. Also, one small (12 cm) tridactyl track has been found at this site (Kirkland 1998; Kirkland *et al.*, 1997; 1998).

East of Gaston Quarry there are three casts of large ornithopod tracks from a sandstone bed (Lockley *et al.*, 1999). Also is the nearby type locality of *Nedcolbertia* (Kirkland *et al.*, 1998a)

Lorrie's Site (Denver Museum of Nature and Science) is currently yielding *Gastonia*. Nearby Tony's Bonebed in the Poison Strip Member of the Cedar Mountain Formation has yielded type specimens of *Planicoxa* and *Venenosurus* (Tidwell *et al.*, 2001; Devcoce and Carpenter, 2001). South of Cisco in the Yellow Cat Member is the type specimen of *Cedarsaurus* (Tidwell *et al.*, 1999).

Also within the Cedar Mountain Formation (Poison Strip Member (Lower Cretaceous)) ostracods have been found.

Plant material is locally known from this region.

A site containing fossils that might be the world's oldest bird tracks was recently found just north of Arches (Jim Kirkland, personal communication, 2005).

West Of Arches

On the west side of Arches there are exposures of Morrison Formation and Cedar Mountain Formation as well as exposures of the contact of the Moab Member of the Curtis Formation and the overlying Summerville Formation.

The Dalton Wells Quarry (Cedar Mountain Formation - Yellow Cat Member) excavations by field crews from Brigham Young University and the Museum of Western Colorado yielded over 4000 dinosaur bones (Britt *et al.*, 1997; Britt and Stadtman, 1997; Kirkland *et al.* 2005). With at least nine taxa represented (including *Utahraptor ostrommaysorum*, *Nedcolbertia justinhofmanni*, *Gastonia burgei*, and *Cedarosaurus wiskopfae)*, the Dalton Wells Quarry is one of the most diverse Early Cretaceous dinoasurian faunas. Fragmentary bones of crocodiles, turtles, champsosaurs and pterosaurs (or

Figure 10: Theropod tracks in the Klondike Bluffs Region on the top of the Moab Tongue Member of the Curtis Formation.

birds) are also known from the site (Kirkland *et al*. 2005).

Ten tracks preserved, one identifiable as a theropod. Single sauropod pes impression from the base of the track-bearing bed.

Isolated bones have been found in the upper Chinle Formation just off the road to Dead Horse Point.

Bodily (1969) reports the most complete nodosaur *Sauropelta* skeleton from near Dalton Wells Quarry in the Poison Strip Member of the Cedar Mountain Formation (Carpenter *et al*., 1999).

Deep dinosaur (sauropod) tracks and a single theropod track are located in the lower Brushy Basin Member in alternating sandstones and mudstones were noted by Engelmann and Hasiotis (1999).

A plant locality, found by Shawn Duffy a former seasonal ranger at Arches, contains fossil tree remains. The site has been stripped down since its discovery with most of the smaller pieces being taken. Dinosaur bone has also been found in the vicinity.

Cycadeoidales *Monanthesia* and abundant cones in Morrison Formation (Furniss and Tidwell, 1972).

This survey reports parallel sauropod and theropod trackways (BAS-3), theropod trackways in the four wheel drive trail (BAS-1), large, branching horizontal burrows (BAS-2), all at the contact of the Curtis Formation (Moab Member) and Summerville Formation.

Moab Megatracksite, Curtis Formation – Moab Member. The megatracksite has been found within and without the park. There are estimated to be millions of *Allosaurus*-like theropod tracks extending from Moab to Crescent Junction (Lockley, 1991).

In the Tidwell Member of the Morrison west of the park on state land the only associated pterosaur skeleton known in the Jurassic of North America has been found. This site also yields many sauropod bones (Czerkas and Michelson, 2002; UGS data base).

Other Areas

Kayenta Formation (Lower Jurassic) yields abundant dinosaur tracks (in oases deposits). A site southwest of Arches contains putative bird tracks consisting of three individual tridactyl prints that have more narrow, elongate and splayed toes than theropod dinosaur tracks.

Chinle Formation (Upper Triassic) in Long Valley, west of the park contains vertebrate bone, phytosaur teeth, and one theropod track (Shawn Duffy, personal communication, 1999).

Summerville Formation (Middle Jurassic) has produced large petrified logs at the contact with the Morrison.

Morrison Formation (Upper Jurassic) fossil tree remains have been found in areas surrounding the park

Mancos Shale (Upper Cretaceous) produces plesiosaur and mosasaur (35 miles outside park).

A partial amphibian skeleton is exposed in an arroyo bottom near Moab (Carpenter, personal communication, 2000; UGS locality data, uncollected).

A *Dystrophaeus* site was rediscovered by Fran Barnes south of Moab. It had been the first dinosaur discovery in western North America (Gillette, 1996a; Gillette, 1996b).

Copper Ridge Tracksite

Three parallel sauropod trackways in the Salt Wash Member west of Highway 191 (Barnes and Lockley, 1994).

Entradasuchus locality in Entrada Formation near Dewey Bridge (Hunt and Lockley, 1995).

Hotel Mesa Quarry in Ruby Ranch Member of the Cedar Mountain Formation near Dewey Bridge yielded brachiosaurid, crocodilians, and *Deinonychus* sp. (Kirkland *et al*., 1997).

Figure 11: Sauropod tracks from outside Arches National Park on the top of the Moab Tongue of the Curtis Formation.

REFERENCES

References Cited

Baars, D.L., 1983. The Colorado Plateau: A Geologic History: University of New Mexico Press, Albuquerque, 279 p.

Barnes, F.A., and Lockley, M.G., 1994. Trackway evidence for social sauropods from the Morrison Formation, Eastern Utah (USA), Gaia: Revista de Geociencias, Museu Nacional de Historia Natural, Lisbon, Portugal, 10: 37-42.

Blakey, R.C., Basham, E.L., and Cook, M.J., 1993. Early and Middle Triassic paleogeography of the Colorado Plateau and vicinity: *in* Morales, M., (ed) Aspects of Mesozoic geology and paleontology of the Colorado Plateau, Museum of Northern Arizona Bulletin, v. 59, p. 13-26.

Bodily, N.M., 1969. An armored dinosaur from the lower Cretaceous of Utah. BYU Geology Studies 16: 35-60.

Britt, B.B., 1996. Paleontology Locality Data from surveys conducted October and November of 1995 on Utah Trust Lands in National Parks, Monuments, & Reservations, 17p.

_____, and Stadtman, K.L., 1997. Dalton Wells Quarry, *in* Currie, P.J. and Padian, K., (eds.), Encyclopedia of Dinosaurs: San Diego, California, Academic Press, p. 165-166.

_____, Stadtman, K.L., and Sheetz, R.D., 1996. The E.K. Dalton Wells dinosaur fauna and the earliest North American titanosaurid sauropod, *in* Abstracts with Programs, Society of Vertebrate Paleontology 56th annual meeting, v. 16 supplement to #3 p. 24A.

Carpenter, K., Kirkland, J.I., Burge, D., and Bird, J., 1999. Ankylosaurs (Dinosauria: Ornithischia) of the Cedar Mountain Formation, Utah, and their stratigraphic distribution; *in* Gillette, D. (ed.), Vertebrate Paleontology in Utah, Utah Geological Survey, Misc. Pub. 99-1, p. 243-251.

Chure, D.J., Carpenter, K., Litwin, R., Hasiotis, S., and Evanoff, E., 1998. Appendix. The fauna and flora of the Morrison Formation: *in* Carpenter, K., Chure, D.J., and Kirkland, J.I. (eds.) The upper Jurassic Morrison Formation: An interdisciplinary study: Modern Geology, v. 23, p. 507-537.

Czerkas, S.A. and Mickelson, D.L., 2002. The first occurrence of skeletal pterosaur remains in Utah; *in* Czerkas, S.J. (ed.), Feathered dinosaurs and the origin of flight, The Dinosaur Museum Journal Vol. 1, The Dinosaur Museum, Blanding, Utah, p. 3-13.

Dane, C.H., 1935. Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U.S. Geological Survey Bulletin 863, 184 p.

DiCroce, T., and Carpenter, K., 2001. New ornithopod from Cedar Mountain Formation (Lower Cretaceous) of eastern Utah: *in* Tanke, D., and Carpenter, K., (eds.) Mesozoic Prehistoric Life, Indiana University Press, Bloomington, IN., p. 183-196.

Doelling, H.H., 1985a. Geology of Arches National Park: Utah Geological and Mineral Survey Paper to accompany Map 74.

_____, 1985b. Geologic map of Arches National Park and vicinity, Grand County, Utah: Utah Geological and Mineral Survey Map 74.

_____, 1988. “Geology of Salt Valley Anticline and Arches National Park” in Doelling, H.H. Oviatt, C.G., Huntoon, P.W., eds., Salt Deformation in the Paradox Region: Utah Geological and Mineral Survey, Bulletin 122, p. 1-60.

_____, 2003. Geology of Arches National Park, Utah: i*n* Sprinkel, D.A., Chidsey, T.C., Jr. and Anderson, P.B. (eds.) Geology of Utah’s Parks and Monuments. Utah Geological Association Publication 28, second edition, p. 11-36.

Duffy, S., 1993. Synopsis of the Dinosaur Megatrack Site in Arches National Park. *in* V.L. Santucci (ed.), National Park Service Paleontological Research Abstract Volume. National Park Service Natural Resources Technical Report NPS/NRPO/NRTR-93/11:4.

Dyer, R., 1983. Upper Tertiary sedimentary rocks of the Salt Valley anticline, southeastern Utah: A preliminary report: Abstracts with Programs of the Annual Meeting of the Geological Society of America, p 332.

Eckdale, A.A., and Piccard, M.D., 1985. Trace fossils in a Jurassic eolianite, Entrada Sandstone, Utah, USA: *in* Curran, H.S., (ed.) Biogenetic Structures: Their use in interpreting depositional environments: S.E.P.M. Special Publication no. 35, p. 3-12.

Elder, W.P., and Kirkland, J.I., 1993. Cretaceous paleogeography of the Colorado Plateau and adjacent areas: *in* Morales, M., (ed.) Aspects of Mesozoic geology and paleontology of the Colorado Plateau, Museum of Northern Arizona Bulletin, v. 59, p. 129-151.

______, and ______, 1994. Cretaceous paleogeography of the southern Western Interior region: *in* Caputo, M.V., Peterson, J.A., and Franczyk, K.J., (eds.) Mesozoic System of the Rocky Mountain region, USA, Rocky Mountain Section, Society for Sedimentary Geology, p. 415-440.

Engelmann, G.F., 1995. Reconstructing the extinct ecosystems of the Jurassic Morrison Formation in the Rocky Mountain Region, Annual Report. National Park Service Contract No. 1443-CA-1200-94-0420, 19 p.

_____, and Hasiotis, S.T., 1999. Deep dinosaur tracks in the Morrison Formation: Sole marks that are really sole marks. *in* Gillette, D.D., (ed.), Vertebrate Paleontology in Utah. Miscellaneous Publication 99-1, Utah Geological Survey, p. 179-183.

Franczyk, K.J., Fouch, T.D., Johnson, R.C., Molenaar, C.M., and Cobban, W.A., 1991. Cretaceous and Tertiary paleogeographic reconstructions for the Uinta-Piceance Basin Study Area, Colorado and Utah: U.S.G.S. Bulletin 1787-Q, 37 p.

Furniss, B.L. and Tidwell, W.D., 1972. Cycadeoidales from the Cedar Mountain Formation near Moab, Utah. Geological Society of America Abstract 4: 377.

Gillette, D.D., 1996a. Origin and Early Evolution of the Sauropod Dinosaurs of North America: The Type Locality and Stratigraphic Position of *Dystrophaeus viaemalae* Cope 1877. *in* Huffman, A.C., Lund, W.E., and Godwin, L.H. (eds.), Geology and Resources of the Paradox Basin: Utah Geological Association Guidebook 25, p. 313-324.

______, 1996b. Stratigrphic position of the sauropod *Dystrophaeus viaemalae* Cope and implications. International Conference on Continental Jurassic of the World, *in* Morales, M. (ed.) The Continental Jurassic: Museum of Northern Arizona Bulletin 60, p. 59-68.

Hasiotis, S.T., and Demko, T.M., 1996. Ant (Hymenoptera: Formicidae) nest ichnofossils, Upper Jurassic Morrison Formation, Colorado Plateau: Evolutionary and ecologic implications: Abstracts with Programs, Annual Meeting of the Geological Society of America, p. A-106.

Hite, R.J., 1960. Stratigraphy of the saline facies of the Paradox Member of the Hermosa Formation of south-eastern Utah and southwestern Colorado: Four Corners Geological Society Guidebook, 3rd Annual Field Conference, p. 86-89.

Hunt, A.P. and Lockley, M.G., 1995. A nonmarine tetrapod from the Middle Jurassic of the United States: a primitive crocodyliform from the Entrada Sandstone of eastern Utah; Journal of Vertebrate Paleontology, v. 15, p. 554-560.

Katich, P.J., 1956. Some notes on the Cretaceous faunas of eastern Utah and western Colorado, in Peterson, J.A., ed., Geology and economic deposits of east central Utah: Intermountain Association of Petroloeum Geologists, Seventh Annual Field Conference, p. 116-119.

Kirkland, J.I., 1997. Cedar Mountain Formation: *in* Currie, P.J. and Padian, K. (eds.) Encyclopedia of Dinosaurs, Academic Press, San Diego, p. 98-99.

_____, 1998. A polacanthind ankylosaur (Ornithischia: Dinosauria) from the Early Cretaceous (Barremian) of eastern Utah: *in* Lower and Middle Cretaceous Terrestrial Ecosystems, Lucas, S.G., Kirkland, J.I., and Estep, J.W., New Mexico Museum of Natural History and science Bulletin No. 14.

_____, Britt, B.B., Burge, D.L., Carpenter, K., Cifelli, R., Decourten, F., Eaton, J., Hasiotis, S., Lawton, T., 1997. Lower to Middle Cretaceous Dinosaur Faunas of the Central Colorado Plateau: A key to Understanding 35 Million Years of Tectonics, Sedimentology, Evolution and Biogeography: *in* Brigham Young University Geology Studies v. 42, Part Two, p. 69-103.

_____, Britt, B.B., Whittle, C.H., Madsen, S.K., Burge, D.L., 1998a. A small Coelurosaurian Theropod from the Yellow Cat Member of the Cedar Mountain Formation (Lower Cretaceous, Barremian) of Eastern Utah: *in* Lower and Middle Cretaceous Terrestrial Ecosystems, Lucas, S.G., Kirkland, J.I., and Estep, J.W., New Mexico Museum of Natural History and Science Bulletin No. 14.

_____, Burge, D., and Gaston, R., 1993. A large dromaeosaur [Theropoda] from the Lower Cretaceous of Utah: Hunteria, v. 2, no. 10, p. 1-16.

_____, Cifelli, R., Britt, B., Burge, D.L., DeCourten, F., Eaton, J., and Parrish, J.M., 1999. Distribution of vertebrate faunas in the Cedar Mountain Formation, east-central Utah: *in* Gillette, D., (ed.) Vertebrate Paleontology in Utah, Utah Geological Survey Miscellaneous Publication 99-1, p. 201-217.

_____, Lucas, S.G., and Estep, J.W., 1998b. Cretaceous dinosaurs of the Colorado Plateau: *in* Lucas, S.G., Kirkland, J.I., and Estep, J.W., (eds.) Lower to Middle Cretaceous Non-marine Cretaceous Faunas, New Mexico Museum of Natural History and Science Bulletin 14, p. 67-89.

_____, Sheetz, R.D., and Foster, J.R., 2005. Jurassic and Lower Cretaceous dinosaur quarries of western Colorado and eastern Utah: in Richard, G. (compiler), 2005 Rockyh Mountain Section of the Geological Society of America Field Trip Guidebook, Grand Junction Geological Society, Field Trip 402, p. 1-26.

Lockley, M.G., 1991. The Moab Megatracksite: A preliminary description and discussion of millions of Middle Jurassic tracks in eastern Utah. *in* Guidebook for dinosaur quarries and tracksites tour, Western Colorado and Eastern Utah. Grand Junction Geological Society, Grand Junction, Colorado. p. 59-65.

_____, Kirkland, J.I., DeCourten, F., Britt, B.B., and Hasiotis, S., 1999. Dinosaur tracks from the Cedar Mountain Formation of eastern Utah: a preliminary report, in Gillette, D., ed., Vertebrate Paleontology in Utah: Miscellaneous Publication 99-1, Utah Geological Survey, p. 179-183.

_____, White, D., Kirkland, J.I., and Santucci, V., 2004. Dinosaur Tracks from the Cedar Mountain Formation (Lower Cretaceous), Arches National Park, Utah; Ichnos v. 11, p. 285-293.

Lohman, S.W., 1975. The geologic story of Arches National Park. U.S. Geological Survey Bulletin 1393, 113 p.

Lucas, S.G., Heckert, A.B., Estep, J.W., and Anderson, O.J., 1997a. Stratigraphy of the Upper Triassic Chinle Group, Four Corners region: *in* Anderson, O.J., Kues, B.S., and Lucas, S.G. (eds.), new Mexico

Geological Society Guidebook, 48th Field Conference, Mesozoic Geology and Paleontologyof the Four Corners region p. 108-114.

_____, Kietzke, K.K., and Godspeed, T.H., 1997b. Paleontology of nonmarine Cretaceous - not nonmarine Triassic - limestone in the salt anticline, southeastern Utah, *in* Anderson, O.J., Kues B.S., and Lucas, S.G. (eds.), new Mexico Geological Society Guidebook, 48th Field Conference, Mesozoic Geology and Paleontologyof the Four Corners region p. 157-161.

Lutrell, P.R., 1993. Jurassic Depositional History of the Colorado Plateau: *in* Morales, M. (ed.) Aspects of Mesozoic geology and paleontology of the Colorado Plateau, Museum of Northern Arizona Bulletin, v. 59, p. 99-110.

McKnight, E.T., 1940. Geology of area between Green and Colorado Rivers, Grand and San Juan Counties, Utah: U.S. Geological Survey Bulletin 908, 147 p.

Mead, J.I., Sharpe, S.E., Agenbroad, L.D., 1991. Holocene Bison From Arches National Park, Southeastern Utah, Great Basin Naturalist, Volume 51, No. 4 December 1991 p. 336-342.

Melton, R.A., 1972. Paleoecology and paleoenvironments of the upper Honaker Trail Formation near Moab, Utah. BYU Geology Studies 19(2): 45-88.

Molenaar, C.M., 1975. Some notes on Upper Cretaceous stratigraphy of the Paradox Basin: Four Corners Geological Society Guidebook, 8th Annual Field Conference, Canyonlands, p. 191-192.

_____, and Cobban, W.A., 1991. Middle Cretaceous stratigraphy on the south and east sides of the Uinta Basin, northeastern Utah and northwestern Colorado; U.S.G.S. Bulletin 1787-P, 34 p.

Peterson, F., 1994. Sand dunes, sabkhas, streams and shallow seas: Jurassic paleogeography in the southern part of the Western Interior Basin: *in* Caputo, M.V., Peterson, J.A., and Franczyk, K.J., (eds.) Mesozoic System of the Rocky Mountain region, USA, Rocky Mountain Section, Society for Sedimentary Geology, p. 233-272.

Santucci, V.L., Kenworthy, J., and Kerbo, R., 2001. An inventory of paleontological resources associated with National Park Service caves: Geological Resources Division Technical Report NPS/NRGRD/GRDTR-01/02, 50 p.

Seilacher, A., 1964. Biogenic sedimentary structures: *in* Imbrie, J., Newell, N., (eds.) Approaches to paleoecology, p. 296-316.

Sharpe, S. E., 1991. Late-Pleistocene and Holocene vegetation change in Arches National Park, Grand County, Utah and Dinosaur National Monument, Moffat County, Colorado: Masters thesis, Northern Arizona University, 96 p.

Shoemaker, E.M., and Newman, W.L., 1959. Moenkopi Formation (Triassic? and Triassic) in salt anticline region, Colorado and Utah: American Association of Petroleum Geologists Bulletin, v. 43, no. 8, p. 1852-1868.

Stevens, D.J., and McCarrick, J.E., 1988. The Arches of Arches National Park, a comprehensive study: Mainstay Publishing, Orem and Moab, Utah, 169 p.

Stokes, W.L., 1952, Lower Cretaceous in Colorado Plateau: American Association of Petroleum Geologists Bulletin, v. 36, p. 1766-1776.

Tidwell, W., Carpenter, K., and Brooks, W., 1999. New sauropod from the Lower Cretaceous of Utah, USA: Oryctos v. 2, p. 21-37.

_____, Carpenter, K., and Meyer, S., 2001. A new titanosauriform (Sauropoda) from the Poison Strip member of the Cedar Mountain Formation (Lower Cretaceous), Utah: *in* Tanke, D., and Carpenter, K., (eds.) Mesozoic Prehistoric Life, Indiana University Press, Bloomington, IN., p. 139-165.

Additional References

DeCourten, F.L., 1998. Dinosaurs of Utah. The University of Utah Press, Salt Lake City, 300 p.

Dubiel, R.F., 1994. Triassic deposystems, paleogeography, and paleoclimate of the western interior, *in* Caputo, M.V., Peterson, J.A., and Franczyk, K.J. (eds.), Meozoic System of the Rocky Mountain Region, USA, Rocky Mountain Section, Society for Sedimentary Geology, Denver, p. 133-168.

Huber, P., Lucas, S.G., and Hunt, A.P., 1993. Late Triassic fish assemblages of the North American Western Interior: *in* Morales, M. (ed.), Aspects of Mesozoic geology and paleontology of the Colorado Plateau, Museum of Northern Arizona Bulletin, v. 59, p. 51-66.

Kirkland, J.I., 1996. Paleontology of the greenhorn Cyclothem (Cretaceous: Late Cenomanian to Middle Turonian) at Black Mesa, Northeastern Arizona; New Mexico Museum of Natural History and Science Bulletin, v. 9, 131 p.

Lockley, M.G., Hunt, A.P., Gaston, R., Kirkland, J.I., 1996. A trackway bonanza with mammal footprints from the Late Triassic of Colorado; Journal of Vertebrate Paleontology, v. 16, sup. to no. 3 (Abstracts), p. 49.

Peterson, F. and Turner-Peterson, C.E., 1987. The Morrison Formation of the Colorado Plateau – recent advances in sedimentology, stratigraphy, and paleotectonics: Hunteria, v.2, no.1, 18 p.

Santucci, V.L., 2000. A survey of paleontologic resources from the national parks and monuments in Utah: *in* Sprinkel, D.A., Anderson, P.B., and Chidsey, T.C., (eds.) Geology of Utah's Parks and Monuments. Utah Geological Association Publication 28, p. 535-556.

_____, Hunt, A.P., and Lockley, M.G., 1998. Fossil vertebrate tracks in National Park Service areas: Dakoterra, v. 5, p. 107-114.

STEWART, J.H., POOLE, F.G., and WILSON, R.F., 1972. Stratigraphy and origin of the Chinle Formation and related Upper Triassic strata in the Colorado Plateau region: U.S. Geological Survey Professional Paper 690, 336p.

WHITE, D. and LOCKLEY, M.G., 2002. Probable dromeosaur tracks and other dinosaur footprints from the Cedar Mountain Formation (Lower Cretaceous), Utah. Journal of Vertebrate Paleontology, v. 22, p. 119A.

WOLNY, D.G., ARMSTRONG, H.J., and KIRKLAND, J.I., 1990. Hadrosaur skeleton from the Mancos Shale, W. Colorado; Journal of Vertebrate Paleontology, v. 10, sup. to no. 3 (Abstracts), p. 31A.

APPENDIX A

Arches National Park Paleo- Species List

The names here are uncritically compiled from the literature and may not always represent the most current taxonomic identifications.

Geologic Time Codes:	
[IP]	Pennsylvanian
[Tr]	Triassic
[J]	Jurassic
[K]	Cretaceous
[Pl]	Pleistocene
[H]	Holocene

PALEOBOTANY

Unclassified Pre-Pleistocene Plants

Ashcaulish wadei (this survey) [J]
Calamites sp. (this survey) [IP?]
Clavator harrisi (Stokes, 1952) [K]
Cypridea cf. (Stokes, 1952) [K]
Cypridea brevicornis (Stokes, 1952) [K]
Cypridea wyomingensis (Stokes, 1952) [K]
Eupera cf. (Katitch, 1956) [K]
Eupera onestae (Katitch, 1956) [K]
Metacypris angularis (Stokes, 1952) [K]
Monanthasia sp. [K]

Spermatophyta

Filicophyta

Tempskyia sp. [K]

Gymnospermae

cycads

Cycadeoidea sp. [K]
Manathesia sp. [K]

Araucariaceae

Araucarioxylon sp. (this survey) [Tr, J]

Cupressaceae

Juniperus osteosperma (Sharpe, 1991) [Pl]

Ephedraceae

Ephedra (Sharpe, 1991) [Pl]

Pinaceae

Pinus flexilis (Sharpe, 1991) [Pl]
Pinus edulis (Sharpe, 1991) [Pl]
Pseudotsuga menziesii (Sharpe, 1991) [Pl]

Angiospermae

Agavaceae

Yucca sp. (Sharpe, 1991) [Pl]
Yucca cf. *angustissima* (Sharpe, 1991) [Pl]

Anacardiaceae

Rhus aromatica (Sharpe, 1991) [Pl]

Apiaceae

Osmorhiza depauperata (Sharpe, 1991) [Pl]

Asteraceae

Ambrosia (Sharpe, 1991) [Pl]
Artemisia ludovicaina (Sharpe, 1991) [Pl]
Chaenactis (Sharpe, 1991) [Pl]
Chrysopsis (Sharpe, 1991) [Pl]
Chrysothamnus (Sharpe, 1991) [Pl]
Cirsium (Sharpe, 1991) [Pl]
Dicoria (Sharpe, 1991) [Pl]
Dyssodia acerosa (Sharpe, 1991) [Pl]
Gutierrezia sp. (Sharpe, 1991) [Pl]
Gutierrezia cf. *microcephla* (Sharpe, 1991) [Pl]
Gutierrezia cf. *sarothrae* (Sharpe, 1991) [Pl]
Senecio (Sharpe, 1991) [Pl]
Solidago (Sharpe, 1991) [Pl]

Boraginaceae

Amsinkia/Cryptantha (Sharpe, 1991) [Pl]
Cryptantha (Sharpe, 1991) [Pl]
Cryptantha cinerea (Sharpe, 1991) [Pl]
Lithospermum incisum (Sharpe, 1991) [Pl]
Tiquilia (Sharpe, 1991) [Pl]

Brassicaceae

Dithyrea wislizenii (Sharpe, 1991) [Pl]
Lepidium (Sharpe, 1991) [Pl]

Cactaceae

Opuntia polyacanthia (Sharpe, 1991) [Pl]
Opuntia sp. (Sharpe, 1991) [Pl]

Caprifoliaceae

Symphoricarpos (Sharpe, 1991) [Pl]

Celtidaceae

Celtis reticulata (Sharpe, 1991) [Pl]

Chenopodiaceae

Chenopodium sp. (Sharpe, 1991) [Pl]
Atriplex canescens (Sharpe, 1991) [Pl]
Atriplex confertifolia (Sharpe, 1991) [Pl]

Cornaceae

Cornus sericea (Sharpe, 1991) [Pl]

Fabaceae

Astragalus (Sharpe, 1991) [Pl]

Fagaceae

Quercus (Sharpe, 1991) [Pl]
Quercus gambelii (Sharpe, 1991) [Pl]

Grossulariaceae

Ribes montigenum (Sharpe, 1991) [Pl]

Loasaceae

Mentzelia (Sharpe, 1991) [Pl]

Malvaceae

Sphaeralcea sp. (Sharpe, 1991) [Pl]

Nyctaginaceae

Abronia (Sharpe, 1991) [Pl]

Oleaceae

Fraxinus anomala (Sharpe, 1991) [Pl]

Onagraceae

Oenothera pallida (Sharpe, 1991) [Pl]

Papaveraceae

Argemone (Sharpe, 1991) [Pl]

Poaceae

Bouteloua (Sharpe, 1991) [Pl]
Heteropogon (Sharpe, 1991) [Pl]
Stipa hymenoides (Sharpe, 1991) [Pl]

Rosaceae

Amelanchier utahensis (Sharpe, 1991) [Pl]
Cercocarpus cf. *montanus* (Sharpe,1991) [Pl]
Coleogyne ramosissima (Sharpe, 1991) [Pl]
Rosa sp. (Sharpe, 1991) [Pl]

Salicaceae

Populus (Sharpe, 1991) [Pl]

Santalaceae

Comandra umbellata (Sharpe, 1991) [Pl]

FOSSIL INVERTEBRATES

Cnidaria

Anthozoa

Rugose corals (this survey) [IP]

Arthropoda

Crustacea

Ostracods (this survey) [K]

Trilobita

Ditomopyge sp. (Melton, 1972) [IP]

Mollusca

Pelecypoda

Acanthopecten carboniferus (Melton, 1972) [IP]
Aviculopecten sp. (Melton, 1972) [IP]
Chaenomya sp. (Melton, 1972) [IP]
Erimondia sp. (Melton, 1972) [IP]
Gryphaea/Texigryphaea (this survey) [K]
Lima sp. (Melton, 1972) [IP]
Limapecten sp. (Melton, 1972) [IP]
Limatula sp. (Melton, 1972) [IP]
Mylania sp. (Melton, 1972) [IP]
Nuculana bellistriata (Melton, 1972) [IP]
Parallelodon (Melton, 1972) [IP]
Permophorus occidentalis (Melton, 1972) [IP]
?*Pseudomonotis* (Melton, 1972) [IP]
Pseudomonotis equistriata (Melton, 1972) [IP]
Pseudomonotis kansasensis (Melton, 1972) [IP]
Pteronites sp. (Melton, 1972) [IP]
Ptychomphalus sp. (Melton, 1972) [IP]
Schizodus sp. (Melton, 1972) [IP]
Septimyalina burmi? (Melton, 1972) [IP]
Unio? sp. (this survey) [K]
Wilkingia sp. (Melton, 1972) [IP]

Gastropoda

Anomphalus rotuius (Melton, 1972) [IP]
Bellerphon sp. (Melton, 1972) [IP]
Bellerphontid sp. (Melton, 1972) [IP]
Euphemites carbonarius (Melton, 1972) [IP]
Gyraulus veternus (Lucas *et al.*, 1997b) [K]
Knightites montfortianus (Melton, 1972) [IP]
Mesopyrigium pendilabium (this survey) [K]
Pharkidonotus percarinatus (Melton, 1972) [IP]
Physa sp. (Lucas *et al.*, 1997b) [K]
Reesidella sp. (Lucas *et al.*, 1997b) [K]
Straparollus sp. (Melton, 1972) [IP]
Worthenia sp. (Melton, 1972) [IP]
Zaptychius? sp. (Lucas *et al.*, 1997b) [K]

Brachiopoda

Chonetes granulifer (Melton, 1972) [IP]
Chonetina flemingi (Melton, 1972) [IP]
Composita sp. (Melton, 1972) [IP]
Composita subtilita (Melton, 1972) [IP]
Derbyia sp. (Melton, 1972) [IP]
Derbyia bennetti (Melton, 1972) [IP]
Derbyia crassa (Melton, 1972) [IP]
Derbyia wabashensis (Melton, 1972) [IP]
Dictyoclostus americanus (Melton, 1972) [IP]
Echinoconchus sp. (Melton, 1972) [IP]
Echinoconchus semipunctatus (Melton, 1972) [IP]
Juresania nebrascensis (Melton, 1972) [IP]
Linoproductus sp. (Melton, 1972) [IP]
Linoproductus meniscus (Melton, 1972) [IP]
Linoproductus prattenianus (Melton, 1972) [IP]
Marginifera lasallensis (Melton, 1972) [IP]
Marginifera wabashensis (Melton, 1972) [IP]
Neospirifer kansasensis (Melton, 1972) [IP]
Neospirifer triplicatus (Melton, 1972) [IP]
Orbiculoidea sp. (Melton, 1972) [IP]
Phricodothyris perplexa (Melton, 1972) [IP]
Punctospirifer kentuckyensis (Melton, 1972) [IP]
Wellerella osagensis (Melton, 1972) [IP]
Wollerella tetrahedra (Melton, 1972) [IP]

Bryozoa

Lacy and branched bryozoans (this survey) [IP]

FOSSIL VERTEBRATES

Osteichthyes

Fish bone beds (Kirkland *et al.*, 1997; 1999) [K]
Lungfish burrows (this survey) [P]
Ceratodus n. sp. (this survey) [K]

Condrichthys

Hybodus? sp. (this survey) [K]

Reptilia

Sauropterygia

Plesiosaur (this survey) [K]

Lacertilia

Mosasaur (this survey) [K]

Chelonia

Turtle shell fragments (this survey) [K]

Crocodylia

cf. ? *Champsosaur* (this survey) [K]
Crocodile teeth (this survey) [K]

Dinosauria

Ornithschia

Ankylosauria

Gastonia burgei (Kirkland, 1998) [K]
Sauropelta (Carpenter *et al.* 1999) [K]

Iguanodontia

Planicoxa venecia
(DiCroce and Carpenter, 2001) [K]

*Iguanodon ottingeri (*Kirkland *et al.*, 1999) [K]

Saurischia

Sauropoda

Undescribed titanosaurid (Britt *et al.* 1997) [K]

Undescribed camarasaurid (Britt and Stadtman,1997) [K]

Undescribed brachiosaurid (Kirkland *et al.*, 1997) [K]

Cedarosaurus (Tidwell *et al.*, 1999) [K]

Venenosaurus (Tidwell *et al.*, 2001) [K]

Theropoda

Coelurosauria

Nedcolbertia justinhofmanni (Kirkland *et al.* 1998) [K]

Mammalia

Proboscidea

Mammuthus columbi [Pl]

Artiodactyla

Bison bison [H]

Ovis canadensis [H]

INVERTEBRATE TRACE FOSSILS

"Caterpillar-track" invertebrate? traces (Kirkland *et al.*, 2004) [K]

Octopodichnus [Tr]

VERTEBRATE TRACE FOSSILS

Reptilia

Dromopus [Tr]

Dinosauria

Saurichia

Sauropoda

Megalobrontes (Britt, 1996) [J]

Brontopodus? (Kirkland *et al.*, 2004) [K]

Theropoda

"Narrow-footed" theropod track (Kirkland *et al.*, 2004) [K]

"Medium-size" theropod track (Kirkland *et al.*, 2004) [K]

Coelurosauria

Tridactyl tracks (Kirkland *et al.*, 2004) [K]

Didactyl tracks (Kirkland *et al.*, 2004) [K]

Mammalia

Rodentia

Neotoma sp. middens [Pl,H]

APPENDIX B

Arches National Park Fossil Specimens In Outside Repositories

This appendix provides information regarding fossil specimens collected from Arches National Park that are in an outside repository.

The following specimens are currently held at Northern Arizona University (NAU) in Flagstaff, Arizona. Three localities have yielded many quaternary specimens (NAU Localities 9144, 9152, and 9157). The number following the species name is the number of specimens collected.

PLANTS

Ambrosia sp. (5); *Amelanchier utahensis koehne* (4); *Argemone* sp.; *Artemesia* sp.; *Artemesia ludoviciana nutt* (2); *Astragalus* sp. (3); *Atriplex* sp.; *Atriplex canescens nutt* (4); *Atriplex confertifolia*; *Atriplex confertifolia* (Torr. & Frem.) *wats* (2); *Bouteloua* sp.; Cactus, unidentified; *Celtis* sp.; *Celtis reticualta torr*. (2); *Ceratoides lanata* (8); *Cercocarpus* cf., *montanus*; *Chaenactis* sp.; *Chenopodium* sp. (8); cf. *Chrysopsis*; cf. *Chrysothamnus* sp. (2); *Chrysothamnus* sp. (2); *Cirsium* sp. (5); *Coleogyne ramosissima*; *Coleogyne ramosissima torr* (5); *Commandra umbellata*; Conifer unidentified (4); *Cornus sericea* (stolonifera) (2); *Cornus stolonifera michx*; cf. *Cryptantha* (2); *Cryptantha* cf. *jamesii* (2); *Cycloloma atriplicifolium* (spreng.) *colilt*; *Dicoria* sp.; *Dithyrea wislizeni engelm* (3); *Dyssodia acerosa* dc. (6); *Ephedra* sp. (3); *Fraxinus anomal torr*. (2); Grass, unidentified (8); *Gutierrezia* sp. (6); *Gutierrezia* cf. *microcephala* (2); *Gutierrezia microcephala* (dc.) gray (7); *Gutierrezia sarothrae* (pursh) britt & rusby (5); *Juniperus osteosperma*; *Juniperus osteosperma* (torr.) little (5); *Lepidium* sp. (7); *Lithospermum incisum lehm* (2); *Mentzelia* sp. (11); *oenothera pallida lindl*.; *Opuntia* sp. (12); *Opuntia polycantha* (2); *Opuntia polycantha haw*. (9); *Osmorhiza depauperata phil*; *oryzopsis hymenoides* (R & S) Ricker (8); cf. *Pinus; Pinus edulis englm* (3); *Pinus flexilis james* (7); *Populus cf. fremontii*; *Pseudotsuga menziesii* (mirb.) *franco* (9); *Quercus* sp. (3); *Quercus gambelii* nutt; *Ribes montigenum mcclatchie*; *Rhus trilobata*; *Rhus trilobata nutt* (7); *Senecio* sp. (2); *Sphaeralceae* sp. (5); *Stipa hymneoides*; *Stipa (oryzopsis) hymenoides*; *Tiquilia* sp.; unknown; *Yucca* sp. (3); *Yucca* cf. *angustissima* (2); Alga, unidentified; Plant, unidentified (45)

VERTEBRATES

Antilocapra americana; *Bison bison* (Linneaus) (14); *Bubo virginanus*; *Canis latrans say* (2); *Dipodomys* sp.; *Equus* sp.; *Erethizon* sp.; *Erethizon dorsatum* (Linneaus) (2); *Lepus* sp. (4); *Lynx rufus* (schreber); *Mammuthus* sp. (11); *Neotoma* sp. (9);*Odocoileus* sp. (36); *Oreamnos harringtoni stock* x 2; *Ovis* sp. (3); *Ovis canadensis shaw* (6); *Sylvilagus* sp. (6); *Sylvilagus idahoensis* (Merriam) (2); *Thomomys* sp.; cf. *Vulpes* sp.; Unknown Microtine; Owl, unidentified; Aves unidentified; Cervid unidentified; Rodent, unidentified; Mammal, unidentified (18);

INVERTEBRATES

Bakerilymnaea (fossaria) dalli (5); *Deroceras laeve* (9); *Discus* sp.; *Discus cronkhitei* (12); *Euconulus fluvus* (9); *Fossaria* sp. (9); *Fossaria (bakerilymnaea) bulimoides*; *Fossaria (bakerilymnaea) fulimoides*; *Fossaria* cf. *obrussa*; *Gastrocopta* sp.; *Gastrocopta pellucida* (9); *Hawaiia minuscula* (6); *Nesovitrea* sp.; *Nesovitrea hammonis electrina* (6); *Oxyloma* sp. (2); *Physella* sp. (2); *Pisidium* sp. (4); *Pisidium* cf. *variable*; *Pisidium* cf. *walkeri*; *Pupilla* sp. (14); *Pupilla blandi* (8); *Pupilla muscorum* (4); *Pupoides hordaceous*; *Vallonia* sp. (2); *Vallonia cyclophorella* (14); *Vallonia gracilicosta* (4); *Zontoides* (4); *Zontoides arboreus*; Snail, unidentified (12); Insect, unidentified (16); Ostracod, unidentified (11); Arthropod, unidentified (7); Mollusk, unidentified (5);

MISCELLANEOUS

Dung, unidentified (3);

The following specimens are in the repository at the New Mexico Museum of Natural History and are from the Cedar Mountain Formation, locality 2573.

PLANTS

Charophytes: *Atopochra triviolis* (30), cf. *Obtusochava* (12)

INVERTEBRATES

Ostracodes: *Cyridea compta* (20), *Bisulcocypris persulata* (2), *Cyclocypris* ? sp. (5);
Gastropods: *Gyraulis veternus* (50+), *Reesidella* sp. (20), *Mesopygium pendilabium* (12), *Physa* sp. (20), *Zaptychius* (12); Bivalves: *Unio* ? sp. (3)

APPENDIX C

Paleontological Localities Within Arches National Park

Brooks Britt's sites (Britt, 1996)

BBB-95-40: Salt Wash Member, Morrison Formation. Unionid clams, *in situ* and weathering out.

BBB-95-56: Entrada Sandstone. Dinosaur tracks.

BBB-95-57: Entrada Sandstone. Theropod trackway site.

BBB-95-59: Salt Wash Member, Morrison Formation. Unionid clams. Two found.

BBB-95-37: Salt Wash Member (?), Morrison Formation. Well-preserved dinosaur bone.

BBB-95-38: Salt Wash Member, Morrison Formation. Dinosaur bone and a microvertebrates.

BBB-95-39: Salt Wash Member, Morrison Formation. Dinosaur bone.

George Engelman's sites (Engelman, 1995)

L-GFE-94-1: Brushy Basin Member, Morrison Formation. Dinosaur bone.

L-GFE-94-3: Brushy Basin Member, Morrison Formation. Dinosaur bone.

L-GFE-94-4: Salt Wash Member, Morrison Formation. Dinosaur bone.

L-GFE-94-5: Unknown stratigraphic unit, Vertical burrows, invertebrate traces.

L-GFE-94-6: Brushy Basin Member, Morrison Formation. Large fragments of dinosaur bone.

L-GFE-94-8: Brushy Basin Member, Morrison Formation. Dinosaur bone.

L-GFE-94-9: Salt Wash Member, Morrison Formation. Dinosaur bone, humerus?

L-GFE-94-10: Salt Wash Member, Morrison Formation. Possible vertebrate traces.

L-GFE-94-11: Brushy Basin Member, Morrison Formation. Invertebrate trace (*Scoyenia*).

L-GFE-94-12: Cedar Mountain Formation? Vertical tubular structures with ironstone coating.

L-GFE-94-13: Dinosaur scrap bone, float but concentrated.

L-GFE-94-14: Brushy Basin Member, Morrison Formation. Dinosaur bone scraps.

L-GFE-94-15: Brushy Basin Member, Morrison Formation. Dinosaur bone fragments.

L-GFE-94-16: Brushy Basin Member?, Morrison Formation. Dinosaur shoulder? girdle.

L-GFE-94-17: Cedar Mountain Formation. Dinosaur bone fragments.

L-GFE-94-18: Brushy Basin Member, Morrison Formation. Invertebrate traces (*Scoyenia*).

L-GFE-94-19: Cedar Mountain Formation. Dinosaur bone fragments.

L-GFE-94-20: Brushy Basin Member, Morrison Formation. Dinosaur elements. Vertebrae, girdle, assorted other pieces. Probably sauropod.

L-GFE-94-21: Brushy Basin Member, Morrison Formation. Scattered dinosaur bone fragments. Probably sauropod.

L-GFE-94-22: Brushy Basin Member, Morrison Formation. Bone scraps and fragments.

L-GFE-94-23: Salt Wash Member, Morrison Formation. Invertebrate traces (*Scoyenia*).

L-GFE-94-24: Brushy Basin Member, Morrison Formation. Silicified wood.

L-GFE-94-25: Salt Wash Member, Morrison Formation. Silicified wood and log impressions.

L-GFE-94-26: Salt Wash Member, Morrison Formation. Concentration of bone fragments.

L-GFE-94-27: Brushy Basin Member, Morrison Formation. Several dinosaur bone fragments.

L-GFE-94-28: Salt Wash Member, Morrison Formation. Silicified wood?

L-GFE-94-29: Brushy Basin Member, Morrison Formation. Invertebrate traces. Pencil-sized holes in top and bottom surfaces creating a "spongy" appearance.

L-GFE-94-30: Brushy Basin Member, Morrison Formation. Large pieces of dinosaur bone, probably sauropod femur.

L-GFE-94-31: Brushy Basin Member, Morrison Formation. Many pieces of dinosaur bone.

New Mexico Museum of Natural History

NMMNH 2573 - ? Cedar Mountain Formation, invertebrates and charophytes in limestone previously reported as being from Sinbad Limestone Member of Moenkopi

Paleo survey sites (May, 2000)

A-1: Brushy Basin Member, Morrison Formation. Caudal vertebrae and rib fragments, may be ankylosaur.

A-2: Brushy Basin Member, Morrison Formation. Sauropod bone fragments.

A-3: Ruby Ranch Member, Cedar Mountain Formation. Crocodile and iguanodontid tracks on heavily bioturbated surface.

A-4: Ruby Ranch Member, Cedar Mountain Formation. Small theropod trackways, peculiar scratch marks that may be pterosaur? feeding traces. Also algae patterns similar to small stromatolites.

A-5: Lower Member, Mancos Shale. Oysters (Pycnodonte newberry unbonata).

A-6: Dakota Sandstone. Plant/woody tissue.

A-7: Poison Strip Member, Cedar Mountain Formation. One large log with an associated smaller log possibly partially burnt.

A-8: Yellow Cat Member, Cedar Mountain Formation. Sauropod elements.

KEY-1: Salt Wash Member, Morrison Formation. Sauropod? bones.

KEY-2: Salt Wash Member, Morrison Formation. Single dinosaur centrum.

KEY-3: Morrison Formation. Scattered fragments of dinosaur bone.

Brooke Swanson's sites (Summer, 2000)

BAS-3: Moab Tongue Member, Curtis Formation. Undertracks of quadruped (sauropod?) and theropod parallel to one another.

BAS-4: Moab Tongue Member, Curtis Formation. Lots of isolated small (2-4 inches long) tridactyl tracks.

BAS-5: Moab Tongue Member, Curtis Formation. Isolated, small (>4 inches long) tridactyl tracks in poor condition. Mainly visible on surfaces coated with desert varnish.

BAS-6: Moab Tongue Member, Curtis Formation. Isolated theropod track.

BAS-7: Moab Tongue Member, Curtis Formation. Pocky surface, questionable theropod tracks.

BAS-8: Salt Wash Member, Morrison Formation. Heavily burrowed block, vertical and horizontal invertebrate burrows.

BAS-9: Kayenta Formation. Pencil-sized invertebrate burrow casts.

BAS-10: Kayenta Formation. Theropod track.

BAS-11: Kayenta Formation. 14 inch long theropod track.

BAS-12: Kayenta Formation (possibly Navajo). Burrow cast 18 inches long, varying diameter (1-1.5 inches minimum)

BAS-13: Moab Tongue Member, Curtis Formation. Burrow casts with ~3 inch diameter and varying lengths.

BAS-15: Morrison Formation. Bone fragments as float.

BAS-16: Navajo Formation. Invertebrate burrows within playa deposit.

BAS-17: Chinle Formation. Burrow casts of invertebrates. Long, fairly straight, none with a diameter larger than a pencil.

BAS-18: Chinle Formation. Small leaves, seed, stems, and what looks like a conifer (?) cone. Layers of this planty strata are laterally continuous.

BAS-19: Chinle Formation. Overhang supports burrows and flute casts.

BAS-20: Chinle Formation. Burrow casts, vertebrate-sized (>3.5 inches wide in diameter).

BAS-21: Chinle Formation. Invertebrate burrows that appear, superficially, like snails. Bulbous top with a either a spiral or a straight extension downward that narrows.

BAS-22: Chinle Formation. Invertebrate branching burrows.

BAS-23: Chinle Formation. Invertebrate, arcuate burrows. No sharp turns.

As the nation's principle conservation agency, the Department of Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the bests interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen partcipation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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