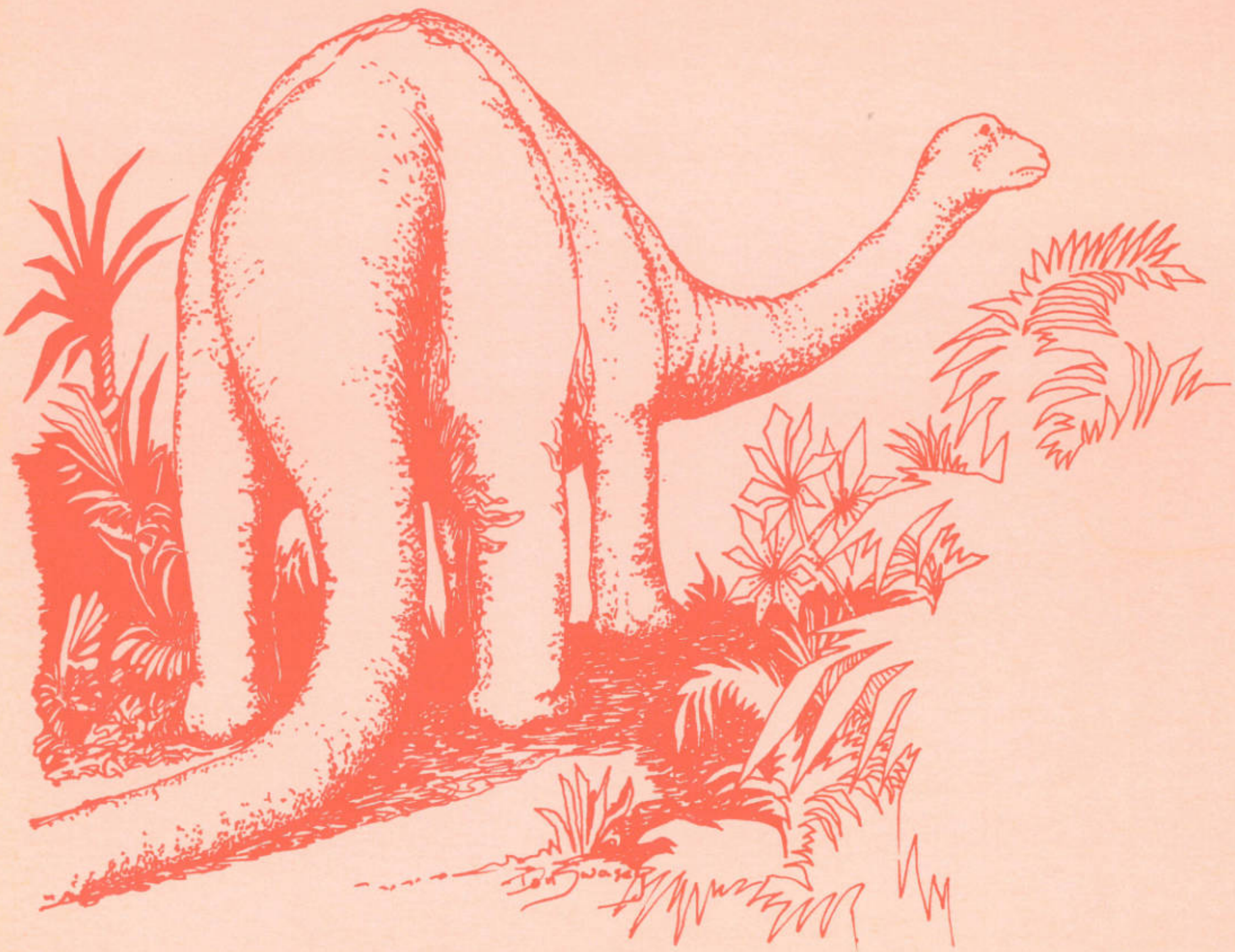
Canyon Legacy

A Journal of the Dan O'Laurie Museum - Moab, Utah

Number 6 $4.50



Extinct Species of Canyon Country

Canyon Legacy

The Journal of the
Dan O'Laurie Museum of Moab

Canyon Legacy was established in 1989 to publish articles on the history, prehistory and natural history of the Colorado Plateau in Southeastern Utah and the Four Corners region.

Materials for possible publication should be submitted to ***Canyon Legacy,*** 118 East Center St., Moab, UT 84532, typed double-spaced with copies of all appropriate graphics, and with sufficient return postage included. ***Canyon Legacy*** will assume no responsibility for statements of fact or the opinions published by contributors.

ISSN: 0897-3423 Summer 1990

WITHIN...

Recent discoveries concerning Canyon Country life as it was in the far distant past have begun to change the perspective of scientists and laymen alike. Although the geologic formations of the Colorado Plateau have long been known to harbor remnants from the Age of Reptiles, recreating the lifeways of dinosaurs and early mammal-like creatures, as well as Ice Age megafauna such as mammoths and sabertooth cats, has been a problem. Through excavation and research, however, part of the veil of time is slowly being lifted and more pieces of this intriguing puzzle are beginning to fall into place.

Travel with us far back in time. Let your imagination roam free over a landscape vastly different from that of today, as you learn about the ***Extinct Species of Canyon Country.***

Jean Akens

Julie Howard, Bureau of Land Management archeologist, shows tracks of the first-discovered sauropod in Utah. This brontosaur trackway lies north of Moab. Photo by Vicki Barker.

Canyon Legacy

Number 6

(ERROR - Photo credits for the Steamboating article in Issue #5 should have read "COURTESY OF MARRIOTT LIBRARY, UNIVERSITY OF UTAH." Sorry, my mistake - Editor.)

Front Cover - Courtesy of talented Moab artist, Don Swasey.

Tracking The Rise Of Dinosaurs In Eastern Utah

by Martin Lockley

The University of Colorado at Denver Dinosaur Trackers Research Group is a project of the College of Liberal Arts and Sciences, sponsored in part by the National Science Foundation.

INTRODUCTION

In the 1980's there has been what Dan Chure, Park Paleontologist at Dinosaur National Monument, has called an "unprecedented spate of research" into all aspects of dinosaur tracks. During this time it has become clear that the Colorado Plateau region (Figure 1) is extremely rich in tracksites from all epochs in the Age of Dinosaurs--Late Triassic to Late Cretaceous. In fact we have been discovering new sites or having them reported to us at the rate of about one a week. In the last few years the CU-Denver Dinosaur Trackers Research group has been focusing attention on the Moab area, documenting several dozen important sites, many of which were previously unknown to science. In this region formations representing the Age of Dinosaurs are replete with fossil footprints. The Moab area can truly claim to be the dinosaur tracks capital of eastern Utah. Based on our present knowledge it is undoubtedly one of the most important areas in the northern part of the Colorado Plateau.

The track bearing formations include, in ascending order, the Late Triassic Chinle Formation, the Lower Jurassic Wingate, Kayenta and Navajo Formations (= Glen Canyon Group), and the Middle and Late Jurassic Entrada and Morrison Formations (= San Rafael Group). See Figure 2. Above the famous bone-rich Morrison Formation lies the Cedar Mountain Formation and a series of Cretaceous deposits representing the latter part of the age of dinosaurs. To find tracks in these strata one needs to move north to the area of Price and Salt Lake City where such younger deposits are well exposed.

Possibly the most interesting aspect of the footprint record in the Moab area lies in the fact that the thick sequence of sandstone deposits between the 210-230 million year old Chinle Formation and the 150-160 million year old Morrison Formation have traditionally been regarded as virtually devoid of fossil remains. For the 40-50 million years represented by Wingate through Entrada time the Moab area, indeed much of the Colorado plateau, was a Sahara-like desert. As William Lee Stokes once pointed out, such deserts are usually regarded as hostile environments, "devoid of life," where water is in very short supply. Undoubtedly there is real validity to this type of reconstruction. There certainly was a great western desert in Lower to Middle Jurassic times and evidence of water is largely restricted to localized deposits representing small playas or oases and ephemeral streams. However, it was precisely these environments that supported and sustained life in this vast ancient desert, and moreover provided

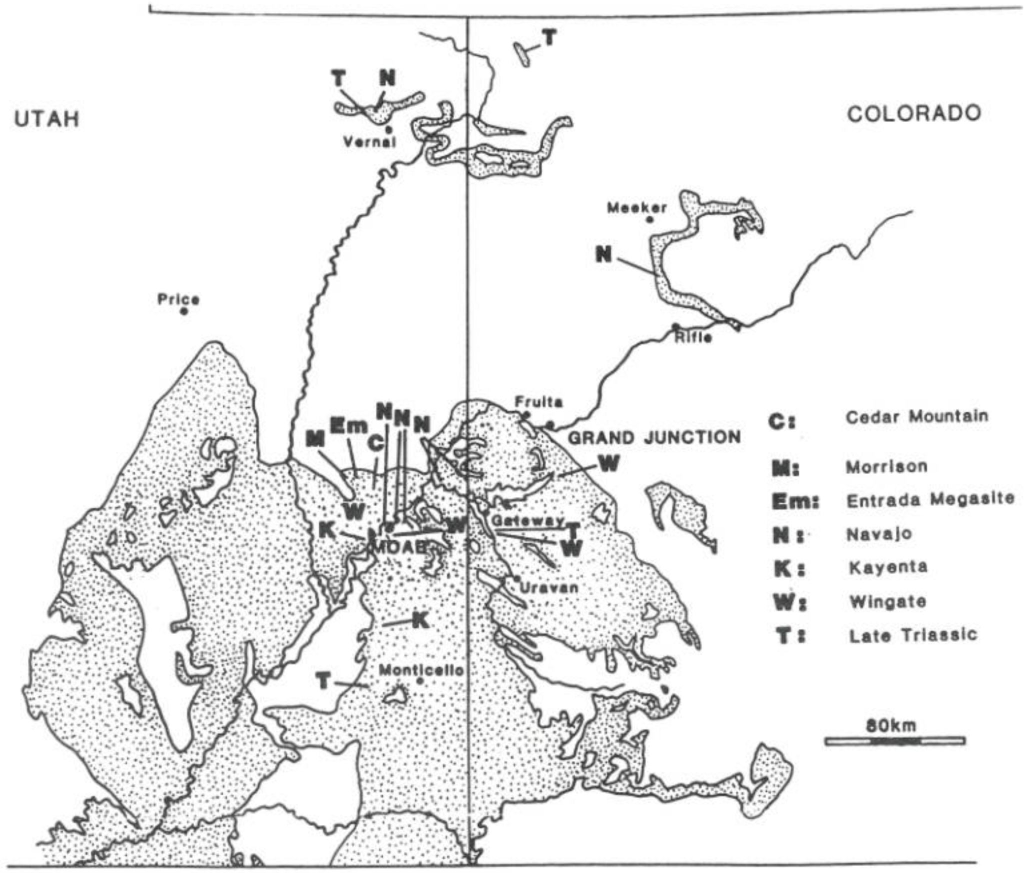


Figure 1. Map of the location of important tracksites in the northern part of the Colorado Plateau region. Stipple indicates strata representing the Age of Dinosaurs.

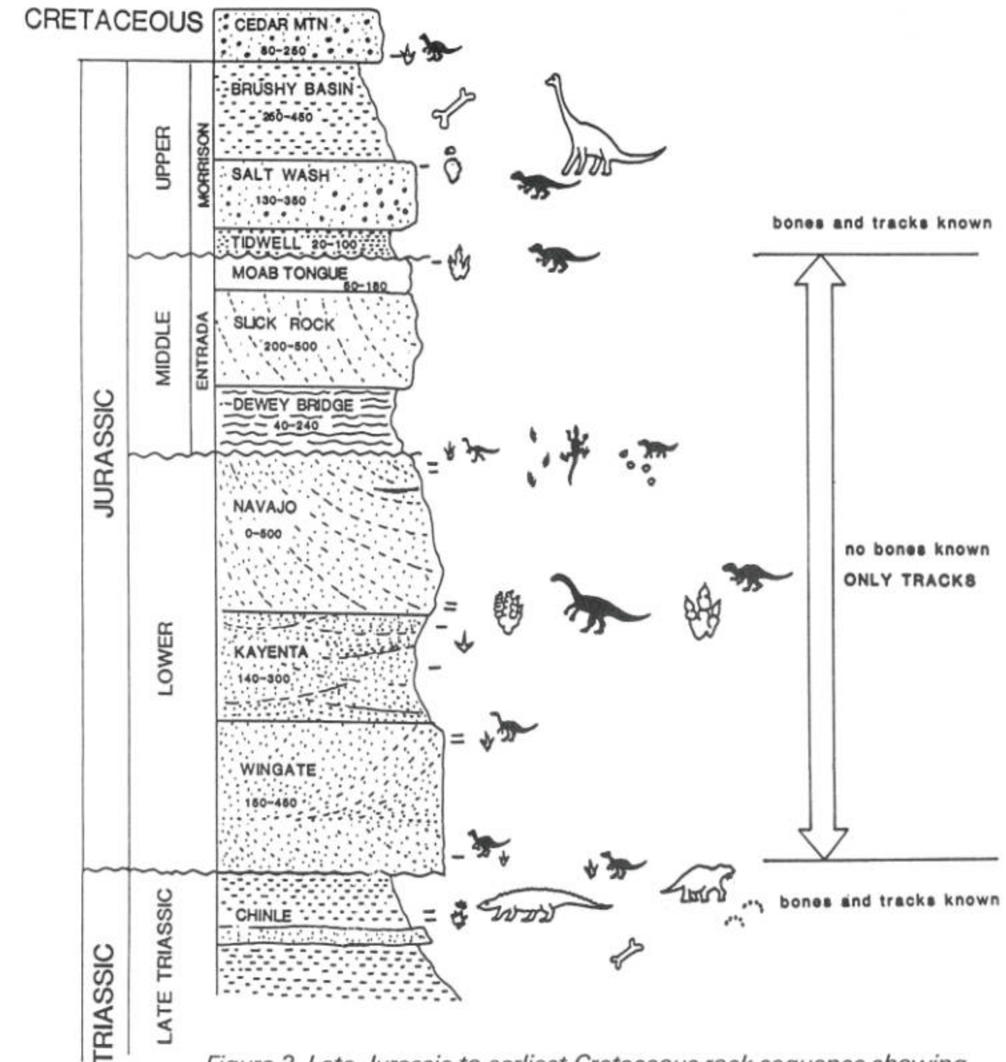


Figure 2. Late Jurassic to earliest Cretaceous rock sequence showing track rich layers in successive formations, and inferred trackmakers; (see text for details).

the wet shorelines and water courses receptive to footprint formation.

THE DAWN OF THE AGE OF DINOSAURS: LATE TRIASSIC EPOCH

The Age of Dinosaurs began towards the end of the Triassic Period, in the Middle and Late Triassic epochs. The Late Triassic of the American Southwest is famous for the Chinle Formation which comprises the Painted Desert landscape and yields the spectacular fossil logs of the Petrified Forest National Monument. These deposits also yield the remains of numerous other plants and animals ranging from delicate fern impressions through snails, clams and crayfish, to fish, large alligator-like amphibians (metoposaurs) to crocodile-like reptiles (phytosaurs), armored reptiles (aetosaurs) and small bipedal dinosaurs like *Coelophysis.*

Despite this diversity of life relatively little was known about footprints, not so much because they are rare, but because they have not been studied. Paleontologists have often been preoccupied with the lure of well-preserved skeletons. At Ghost Ranch in New Mexico numerous complete *Coelophysis* skeletons have been unearthed at a spectacular mass-mortality site that attests to the sudden demise of a herd or flock of these bird-like *Coelophysis.*

The track record for this epoch is best known from two sites, one in the Chinle Formation south of Moab in the vicinity of Canyonlands National Park, and the second much further to the northeast in the vicinity of Dinosaur National Monument. The Canyonlands site is dominated by the tracks of a four-footed animal whose hind feet had five toes and left tracks that bear a remarkable resemblance to a human hand. For this reason the tracks have been named *Chirotherium,* meaning "hand animal" or in this case *Brachychirotherium* ("broad hand animal") see Figure 3. The toes are blunt without well developed claw impressions and so have been interpreted as the tracks of the herbivorous armored reptiles known as aetosaurs.

Tracks of another large five-toed herbivore have also been reported from this site. These have been named *Pentasauropus* ("five-toed reptile track") and are probably attributable to mammal-like creatures known as dicynodonts. By contrast, three-toed dinosaur tracks are relatively rare. Out of a total of about forty trackways only about four are attributable to dinosaurs. This gives us a general indication that dinosaurs represented only about 10% of the population. The dinosaurian tracks are similar to footprints from the Late Triassic of Pennsylvania and New Jersey that have been named *Atreipus* in honor of Atreus Wanner, a 19th century dinosaur tracker from this region. There is some uncertainty about the animal that made these tracks. Its hind feet resemble those of a small to medium-size carnivorous dinosaur (theropod), but in the New Jersey and Pennsylvania trackways small forefoot impressions are usually visible. These make the trackways more reminiscent of bipedal herbivores known as ornithopods. In any event the tracks testify to the presence of an early dinosaur, still unknown from skeletal remains.

The other important Late Triassic locality is in northwestern Colorado near Dinosaur National Monument. Here in lake shore deposits a number of trackways attest to the former presence of a small *Coelophysis*-like dinosaur not much larger than a chicken or a turkey. Here again however, only a few dinosaurs are represented and the vast majority of tracks provide evidence of lizard-like species and another distinctive lake-dwelling reptile known as *Tanytrachelos,* or one of its relatives

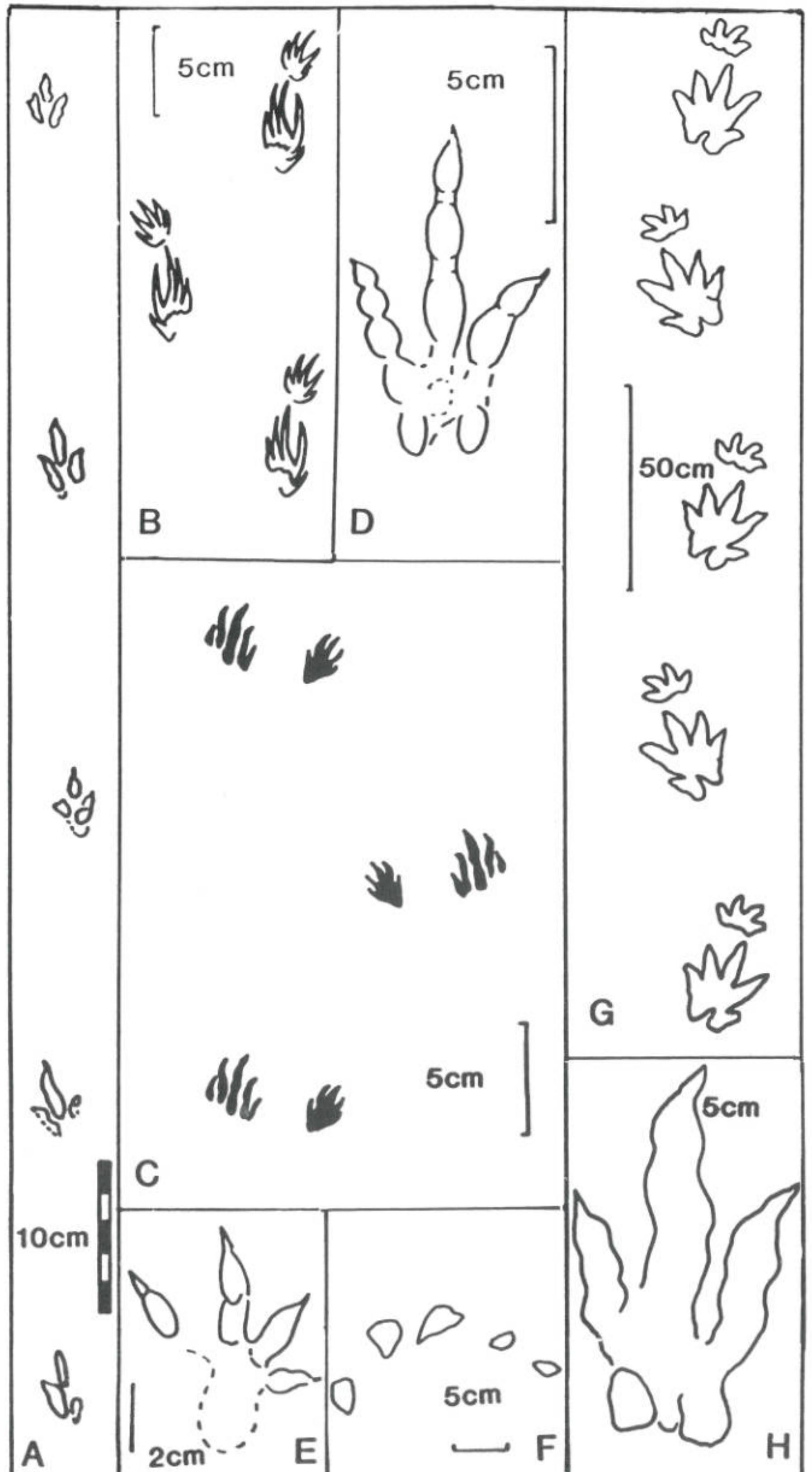


*Figure 3. Late Triassic track types from eastern Utah and western Colorado. A. Small dinosaur trackway from the Popo Agie Formation of northeastern Utah (equal to the Chinle Formation in Canyon Country). B and C. Non dinosaur trackways (*Gwyneddichnium *and* Rhynchosauroides*) from the Popo Agie Formation of northwestern Colorado, and D and E dinosaurian tracks from the same location. F, G and H respectively represent* Pentasauropus, Brachychirotherium *and* Atreipus*-like tracks from the Chinle Formation of the Canyonlands region.*

(Figure 3).

Together these two sites provide some of the best footprint evidence available from the Late Triassic of the western U.S.A. They indicate that dinosaurs made up a relatively small proportion of the animal communities at this time and that many other types of reptiles were far more abundant.

THE JURASSIC PERIOD: THE EARLY DAYS - EARLY JURASSIC EPOCH

When we move forward in time to examine the footprints known from the Wingate Formation there are some dramatic changes in the track record. No longer do we find that dinosaur tracks are rare in comparison to other reptilian footprints. In fact the reverse is true. Dinosaur tracks make up by far the greatest proportion of tracks, sometimes comprising 100% at particular sites.

We now know of about a dozen sites in the Wingate Formation including several in the immediate vicinity of Moab and a couple near Gateway and Grand Junction in western Colorado. The tracks reveal the presence of a large number of small, three-toed dinosaurs; these footprints have been named *Grallator* (meaning like tracks of wading birds). A few much larger three-toed tracks are also known; these are named *Eubrontes* (meaning true thunder) and imply the presence of at least a few good sized carnivores that probably weighed in at about a half a ton. Both track types are well known in early Jurassic age strata from other parts of the world. They were among the first dinosaur tracks ever described in the 19th Century by Edward Hitchcock of Amherst College in Massachusetts, the founder of the science of Mesozoic tracking.

Next we can move on to the track record in the Kayenta Formation. Here again we find evidence of ancient animal communities dominated by dinosaurs. *Grallator* and *Eubrontes*-like tracks are abundant along with another large three-toed track known as *Kayentapus* (meaning footprint from the Kayenta). *Kayentapus* was first described by Samuel Welles from a accessible roadside site near Tuba City in northeastern Arizona. He also

described a magnificent dinosaur skeleton from nearby and named it *Dilophosaurus.* He inferred that the animal may have been responsible for making some of the three-toed tracks in the area and named some of the footprints *Dilophosauripus* (Dilophosaurus tracks). Today many trackers would argue that it is hard to match a track to a particular species of dinosaur. Some find the abundance of three-toed tracks a little frustrating since they indicate the activity of many different carnivorous dinosaurs without allowing clear differentiation of the number or variety of species. One point is clear however and that is that the maximum size of three-toed theropod tracks increases considerably from Late Triassic (Chinle Formation) through to the latter part of the Early Jurassic (Navajo Formation). See Figure 4.

When we move on to look at the Navajo Formation we encounter a little more variety in the track record. At some sites one still finds footprint assemblages dominated by three-toed tracks. The roadside locality on the Potash road about seven miles south of its junction with Highway 191 is a good example. Some geologists have referred this track-bearing layer to the Kayenta Formation, but a detailed graduate study by James Gilland indicated that the footprint-rich layers represent a small limey playa lake deposit in the lower part of the Navajo Formation. Similar track-bearing playa lake sediments are found elsewhere at the base of the Navajo Formation near Moab. At one site a very distinctive track type known as *Otozoum* (meaning giant animal) is found (Figure 5). This again was one of the first fossil footprints ever discovered and described by Edward Hitchcock. Generations of trackers have debated whether the tracks were made by some form of crocodilian, a prosauropod dinosaur or some other creature. The Moab trackways are rather useful in helping address this debate because one trackway indicates a very erect-walking, long striding animal. Such locomotion is more dinosaurian than crocodilian, even though many ancient crocodilians were erect, non-sprawling forms.

Before the discovery of *Otozoum* there was only one prosauropod trackway type (*Navahopus* meaning

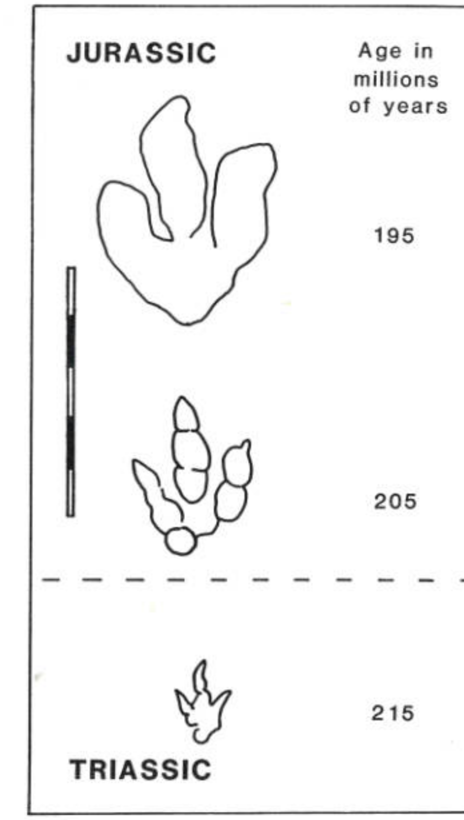


Figure 4. Theropod tracks show an increase in maximum size through time. Examples taken from the Chinle, Wingate and Navajo Formations.

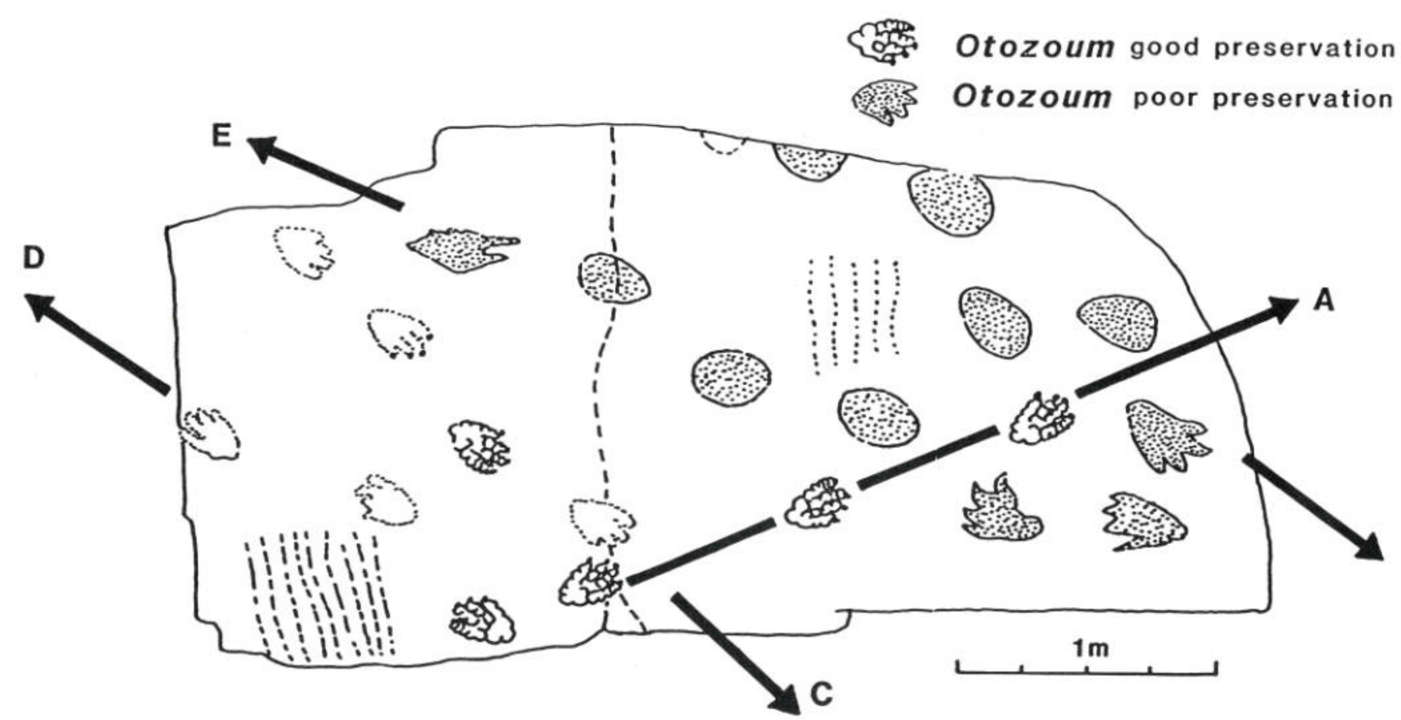


Figure 5. Otozoum trackways from near Moab; trackways were probably made by a prosauropod.

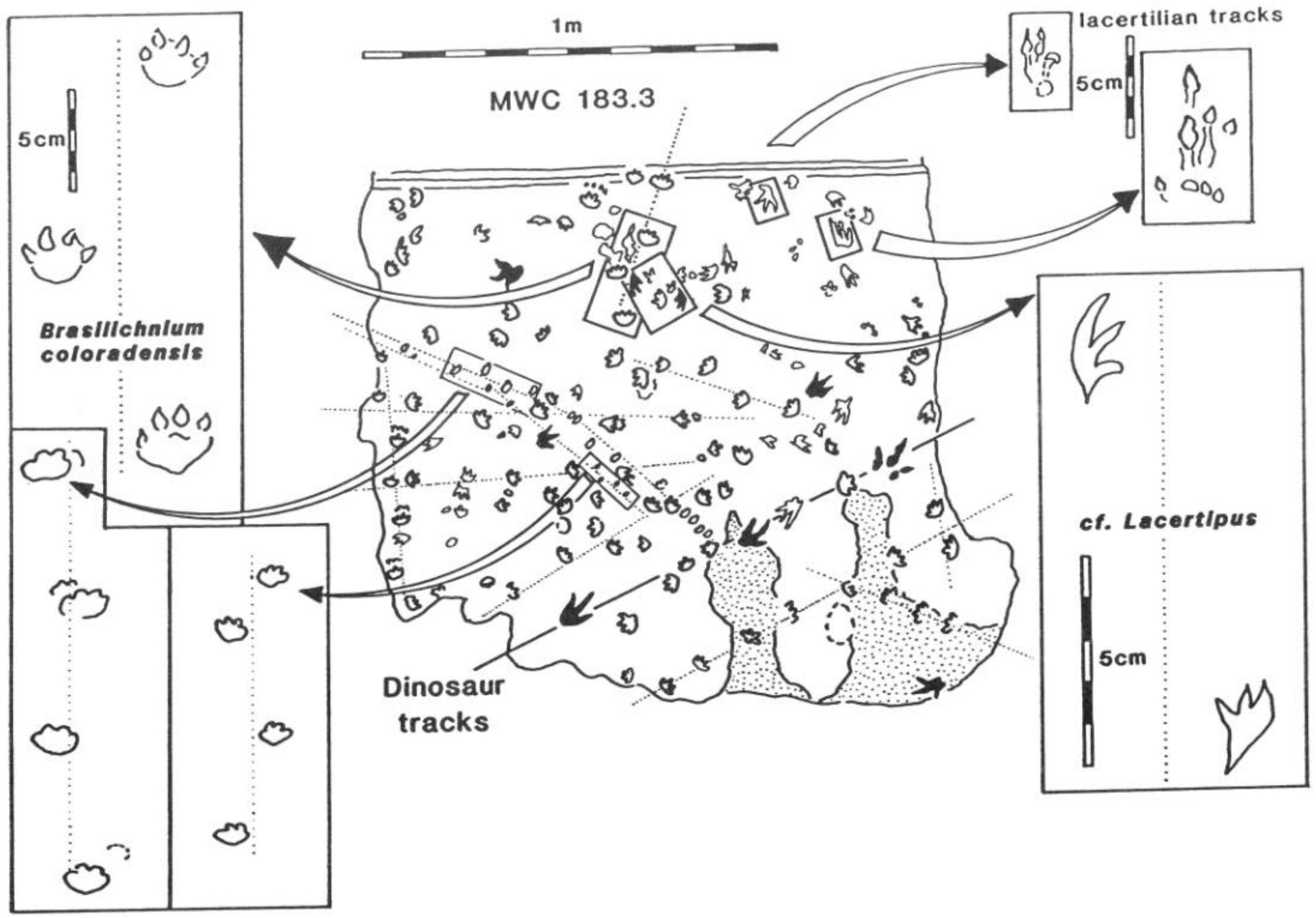


Figure 6. Complex track-bearing slab from the Navajo Formation near Moab. Tracks shown include those of mammal-like forms, lizard-like species and dinosaurs. The slab is on display outside the BLM regional office in Moab.

Navajo footprint) reported from this formation. However, *Navahopus* represents a much smaller animal than the maker of the *Otozoum* trackway and must have been a "giant animal" by comparison.

Despite the importance of the prosauropod track discoveries near Moab it is another collection of tracks from near the top of the Navajo Formation that have generated the most excitement and controversy. Discovered by Lin Ottinger in the early 1970's, and recognized as distinctly non-dinosaurian in appearance, these small tracks were attributed to pterosaurs by William Stokes and his colleagues. Stokes had also described similar inferred pterosaur tracks from the younger Morrison Formation. Because the footprints were never thoroughly studied, no one questioned the trackmaker identification until Kevin Padian (a pterosaur expert) and his colleague Paul Olsen re-examined the Morrison Formation tracks. They concluded that the tracks were made by a crocodilian, not necessarily a habitually aquatic form but possibly one of the many more terrestrial types that existed in Jurassic times. Because these researchers had reinterpreted the Morrison tracks it was assumed that the Navajo tracks were also crocodilian in origin and one author even stated as much. Assumption of course is a dangerous business, especially in science.

Recent work by the CU-Denver Dinosaur Trackers research group suggests an entirely different interpretation. The majority of tracks were made by mammals, probably the dog-like Jurassic varieties known as Tritilodonts. These are often referred to as mammal-like reptiles or reptile-like mammals. The track-bearing slabs (Figure 6) exhibit numerous intersecting trackways. As many as a dozen mammal-like individuals appear to be represented by their tracks in an area little more than a square yard in

size. Also in the same small area we find a few lizard-like tracks and a couple of trackways attributable to small turkey-sized dinosaurs. Thus the picture of life around these desert oases is different from the previous notion of a waterhole frequented by pterosaurs and not much else (Figure 7). Our mammal ancestors appear to have been adapted to desert environments almost 200 million years ago.

THE MIDDLE JURASSIC EPOCH

In the Moab area the Middle Jurassic is represented by only one Formation, the Entrada Sandstone, well-known for the spectacular natural sculpture comprising the famous Arches National Park. In many respects the Entrada is similar to the Wingate and Navajo Formations representing a later phase of sand sea development in the Great Western Desert. Traditionally it has been regarded as almost completely devoid of any evidence of life. A few dinosaur tracks were reported from the formation - in the 1940's - but they remained largely undocumented. For this reason the discovery of very extensive track-bearing layers came as something of a surprise. At the top of the formation several dozen track sites have been discovered. However, these sites are not separate entities; rather they are small parts of a much larger track-bearing complex or carpet that extends continuously over an area of several hundred square miles.

Such an extensive layer of footprint bearing strata apparently originates when large flat lying areas of wet coastal plain get trampled by several generations of dinosaurs. Unlike the small playas of Navajo time that were on the order of a single square mile the sediments of late Entrada time represent an environment more like the low lying coastal plain of the Gulf of Mexico. Indeed, geologists identify a shallow gulf-like sea that encroached into the Utah area in middle Jurassic time. The sea was fringed by extensive mud and sand flats that were receptive to the footfalls of dinosaurs over a wide area. The result was a "megatracksite," a "new" phenomenon, hitherto unrecognized in the geological record.

In the last two years trackers and geologists have recognized three megatracksites. Two are in Cretaceous rocks in Colorado and Texas respectively. This leaves the Entrada site as the only Jurassic megatracksite currently known anywhere in the world. All the tracks appear to be those of carnivorous dinosaurs (theropods) that ranged in size from emu and ostrich-sized creatures to much larger individuals the size of a full grown Allosaurus. In places as many as 2,000

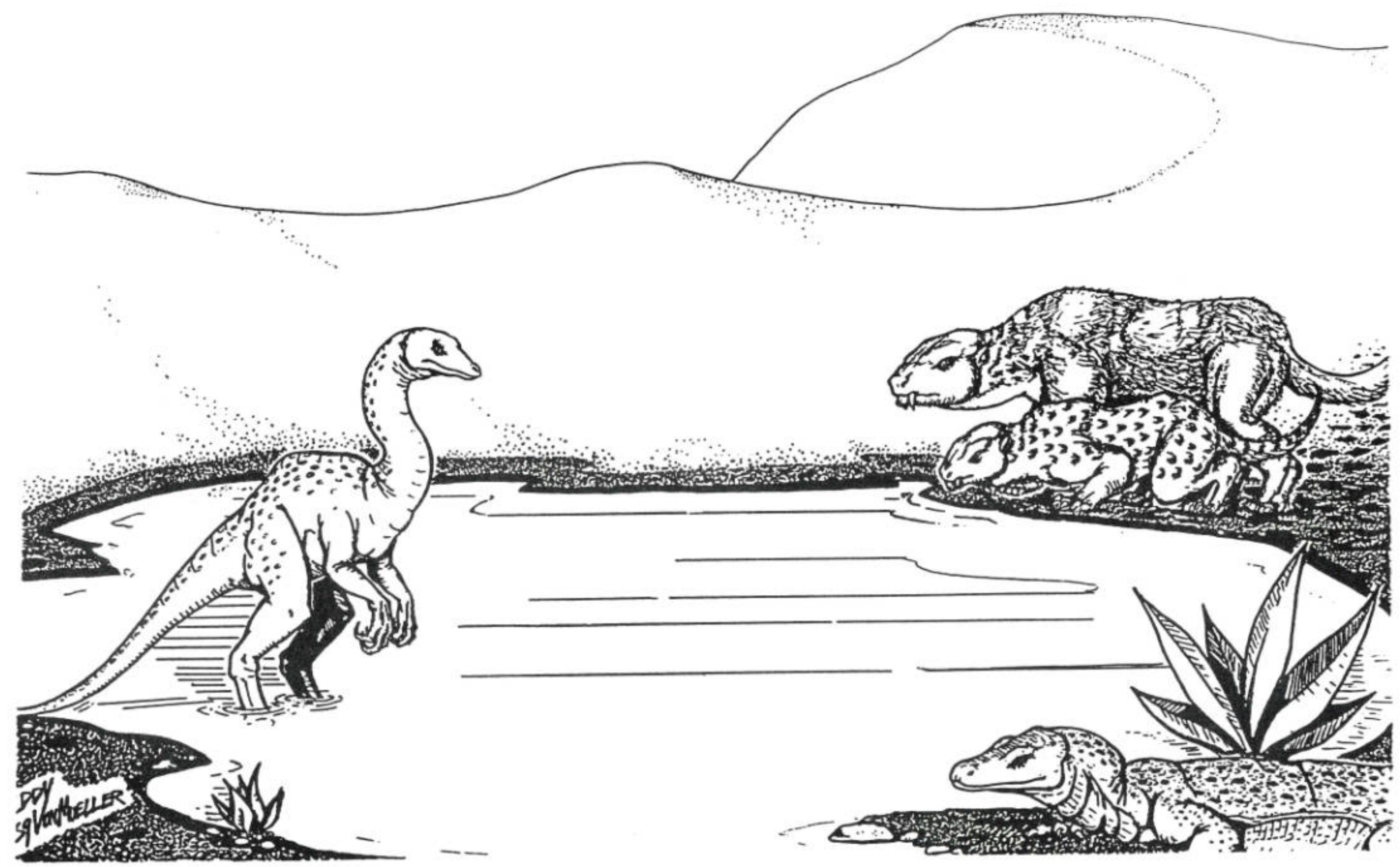


Figure 7. Reconstruction of a Navajo period oasis based on track-bearing slab shown in previous figure.

tracks have been documented in an area of about one acre. This density indicates several million tracks per square mile or literally billions in the entire megatracksite area. It is astonishing to realize that one passes over several million tracks when driving the 30 mile stretch of road from Moab to Crescent Junction.

THE LATE JURASSIC EPOCH: AGE OF BRONTOSAURS

The Late Jurassic is represented in many parts of the Colorado Plateau by the world-renowned Morrison Formation. For over a century the formation has been famous for yielding a wealth of skeletons of famous giants like *Stegosaurus, Allosaurus, Brontosaurus (=Apatosaurus), Diplodocus* and *Ultrasaurus (=Brachiosaurus)* to name but a few. However until recently the formation had yielded very few tracks and none had been documented from Utah.

In the summer of 1989, Linda Dale Jennings of Grand Junction, working in conjunction with the CU-Denver Dinosaur Trackers, located the first important site in Utah. Situated north of Moab, the site reveals both brontosaur and carnivorous dinosaur tracks (see Figure 8). Not only is the site the first brontosaur tracksite reported from Utah but it is the only example known that shows a brontosaur making a sharp turn, in this case to the right.

Above the Morrison Formation there are a few Cretaceous layers exposed in the Moab area. The Cedar Mountain Formation has yielded a very small tracksite but it is not nearly as important as those discussed above. Further to the north, however, later Cretaceous formations are replete with tracks. Good examples of Cretaceous tracks can be observed at the Price Museum and at the Dinosaur Valley Museum in Western Colorado.

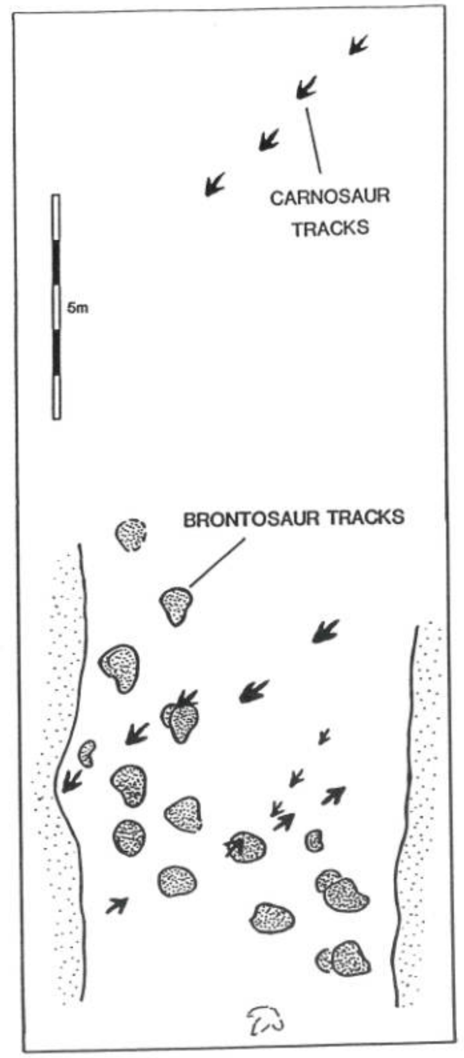
CONCLUSIONS AND ACKNOWLEDGMENTS

The Moab area is truly the dinosaur tracks capital of Eastern Utah and possibly of the whole state. Other parts of Utah also appear quite rich in tracks but they have yet to be shown to be as abundant elsewhere as they are in the areas discussed in this paper. Despite their abundance, dinosaur tracks are essentially a non-renewable resource, worthy of respect and protection. The science of dinosaur tracking is still in its infancy and much has yet to be learned about the full value of tracks in helping us interpret dinosaur behavior, ecology and habitats.

The sites discussed in this paper are still being studied and full length technical papers are either in press or in preparation. The location of sites has been deliberately not publicized until decisions are made regarding the advisability of interpretive trails, signs, and public access. The research was conducted by the CU-Denver Dinosaur Trackers research group including the author, Dr. Michael Parrish, Kelly Conrad, Emily Bray and Edward Meuller. We were ably assisted by Dr. Masaki Matsukawa of Ehime University, Japan, Joachin Moratella of Universidad Autonoma Madrid, Spain, Jeffrey Pittman of the University of Texas and Linda Dale Jennings. Special thanks also go to Fran and Terby Barnes who have discovered several sites and generously shared information with us. Julie Howard of the B.L.M. was also very supportive of our research efforts and has facilitated initial moves to protect several of the more important sites and specimens. The same support has also come from Jim Madsen, former State Paleontologist, and David Gillette, current State Paleontologist.

The dinosaur tracks of the Moab area are a unique resource that will achieve growing national and international recognition as their full significance is documented. We ask that all dinosaur and natural history enthusiasts help preserve and protect this valuable facet of Utah's natural heritage -- this unique dinosaur legacy.

The CU Denver Dinosaur Trackers Research Group is a project of the College of Liberal Arts and Sciences. Contribution 90.2



© MGL

Figure 8. A brontosaur trackway and four theropod trackways from the Morrison Formation near Moab. Note that the brontosaur made a sharp turn to the right.

ABOUT THE AUTHOR

Martin G. Lockley has a PhD from Birmingham University in England. He is currently an Associate Professor of Geology at the University of Colorado in Denver, and leader of the CU Denver Dinosaur Trackers Research Group. Lockley is considered one of the foremost experts on dinosaur trackways, and is co-author of a college textbook on the subject.

* * *

Utah's Early Place In Paleontological History

by F. A. Barnes

THE BEGINNING

The first dinosaur remains to be identified as such were found in 1822 in England. Although prehistoric remnants had been found before this, the large bones were assumed to be those of extinct giant humans, as proclaimed in various folklore tales.

These first bones identified as belonging to some prehistoric beast were found by the wife of a country doctor. The doctor later attempted to reconstruct the form of the original animal, but with mixed success. Too little was known at that time about the basic anatomy and function of dinosaurs.

Two years later an English geologist did a somewhat better job of reconstructing from other bones a dinosaur that he named *Megalosaurus.* This started a world-wide search for prehistoric dinosaur bones, and a more realistic identification of the long-extinct creatures to whom they belonged.

In America, in a Massachusetts exposure of sandstone, the strange three-toed tracks of giant "birds" had been reported by a farm boy in 1802, but these were not recognized as having been made by dinosaurs until sixty years later.

An English paleontologist coined the term "dinosaurs," meaning "terrible lizards," in 1841. By then, other dinosaur bone discoveries were being made, and earth scientists in every modern nation were taking a keen interest in this development.

The first American dinosaurs were identified in 1856 by a Philadelphia anatomist, Joseph Leidy, from some teeth found in Montana by Dr. Ferdinand Hayden, leader of the famous Hayden Survey, one of the several great explorations that opened the unknown lands of the American West. In 1858, Leidy reported on some dinosaur bones found in New Jersey.

Thus, at this time, 132 years ago, the existence of dinosaurs was known, but detailed and accurate knowledge was extremely scarce. The whole subject was new to the field of science. Even so, one very unusual man who has long been neglected by both conventional and scientific historians, a physician by profession, had gone to the trouble to acquire what information was available, and was thus well-prepared when he made a highly serendipitous discovery in 1859.

THE 1859 MACOMB EXPEDITION

In 1859, the U.S. Army organized a mapping expedition into what was then the almost entirely unknown region now defined as southeastern Utah. One purpose of the expedition was to locate the confluence of the Green and Grand (Colorado) rivers, which was unknown at that time. Earlier Spanish and Mexican traders had developed a trail of sorts through the region, but knew little about the arid land beyond the location of the next reliable water hole. Hostile Indians were still a serious problem, so Captain John Macomb, who was a topographical engineer, took with his survey party a contingent of soldiers for protection.

Historic photograph of Captain John N. Macomb, U. S. Army Corps of Topographical Engineers, circa 1865. Courtesy of F. A. Barnes.

He also took along Dr. John S. Newberry, as expedition physician and general scientist. Dr. Newberry was officially collecting scientific specimens for the Smithsonian Institution, as he had done the previous year on the Ives Expedition up the lower Colorado River and across what is now northern Arizona.

John Newberry's early efforts for the Smithsonian seemed to drop out of sight in historical archives. He receives no mention in a Smithsonian book about its early field collectors. Yet at least one of his field discoveries was extremely important, both historically and scientifically.

The reason historians, and even most scientists, have over looked Dr. Newberry is probably a matter of unfortunate timing. His efforts and discoveries took place just before the beginning of the Civil War, and were thus overshadowed by this tragic event. Even today, historians have not caught up with this oversight, and it was only very recently that earth scientists made any serious effort to fill in the gap left by neglecting to study Newberry's contributions to the Smithsonian Institution and the world of science. Even now, that effort is just beginning.

The Macomb Expedition set out from a military outpost near Santa Fe, New Mexico, in mid-July of 1859, following the Spanish Trail as then known from various records, maps and travelers' journals. They had an interpreter along, and hired Indian guides who knew the local terrain as they traveled.

After an uneventful trip up into what is now southwestern Colorado and then northwest across the high sage-plains there, the expedition dropped down into lower country northeast of the present town of Monticello, by descending into a deep canyon that Newberry dubbed "Canon Pintado," or "Painted Canyon," because of the bright hues in its sandstone walls. The group camped about halfway down the broad six-mile-long canyon, near a cliff-base.

As usual, Newberry was immediately out scouting around for plant, animal and mineral specimens. While the details of his actions that evening are now lost to history, a recent study, including an analysis of Newberry's unpublished field notes and a previously unknown personal journal about the expedition, has permitted the following reconstruction of that historic evening.

At the base of the soaring cliff, Newberry found a few small pieces of petrified bone and, from his knowledge of what had been taking place in the field of paleontology, recognized what he had found. With some help, Newberry managed to find a very dangerous route to the top of the cliff about a quarter mile from the camp. He then worked his way back along the treacherous slope above the cliff to above the place where he had found the bone pieces.

Historic steel engraving of Dr. John S. Newberry at age 65, in 1887, with his signature.
Courtesy of F. A. Barnes.

There, he found many more petrified bone fragments and, before it became too dark to get back down safely, managed to trace the bone shards up the steep slope to their origin, a colorful layer of somewhat softer sediments sandwiched between massive, hard sandstone strata.

The next morning the expedition set out again, and official records do not mention a return that way, but Newberry's unpublished, hand-written field notes reveal that several days later, as the expedition was returning south, Newberry took several helpers and spent an entire day at his discovery site, excavating with great effort several large pieces of dinosaur bone. At the end of the expedition and back in Santa Fe, Newberry sent these bones to the Smithsonian Institution, along with the rest of his large natural history collection.

Unpublished letters written by Newberry that were preserved in historical archives tell what happened next. The bones he collected in "Canon Pintado," only recently identified as East Wash Canyon, were sent to the anatomist who had already done similar work, Joseph Leidy, for study and identification.

But Leidy was evidently preoccupied. Several letters from Newberry pleading for study results so they could be included in the expedition's official report went unanswered by Leidy.

Then, with the advent of the Civil War, national priorities changed. Macomb was assigned military duty, Newberry used his medical training to serve the war effort, and the official report about the 1859 Macomb Expedition was not published until 1876, after the ending of the Civil War, seventeen years after the expedition, and at a time when governmental efforts and public attention were strongly focused on the several other big survey expeditions then taking place, and the startling new discoveries these were reporting. Thus the Macomb Expedition, and Newberry's numerous earlier findings, dropped into the cracks of science and history, to be neglected, forgotten, for more than a century.

A year after the official Macomb Expedition report was finally published, Edward D. Cope, of the two famous rival paleontologists, Cope and Marsh, finally did a study of the bones collected by Newberry in "Canon Pintado." He determined that they belonged to a type of huge, quadruped plant-eating dinosaur called

Portion of rib-bone from Newberry's sauropod, photographed in situ at the original discovery site on the day of its rediscovery. This bone was collected for further study by Dr. David Gillette, September 1989.
Photo by F. A. Barnes.

sauropods, and he named Newberry's specimen *Dystrophaeus viaemalae* Cope.

Shortly after the publication of Cope's report, a German scientist who was highly interested in dinosaurs wrote a second report, describing the fossil bones Newberry had found and quoting Cope's report. That was the last serious attention given Newberry's *Dystrophaeus* until about fourteen years ago.

THE REDISCOVERY

In the mid-1970s I was asked by two well-known paleontologists, Dr. James A. (Dinosaur Jim) Jensen of Brigham Young University and Professor John McIntosh of Wesleyan University, to see if I could locate where John Newberry had made his historic find. Professor McIntosh had tried and failed to relocate the site, and had asked "Dinosaur Jim" if he might have excavated the site unknowingly. He hadn't, but decided to tempt me with the problem, since he knew that I was systematically exploring a lot of southeastern Utah terrain, and knew the area fairly well.

I took the bait, and what followed was twelve long years of field and historical archive research. I couldn't even begin to find Newberry's sauropod bone site until I knew the route of the Macomb Expedition, and it soon became obvious that the few historians who had written anything at all about the 1859 Macomb Expedition actually knew little beyond what had been published in the official 1876 report. They certainly didn't know the wild terrain through which the expedition traveled. And even though Macomb was known to have followed the Old Spanish Trail to a certain point, and to have used the water holes on that historic route, the actual locations of two of those critical water holes in southeastern Utah were not known by modern historians.

My long and difficult search for the Macomb Expedition route within

Dr. David D. Gillette, Utah State Paleontologist, (left), unidentified helper (right) and Terby Barnes (center) working at the Newberry sauropod discovery site, September 1989.
Photo by F. A. Barnes.

southeastern Utah was finally successful, and I reported a summary of my findings to the various scientists and historians who had been following my search, as well as to the Utah State Historical Society and to the Utah State Paleontologist.

Some responded and some had apparently lost interest by then. I also wrote and published a book summarizing my findings. I titled it **CANYONLANDS NATIONAL PARK -Early History & First Descriptions** because, as it turned out, three members of the Macomb Expedition were the first to view, enter and describe in writing the terrain that is now within Canyonlands National Park.

Thus, by the time I had completed my research, considerably more was known about the much-neglected 1859 Macomb Expedition, and the long-lost location of Dr. John Newberry's historic dinosaur discovery was rediscovered.

INTEREST RENEWED

Then things started moving again. Utah State acquired a new paleontologist, Dr. David D. Gillette, one who immediately took a keen interest in the Newberry sauropod site. Although at that time the actual location of the Newberry site was still known only to those of us who had found it, Dr. Gillette soon changed that. In early 1989 I took him up to the rediscovery site via the route Newberry originally had to take, and showed him the closer, easier route up the cliff that Newberry had constructed on his second visit, via a series of "Moki" steps, (foot and hand holds carved into the rock) since then eroded almost completely away. Dave made plans to do more excavating, and soon acquired funds for this purpose.

After Dr. Gillette and his wife, who is also a paleontologist, had carefully gone over all the historic documents I had acquired and studied during my twelve years of field and literature research, they were confident enough about my conclusions to write and present an official paper announcing the rediscovery of Newberry's sauropod site, at a paleontological symposium in Flagstaff, Arizona, in early September, 1989. A partial quote from this abstract summarized both the historical and scientific importance of the site:

> "Recent reconnaissance in San Juan County, Utah, has identified the type locality and established the existence of additional bones in situ for *Dystrophaeus viaemalae* Cope 1877, a sauropod dinosaur of uncertain affinity. The site is in the lower part of the Tidwell Member of the Morrison Formation (Upper Jurassic), approximately 30 feet above the contact with the Entrada Formation. The type materials are the first sauropod dinosaur bones discovered in the New World, and only the second dinosaur bone discovered in Western United States."

Soon thereafter, with an appropriate Bureau of Land Management permit, they organized a ten-day dig at the Newberry site. In the meantime, Professor John McIntosh, who had started my long search to begin with, visited Utah, and the original bones that Newberry had collected were sent by the Smithsonian Institution to Brigham Young University for further study.

Professor McIntosh and Dr. Gillette then compared the original bones with specimens taken from the rediscovery site and concluded that I had, indeed, found Newberry's original site. They also verified something else that I had reported earlier, that the bones were located in a geologic stratum that was much older than previously discovered sauropod bones, thus making Newberry's sauropod one of the oldest, if not THE oldest, sauropod to be discovered to date.

After Dr. Gillette's new work at the Newberry site, he summarized his findings in a report to the Bureau of Land Management, which issued the excavation permit, partially quoted here:

> "During the period September 12 - 22, 1989, the Division of State History under my supervision sponsored the exploratory excavation of dinosaur bones at the type locality of the sauropod dinosaur *Dystrophaeus viaemalae* in East Canyon.
>
> "Mr. Fran Barnes of Moab has spent several years tracing the route of the Macomb Expedition, and in the course of his research he identified the type locality. I am convinced that Fran is correct, and that the site we worked in September is the type locality.

"Our excavation work last fall was designed as preliminary, with the main purposes being to establish the site as the type locality and to determine the extent of additional bones. We achieved both goals: preservation and sediment types match the original materials, and there are more bones in place.

"Our on-site work involved personnel from the Division of State History, volunteers selected through our office, Fran and Terby Barnes, Lynett Gillette, and two volunteers with professional experience from the Southwest Paleontology Foundation, Inc. from Albuquerque. We moved 2 - 3 cubic yards of matrix, and exposed a ledge of bone extending horizontally for 30 meters. Much of the bone was difficult to extract without extensive damage. We left most in place, in anticipation of renewed excavation with more and better equipment that will minimize damage and loss of information.

"My academic interest in the site has three facets: historical, taxonomic, and stratigraphic. The historical aspects are inherently important, and constitute an appealing story for Utahns. Taxonomic questions need additional study, but may not be answered without further excavation. The stratigraphic position is important because the site is low in the Morrison Formation, near its base, indicating that *Dystrophaeus* is one of the earliest sauropod dinosaurs in North America and may occupy an important evolutionary position as ancestral to some or all later sauropods.

"Research and evaluation are in progress. One technical paper has been presented on the site (Annual Symposium on Paleontology and Geology, Museum of Northern Arizona) and additional technical publications are being prepared."

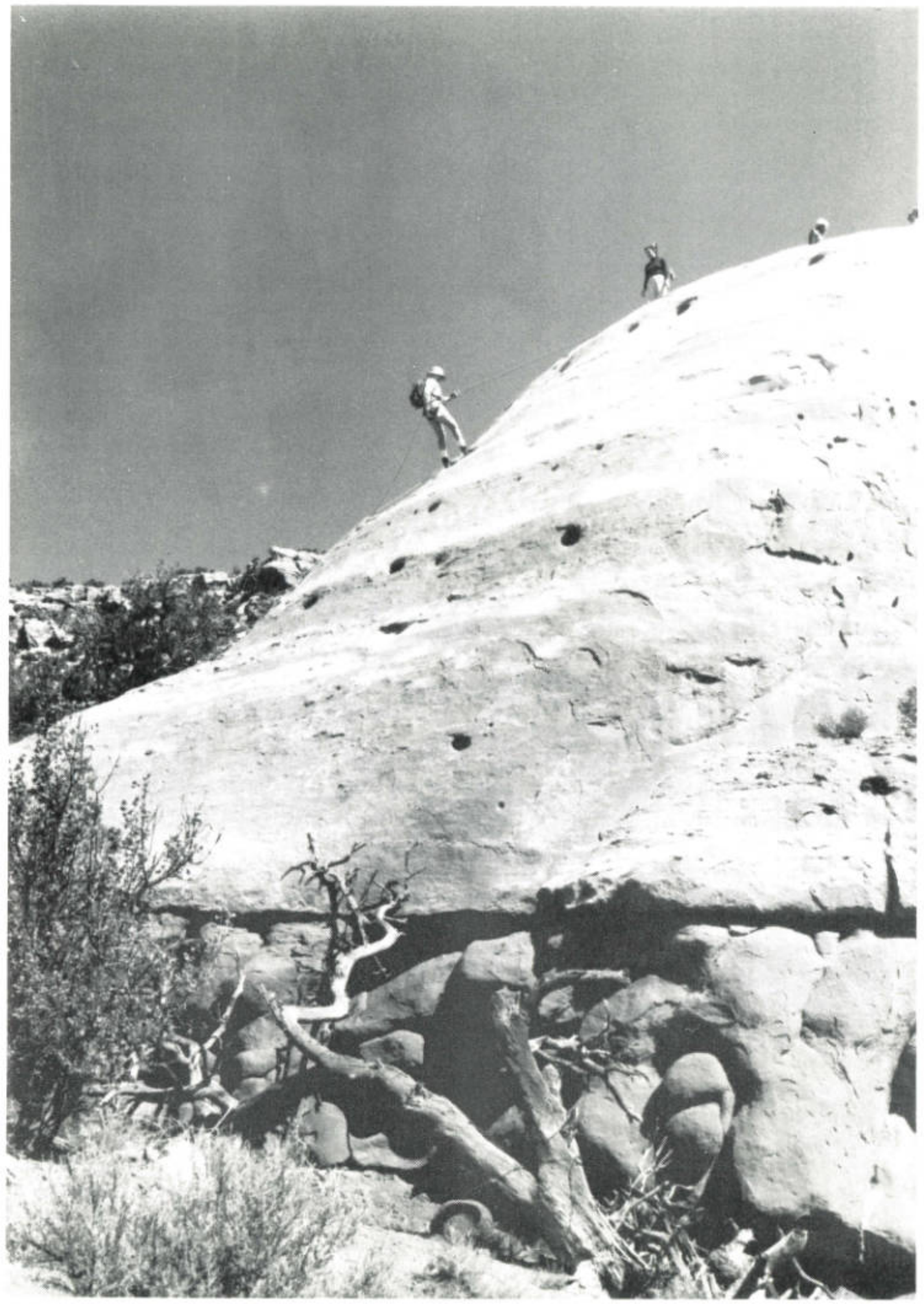
Dr. David Gillette (center), Dr. Lynett Gillette (bottom) and unidentified helper (rear) working at the Newberry sauropod discovery site, September 1989.
Photo by F. A. Barnes.

WHAT'S NEXT?

One part of Dr. Gillette's report to the BLM underscored the problem that makes this question necessary:

> "Access to the site is difficult and dangerous. Because of the safety issues, I have decided to delay resumption of the excavation until better access can be devised --"

Thus, the remote and hazardous location that prevented the easy rediscovery of the Newberry sauropod site for more than a century is now preventing further study. In his original report, Newberry noted that better tools would be needed for further work at the site. Unfortunately, modern technology has still not designed tools that will make work at this hazardous site any easier, and its location may indefinitely delay



Terby Barnes rappelling down from the Newberry sauropod discovery site after a day's dig, September, 1989.
Photo by F. A. Barnes.

resolution of the mystery of the true identity of Newberry's sauropod.

My part in solving this historical-scientific puzzle is over. Now it's up to the men of science, and the whims and priorities of those who arrange for the financial support of scientific research. I can only hope that the whole matter does not drop back into the dusty cracks of science and history.

FURTHER READING

Barnes, F. A., **CANYONLANDS NATIONAL PARK - Early History & First Descriptions,** Canyon Country Publications, 1988

HIKING THE HISTORIC ROUTE of the 1859 MACOMB EXPEDITION, Canyon Country Publications, 1989

Colbert, E. H., **The Great DINOSAUR HUNTERS and Their Discoveries,** Dover Publications, 1984

Lambert, David, **A FIELD GUIDE TO DINOSAURS,** Avon Books, 1983

Paul, G. S., **PREDATORY DINOSAURS OF THE WORLD,** Simon & Schuster, 1988

* * *

ABOUT THE AUTHOR

F.A. (Fran) Barnes is an ex-aeorspace engineer and originator of the popular Canyon Country series of guidebooks and maps. He is the author of all but two of the series. Barnes has spent the last twenty-five years systematically exploring, studying and photographing the magnificent public lands of southeastern Utah, and considers that he has just begun to tap the region's limitless scenic beauty, its unique scientific values and its diverse recreational opportunities. Fran will release numbers 21 and 22 in his series by mid-1990, and is already well along with number 23.

THE LONG WALK QUARRY:
A New Horizon in Dinosaur Research

by Frank. L DeCourten

INTRODUCTION

Utah!

To paleontologists all over the world, the name alone evokes images of a Mesozoic wonderland where dinosaur bones litter the surface of red rock deserts, offering clues to the nature of one of the most fascinating groups of extinct animals known to science. That slightly exaggerated image does, of course, have some basis in reality. During the 130 years since dinosaur bones were first discovered in Utah, literally thousands of bones have been excavated from the eastern portion of the state. A great deal of what we know about dinosaurs and their world has been gleaned from the analysis of Utah fossils and the rocks enclosing them. When it comes to the study of dinosaurs, Utah is definitely one of the most fervent and productive regions in the world.

There are many reasons why the Beehive State has figured so prominently in the history of dinosaur paleontology. The Mesozoic rock succession in the Utah portion of the Colorado Plateau is, for starters, remarkably complete. As much as 13,000 feet of sediment accumulated in some areas of eastern and central Utah during the 178 million-year span of the Mesozoic Era. With the exception of a few relatively brief intervals, the accumulation of sediment (and therefore the potential for fossilization of dinosaur material) was more or less continuous throughout this great "Age of Reptiles." Moreover, much of this enormous volume of sediment consists of sand, mud, and silt deposited in river channels, in swampy environments, or on river floodplains. These lowland environments were, in turn, well suited to the ecological requirements of large terrestrial reptiles, offering lush plant communities to support the food chain and few obstacles to the seasonal migrations undertaken by the expansive herds of dinosaurs. The climate in eastern Utah in the Mesozoic was also much less hostile than the blistering aridity we know today. Warm semi-tropical to semi-arid conditions were the rule during most of the time dinosaurs occupied their paradise in the Colorado Plateau. These favorable conditions were, of course, not restricted to Utah during the Mesozoic. We suspect that similar habitats prevailed in Asia, in Europe, in parts of sub-Saharan Africa, and in eastern North American during the Mesozoic Era.

It is also the modern character of our canyonlands that separates Utah's Dinosaur Country from other areas of fossiliferous Mesozoic strata. Imagine yourself transported to some random location in the red rock country of eastern Utah. Look around. What do you see? ROCKS! No thick soil, no dense vegetation, no shopping malls, and few roads to obscure the sweeping vistas of bare stone. To the paleontologist, the vast exposures of unconcealed, potentially fossiliferous, rock in the Colorado Plateau are exciting beyond description.

When the natural processes of erosion exhume the buried remains of dinosaurs, the undeveloped character of the land coupled with the restricted plant growth and relatively thin soil profiles associated with the present desert climate, allows them to be easily discovered. By way of contrast, there are almost certainly many dinosaur bones in North Carolina (a few have actually been found), but the chances of locating them beneath the thick mantle of soil and jungle-like foliage are far more remote than in the deserts of eastern Utah. It is certainly no surprise, then, that generations of paleontologists have been lured here from all over the world by the promise of the abundant clues to the mysteries of the Mesozoic Era that await the observant researcher.

A GAP IN THE RECORD

As richly fossiliferous as the Mesozoic strata of eastern Utah are, the vast majority of dinosaur fossils have been excavated from two main rock units in the Colorado Plateau. These are the late Jurassic Morrison formation (about 150 million years old) and the Late Cretaceous Mesaverde Group (80-65 million years old) and their respective equivalent strata. Although the accumulation of sediment in the region was nearly continuous throughout Mesozoic time, it is really only during these two periods that dinosaur remains were preserved in great abundance (see figure 1).

The Morrison Formation is one of the most intriguing units of sedimentary rock in the world. The lavender and gray badlands into which the Morrison mudstones weather present a distinctive and colorful spectacle to even the casual visitor. But, beneath the surface, these same rocks yield many fascinating bits of information on the vanished world of the dinosaurs. The size, shape, and composition of the sediment grains, and their style of layering, are the clues by which geologists can reconstruct the ancient geography of eastern Utah 150 million years ago. Applying the principles of analysis of sedimentary environments to these strata, the Morrison Formation becomes a historical record of changing landscapes occupied by the reptilian giants of the Jurassic.

Dinosaur bones are so numerous in the Morrison Formation that is has been referred to as the "Great Dinosaur Graveyard of the West." Bones and bone fragments are found in

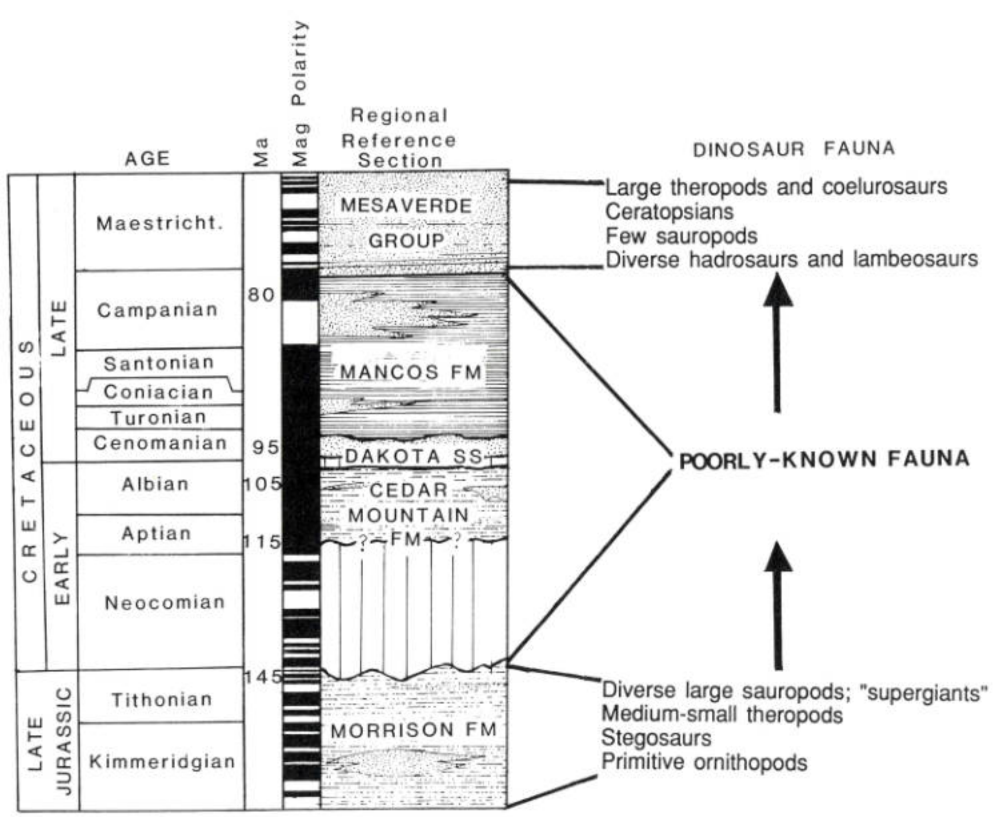


Figure 1. Stratigraphic column for part of the Mesozoic rock succession of the northern Colorado Plateau. Note the gap between the Morrison and "Mesaverde" dinosaur faunas. The Cedar Mountain Formation is the only rock unit deposited during this interval under conditions that favored preservation of dinosaur fossils.

almost every exposure of the Morrison sediments. In some places, like the Cleveland-Lloyd Quarry and Dinosaur National Monument, the concentration of dinosaur bones is nothing less than spectacular. Add to this the equally productive Morrison quarries in Colorado, New Mexico, and Wyoming and the number of recovered bones becomes staggering. We may not know everything about the dinosaur fauna in Utah during the late Jurassic, but what we do know is substantial and we are learning more all the time through the study of Morrison fossils.

Though each quarry in the Morrison Formation represents a unique situation, the late Jurassic dinosaur communities have a distinctive and more or less uniform character. The Morrison faunas are dominated by the large sauropod species such as *Apatosaurus, Brachiosaurus, Camarasaurus,* and the controversial supergiants *"Supersaurus," "Ultrasaurus,"* and *"Seismosaurus."* Predators are almost exclusively represented by the Utah State Fossil Allosaurus, along with a few carnivorous relatives such as *Ceratosaurus, Marshosaurus,* and *Stokesosaurus*. In addition, the ornithopod (duck-bill like) *Camptosaurus* and the plated *Stegosaurus* are not uncommon in Morrison localities.

As one moves upward (and forward in time) in the succession of Colorado Plateau Mesozoic strata from the late Jurassic, few dinosaur bones are encountered until we reach the late Cretaceous sandstones and mudstones in rock units such as the Kaiparowits, North Horn, Wahweap, and other formations (all at least partly equivalent to the "Mesaverde Group" of common geologic terminology). In these layers, dinosaur remains are once again common, but the fauna is of a completely different character from that observed in the Morrison sediments. Gone are the great herds of giant sauropods. Only one, and a relatively small one at that *(Alamosaurus)* has been discovered in the late Cretaceous rocks of Utah. In addition, no trace of the stegosaurs has ever been found in the late Cretaceous formations. The herbivorous fauna is instead dominated by the horned ceratopsian dinosaurs, including the famous *Triceratops,* none of which were present during the late Jurassic. The ornithopods (duck-billed dinosaurs) are uncommon in the Morrison, but are extremely abundant in the Mesaverde fauna, including such forms as the snorkel-crested *Parasaurolophus*. The dinosaur predators come in two distinct size ranges in the late Cretaceous: the enormous tyrannosaurs and the much smaller and more delicate coelurosaurs, both of which have been documented in the late Cretaceous of Utah by rather rare and fragmentary fossils.

Altogether, these late Cretaceous species, from about 80 to 65 million years old, present a striking contrast to the sauropod dominated array of Morrison dinosaurs that preceded them by about 70 million years. What could have been responsible for such a dramatic change in the character of Utah dinosaur communities during this time? What changes in the terrestrial ecosystems might have initiated these evolutionary changes? Why did so many of the gigantic sauropods and all of the stegosaurs become extinct? What kinds of dinosaurs were the ancestors of the horned ceratopsians?

These, and many other mysterious questions, have traditionally eluded us because very little fossil material is available from rocks deposited during this 70-million year "missing link" in the story of Colorado Plateau dinosaurs. This gap in the fossil record occurs at a time of great change in the dinosaur ecosystem, when geological events were leading to profound environmental changes and, in response, evolutionary lineages were shifting directions, branching off along new trends, or disappearing altogether. The early part of the Cretaceous period, around 110 million years ago, is a critical chapter in the biography of Utah dinosaurs. It is the one phase of dinosaur history where good information is needed the most, and...as luck would have it...it is the one interval which has yielded the fewest dinosaur fossils! That unfortunate situation began to change in 1987, the year operations commenced at the Long Walk Quarry.

FILLING IN THE FAUNAL GAP

Throughout central and eastern Utah, the early part of the Cretaceous period is represented by 3000 feet or so of various sedimentary rocks from which geologists have identified several different formations. Only one of these formations, however, was deposited under conditions favorable to the preservation of dinosaur fossils: the Cedar Mountain Formation (the equivalent strata in most areas east of the Colorado River are known as the Burro Canyon Formation).

The Cedar Mountain Formation was first described by Stokes (1944, 1952), who separated it from the underlying Morrison Formation on the basis of several subtle differences in the character of the mudstone and sandstone in the two units. And subtle the distinctions are...such as the somewhat less distinct color banding, more calcareous (calcium carbonate rich) nature of the soft mudstones, and relatively more common "gastroliths" in the Cedar Mountain Formation. In fact, from a distance, the Cedar Mountain and Morrison Formations are not easily separated even to geologists who, prior to Stokes' work, mapped them together as a single package.

The distinctions documented by Stokes are nonetheless useful, at least in the northern San Rafael Swell where his observations were made, and they do signify a shift in the pattern of sedimentation in that area. The nature of the boundary between the two formations is still not well established on a broad scale. In some places, it appears that deposition was continuous from the uppermost Morrison Formation to the lowest Cedar Mountain Formation. In other areas, a massive conglomerate or a scoured surface suggests that there was an interval of non-deposition and/or erosion before the Cedar Mountain sediments began to accumulate on the exposed Morrison surface.

In western Emery County, the upper part of the Cedar Mountain Formation has been dated as Albian-Aptian in age (late in the early Cretaceous, about 110 million years old) on the basis of pollen, mollusks, and other rare fossils. If these age determinations are accurate, and they are probably reasonably close, then the Cedar Mountain sediments were deposited almost exactly in the middle of the "faunal gap" described above!

Moreover, the overall similarity in the sediments of the Cedar Mountain and Morrison Formations implies that the strata accumulated under similar general conditions. Though there were some differences between the late Jurassic and early Cretaceous landscapes of Utah, an interior lowland nestled between more mountainous regions existed during both intervals of the Mesozoic Era. This general setting would have favored the development of large populations of dinosaurs and other terrestrial vertebrates and, ultimately, the preservation of their remains as fossils. And yet, in the 40 years since the Cedar Mountain Formation was defined, it has come to be regarded as notoriously unfossiliferous. Only a small handful of vertebrate fossils have been described from this unit and most of these are fragmentary and so poorly preserved as to be difficult to identify with precision (see Figure 1, Table 1).

Because of its early Cretaceous age, the Cedar Mountain Formation is exciting to paleontologists as a potential solution to the "faunal gap" mystery, but it has proven to be a historical disappointment. Why? The answer, it now seems, is that perhaps few people bothered to look for the clues in the right places. Deterred by the dazzling abundance of dinosaur bones in the underlying Morrison Formation, the Cedar Mountain has been overlooked as a source of information on the later history of dinosaurs in the Colorado Plateau. Overlooked, that is, until recently. During the past three years, the Utah Museum of Natural History has been actively excavating a new dinosaur locality, known as the Long Walk Quarry, in the lower Cedar

DINOSAURS OF THE CEDAR MOUNTAIN FORMATION

Order Saurischia

Suborder Theropoda

Infraorder Deinonychosauria

Deinonychid theropod (Bakker, pers. comm., 1988)

"small theropod(s)" (Nelson & Crooks, 1987)

Infraorder Carnosauria

Acrocanthosaurus(?)

Suborder Sauropodamorpha

Family Brachiosauridae/Titanosauridae

Pleurocoelus

Order Ornithischia

Family Iguanodontidae

(?)*Iguanodon* (Galton & Jensen, 1979)

Tenontosaurus (Weishampel & Weishampel, 1983)

Family Nodosauridae

Hoplitosaurus? (Bodily, 1969)

Table 1. Dinosaurs reported from the Cedar Mountain Formation. Note that nearly all of these identifications are either questioned or very general. Acrocanthosaurs and Pleurocoelus *(in bold) are from the Long Walk Quarry, making it the most productive of any site thus far discovered in the Cedar Mountain Formation.*

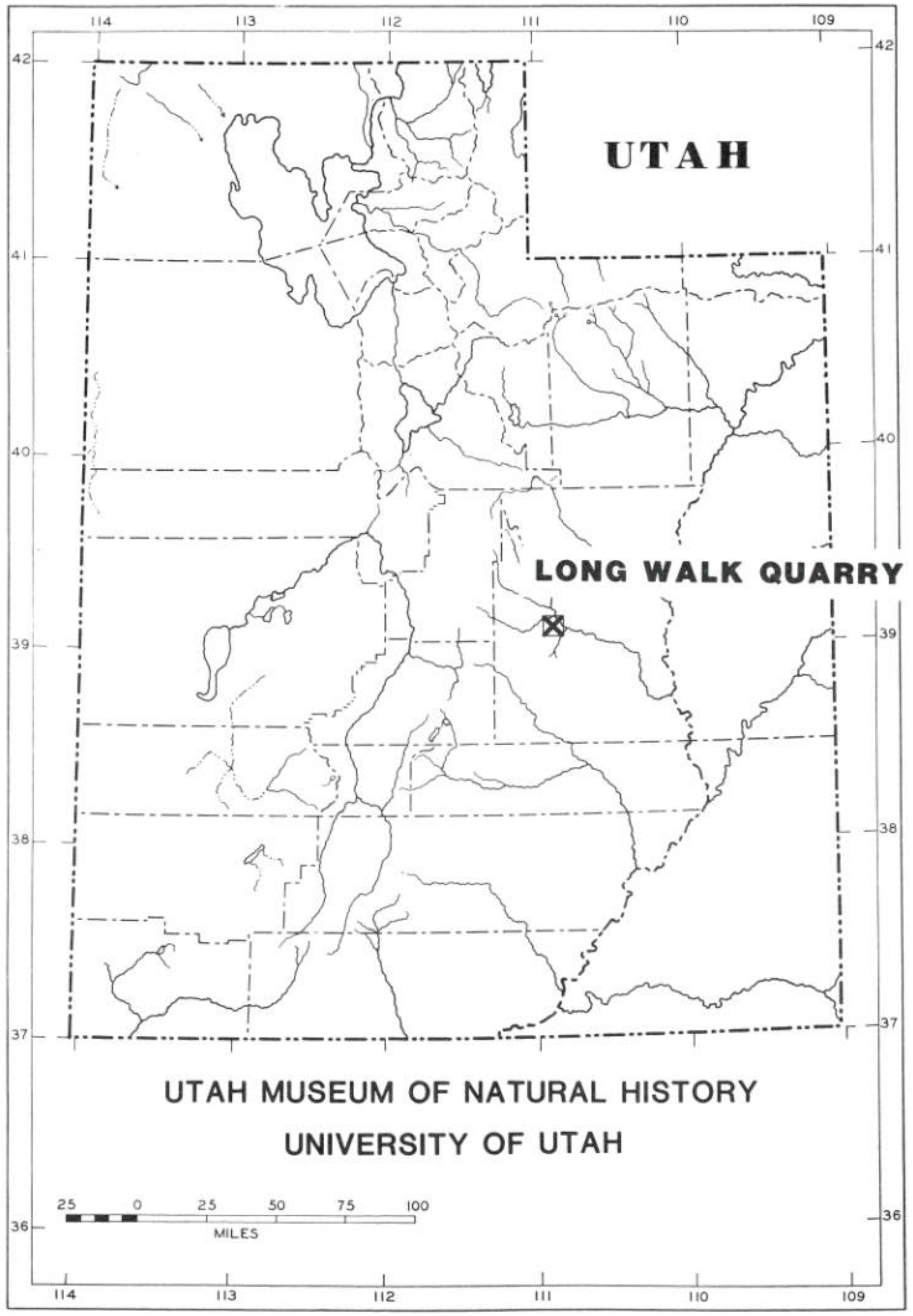


Figure 2. Index map to the location of Long Walk Quarry, Emery County, Utah.

Mountain Formation. Located southeast of Castle Dale, Utah (Figure 2), this new site has already produced the remains of two dinosaur species never before documented in Utah. Potentially, when the bone bed is fully excavated as many as 5,000 bones may be recovered from a rock unit that has heretofore produced not much more than a shoebox full of fragmentary remains.

THE LONG WALK QUARRY

Finding fossils of any kind in the Cedar Mountain Formation has never been easy. In fact, in the 40 years since this formation was formally separated from the Morrison Formation, only a few dinosaurs (and other types of fossils) have been identified (see Table 1). All of the dinosaurs thus far recognized in the Cedar Mountain Formation are based on extremely fragmentary material. The "(?)*Iguanodon*" reported by Galton and Jensen (1979), for example, is based on a single, very small, part of the upper jaw bone. [In addition, it is not absolutely certain that this material even came from the Cedar Mountain Formation, because the bone fragment was found in an area where it is difficult to separate those strata from the Morrison beneath it.] Similarly, the reports of such dinosaurs as *Hoplitosaurus*, "deinonychid theropods," and *Tenontosaurus* are based on very scrappy and isolated fossil material.

We simply don't know very much about lower Cretaceous dinosaurs in the Colorado Plateau and what we do know is not very well documented. For this reason, when reports of abundant dinosaur bones weathering out of what was thought to be the Cedar Mountain Formation reached the Utah Museum of Natural History in 1986, it generated great excitement. Preparator Glen Ungerman, who learned of the site from Mr. Carlyle Jones of Castle Dale, led Frank DeCourten and Ray Davis to the site in the fall of 1986. After determining that the bone-bearing horizon was indeed located in the Cedar Mountain Formation, about 15 meters (48 feet) above the uppermost beds of the Morrison Formation, the Museum decided to organize an excavation project. With funding from the National Geographic Society, Utah Power and Light Company (owners of the land adjacent to the quarry), and several private contributors, excavation work has been undertaken continuously for the past three summers.

Twenty-five large blocks of bone-bearing limestone have thus far been quarried and are presently being prepared in the UMNH Paleontology Laboratory. The unyielding nature of the enclosing rock and the fragility of the fossil bones makes this stage of the work extremely difficult and time-consuming, but some exciting new material has already been recovered. Little-by- little, bone-by-bone, a new view of the mysterious early Cretaceous dinosaur community of the Colorado Plateau is beginning to unfold.

The most abundant and distinctive bones recovered thus far from the Long Walk Quarry are those of the small sauropod *Pleurocoelus*, heretofore unknown in the Colorado Plateau. This dinosaur is somewhat similar to the late Jurassic *Camarasaurus*, but was smaller (only about 20 feet long) and has vertebrae characterized by very deep lateral cavities ('Pleurocoelus'...the basis for the genus name). The osteology of *Pleurocoelus* is not well established and, even though fragmentary remains have been found in Maryland, Texas, Oklahoma, and Montana, it remains one of the least understood dinosaurs. The Long Walk Quarry has produced several different vertebrae, ribs, limb elements, teeth, and a partial jaw, which ultimately may allow a better perception of the anatomy and relationships of this dinosaur. In addition, the Long Walk Quarry *Pleurocoelus* is especially significant because it will eventually help address the question of why we see such a decline in the diversity and abundance of sauropod dinosaurs after their 'golden age' in the late Jurassic.

Pleurocoelus is not the only dinosaur represented at the Long Walk Quarry. Two nearly complete large teeth (along with some smaller fragments) that belong to an entirely different dinosaur have been discovered. As much as 12 cm (4') in size with jagged serrated edges, these teeth are those of a large carnivorous dinosaur. No large dinosaur predators have previously been identified from the early Cretaceous of the Colorado Plateau and so these teeth are as important as the *Pleurocoelus* remains and for the same reasons. Currently, it is not possible to identify the owner of the teeth with precision, but a good candidate seems to be a dinosaur like *Acrocanthosaurus*, known previously only from Texas and Oklahoma.

The main problem in identifying the Long Walk Quarry specimens is that the material used to originally establish and define *Acrocanthosaurus* (Stovall and Lanston, 1952) did not include any teeth. No one knows for sure what kind of teeth this predator had, but it did live in Texas about the same time the Long Walk Quarry sediments were deposited in Utah, was about the same size, and almost certainly had teeth of the same general form. For now, we can only refer to this dinosaur as *Acrocanthosaurus(?)*. As more material is excavated and prepared from the Long Walk Quarry, this large predator may prove to be something completely new to science.

There are several other tantalizing hints that the Long Walk Quarry may produce some additional exciting discoveries in the near future. An ilium (hip blade) has also been excavated that definitely belongs to a carnivorous dinosaur (a "theropod," in the language of the paleontologists), but it is far too small to belong to the *Acrocanthosaurus(?)*. Consequently, we know that there is at least one other, smaller, meat-eater represented at the site, but until the bone is fully prepared and more material from this

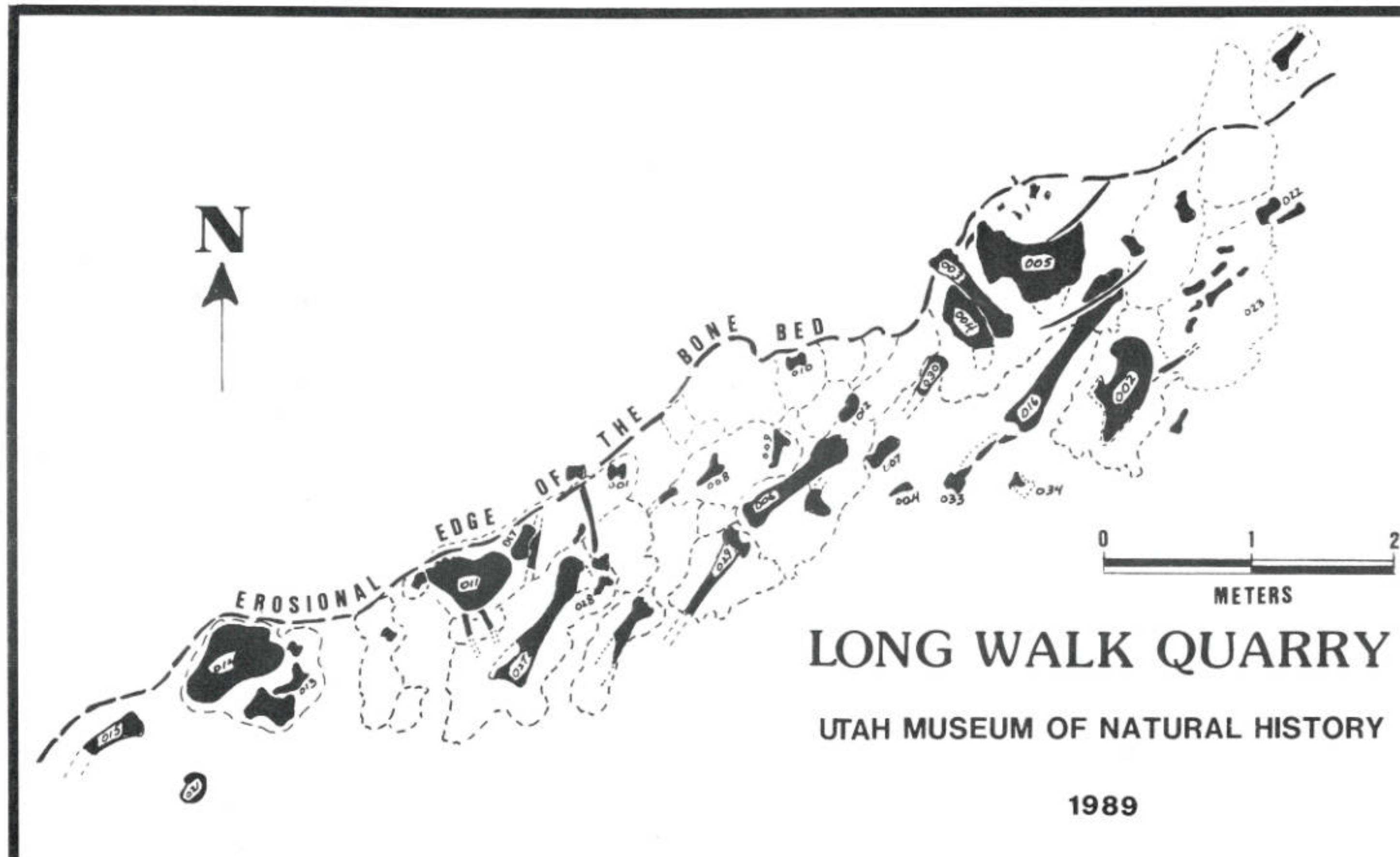


Figure 3. Detailed map of Long Walk Quarry. Only the larger bones are numbered and many more small elements are present that cannot be included on a map of this scale. The dashed lines represent the approximate limits of the twenty-five blocks that have thus far been quarried.

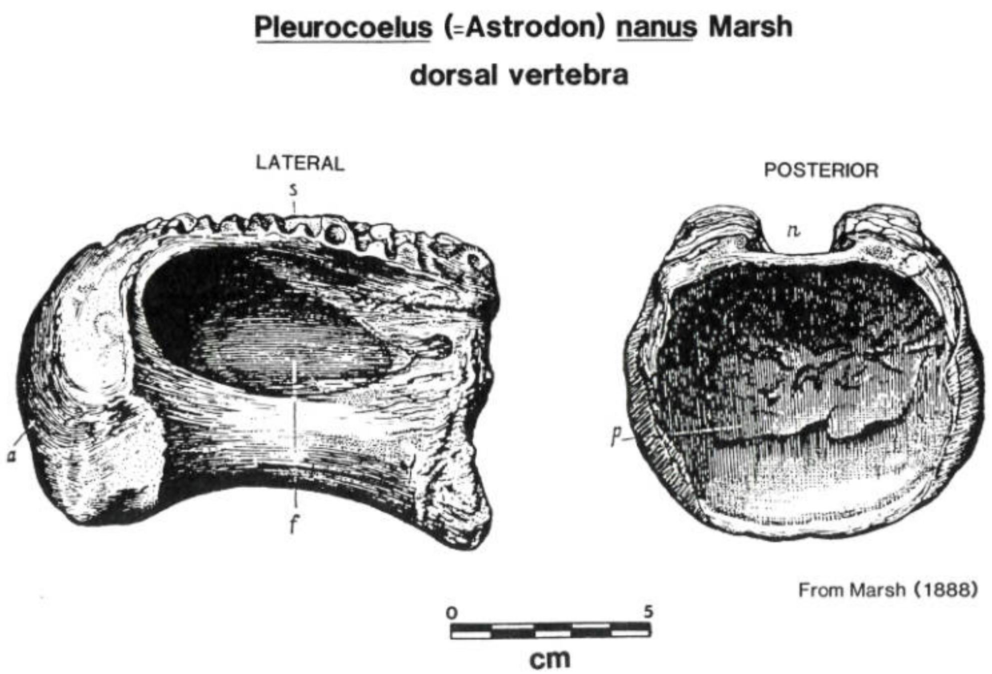


Figure 4. Sketch of a dorsal vertebra of Pleurocoelus from Marsh's original description in 1888. Compare this Maryland specimen with the Long Walk Quarry material in photo below.

specimen recovered, its identity will remain a mystery. In addition, the *Pleurocoelus* teeth thus far recovered have two distinct shapes and sizes: 1) a large, slightly flattened form, and 2) smaller, more conical, and gently curved types. Are two individuals, male and female or young and old, represented at the quarry? Or, did *Pleurocoelus* have different kinds of teeth in different places in the jaw? The answers to these questions will require the analysis of additional material and, in this early stage of the development of the Long Walk Quarry, they continue to elude us.

A JUMBLE OF BONES

The bone bed at the Long Walk Quarry is a nodular limestone layer, about 18' thick, sandwiched between thicker units of calcareous mudstone. This very hard host rock makes quarrying the individual bones impossible and necessitates the removal of large blocks of the rock matrix, which most often contain many different fossil bones. The map of the excavated portion of the bone bed (Figure 3) reveals a rather chaotic arrangements of fossils. There are no skeletons at the Long Walk Quarry, but instead individual bones are packed closely together without any direct anatomical association between adjacent elements. Limb bones are found next to jaw bones, which in turn may rest in close proximity to ribs. This implies that the Long Walk site was not the place the dinosaurs laid their several tons to permanent rest. Instead, the concentration of dinosaur remains in the bone bed is the probable result of transportation of skeletal material to a point of accumulation after some limited decomposition and decay of the carcasses.

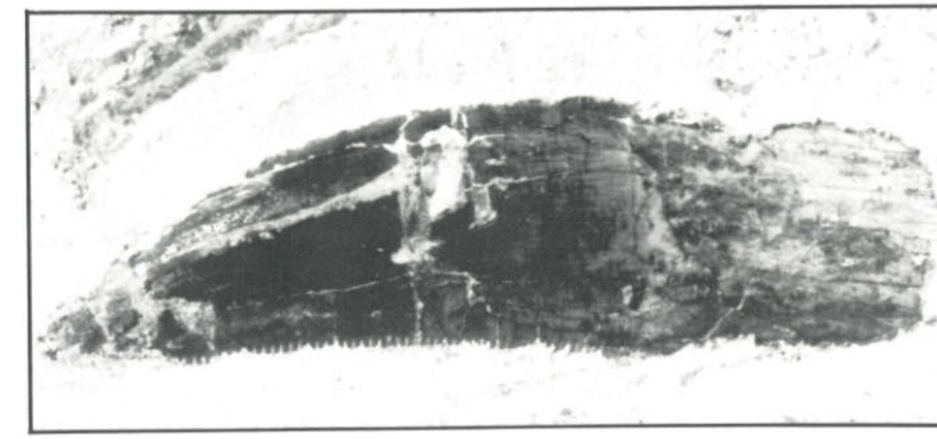
There are other indications of preburial weathering of the bones. Many of the fossils, once they are completely freed of the limestone matrix, exhibit small fractures in the outer laminar bone surface that are filled with the same limestone that originally enclosed them. This suggests that the outer surface of the bones had already cracked under the influence of the elements before burial and limestone deposition took place. Some, but certainly not all, of the bones from the Long Walk Quarry also show abraded ends and surfaces that were most likely produced during the transport of the bones to the point of accumulation.

The nodular limestone bone bed most probably represents a well-developed "hardpan" of caliche, a calcium carbonate crust that develops in the soils of warm, semi-arid to arid regions. The mudstones above and below the limestone bone bed are typical of the fine-grained silt and clay that is deposited on low floodplains adjacent to sluggish rivers. There are some beautiful lenticular sandstones, weaving back and forth across the hilly terrain like a rocky ribbon, within the mudstones exposed at the Long Walk Quarry. These no doubt represent the sand and gravel washed along in the meandering channels of an ancient river system flowing from the west. It is clear that the sediments of the Cedar Mountain Formation in the vicinity of the Long Walk Quarry represent a variety of different types of sediment transported and deposited by a large, complex river system.

Lateral view of the main part (centrum) of a dorsal vertebra of pleurocoelus from the Long Walk Quarry. Note the deep cavity (pleurocoel) in the side of the vertebra and the wrinkled upper surface where the neural spine attached.

What about the bones? How did they become concentrated and preserved in this setting? A preliminary interpretation of the geologic evidence, coupled with observations of the details of the bone preservation, allows the formulation of the following theoretical, but nonetheless plausible, scenario: *Pleurocoelus* and the other dinosaurs probably died on the low floodplains adjacent to river channels. Since nodular caliche forms most readily in warm regions, and in view of the great abundance of this material in the Cedar Mountain Formation, we may further postulate a warm, dry climate for the area. Perhaps the death of these dinosaurs was related to a persistent or seasonal drought. As the soft tissues of the dinosaur carcasses, decayed the skeletons were exposed to the sun, weather, scavengers, and other agents of physical decomposition. Then, before the bleached and drying bones were completely reduced to splinters and dust, the rains came. The dry river channels filled to capacity before the water ultimately rose above the banks to surge out across the nearly flat floodplains. The flood washed, rolled, and tumbled the partly decomposed bones to the lowest point on the floodplain where the mixture of water, mud, and bones came to rest. The floodwaters then receded as the rains passed and dry conditions returned to the region. As the ponded floodwater began to evaporate, calcium carbonate was precipitated around the jumble of bones. Later, subsequent floods washed more fine silt and mud over the accumulation of bones, eventually to harden into the mudstone above the bone bed.

Over 50 million years passed before geologic forces began to elevate the San Rafael Swell and a comparably long period of erosion was required to wear away the overlying rocks. Eventually the layers above the bone bed were completely removed and the nodular limestone was exposed along the flanks of a small hill. The weathering of the bones, begun in the early Cretaceous but arrested by the flood-related burial, resumed in the very recent geologic past as the fossils were once again exposed to the elements and bone fragments began to litter the surface. Enter, at that point, Mr. Jones, Mr. Ungerman, and the Utah Museum of Natural History.



A large tooth from a carnivorous dinosaur, probably similar to Acrocantosaurus, from the Long Walk Quarry. This tooth is over 4 inches long, much larger than an average tooth from Allosaurus, the most common dinosaur predator from the Morrison Formation of late Jurassic age.

THE FUTURE OF THE LONG WALK QUARRY

In vertebrate paleontology, and particularly in dinosaur paleontology, new data comes very slowly. Even after the bones are excavated, it may take months (or years, depending on funding!) to work the material through the meticulous process of cleaning the hard matrix from the fossils in the laboratory. Even then, a lengthy analysis and comparative study of bone is required. If the fossil material is new to science or so rare that little comparative material exists, further delays can be anticipated. All of these factors apply to the Long Walk Quarry project.

The Long Walk Quarry has the potential to become the most significant early Cretaceous dinosaur locality in western North America and one of the most important sites of this age in the world. The bone-producing horizon can be traced around three sides of a small hill and, assuming subsurface continuity, it is estimated that at least 500 square meters could be exposed by removing the 6 meters of overlying mudstone. So far, in three seasons of field work, only about 15 square meters (3%!) of the bone-bed has been excavated; even less has currently been completely prepared in the lab. At current levels of effort, the Long Walk Quarry will be fully developed sometime in the mid 21st Century. If this sounds excessively slow, bear in mind that the first dinosaur bones were collected From Dinosaur National Monument in 1909 and organized collecting at the Cleveland-Lloyd Quarry began in the 1930s. Both sites are still producing new fossils and neither has reached its full potential as a source of information on Utah dinosaurs and the world they occupied.

On the basis of the density of bones in the blocks collected from the Long Walk Quarry thus far, it can be conservatively estimated that at least 5000 elements may ultimately be recovered from the site. In view of the extreme scarcity of early Cretaceous dinosaur fossils from the Colorado Plateau, the Utah Museum of Natural History remains committed to the on-going work at the locality. The scientific potential of the Long Walk Quarry is far too great to leave untapped, no matter how difficult, costly, or time-consuming the work becomes. In partnership with the current and future project sponsors, numerous volunteers, local residents, and professional colleagues, the Museum will coordinate work at the site for years to come. The Long Walk Quarry will continue to yield information necessary for a more complete understanding of our natural heritage and the world around us. That, in the final analysis, is the ultimate goal of all science.

ACKNOWLEDGMENTS

The work at Long Walk Quarry by

UMNH Research Associate Ray Davis at Long Walk Quarry in the summer of 1989. The plaster-encased blocks are removed along natural fractures in the limestone bone bed.

the Utah Museum of Natural History has been a team effort since the first visit in 1986. Ray Davis, Preparator and Research Associate, has overseen most of the actual field operations and performed nearly all of the meticulous preparation of the delicate fossils. The site was first brought to the attention of Museum paleontologist Glen Ungerman, Senior Preparator. Many volunteers have provided additional service throughout the project and, in particular, the efforts of John Akens, Harmon King and Nelda King are gratefully acknowledged. UMNH Director Donald Hague has consistently supported our research activities at the site. Funding for this project has been provided by the National Geographic Society, Utah Power and Light Company, and private contributors. Jon Judd, Wick Huntington, and many other residents of Castle Dale have been wonderfully supportive of our work and have been a delight to work with throughout the project.

(This article represents UMNH Contribution 90-1.)

REFERENCES

Bodily, N.M. (1969) "An Armored Dinosaur from the Lower Cretaceous of Utah," *Brigham Young University Geology Studies,* v. 16, p. 35-60.

Galton, P.M. and J.A. Jensen (1979) "Remains of Ornithopod Dinosaurs from the Lower Cretaceous of North America," *Nature,* v. 257 p. 668-669.

Marsh, O.C. (1888) Notice of a new genus of Sauropoda and other new dinosaurs from the Potomac Formation: *American Journal of Science,* (3)35, p. 85-94.

Nelson, M.E. and D.M. Crooks (1987) "Stratigraphy and Paleontology of the Cedar Mountain Formation (Lower Cretaceous), Eastern Emery County, Utah," *Paleontology and Geology of the Dinosaur Triangle: Museum of Western Colorado,* Grand Junction, p. 55-63.

Stokes, W.L. (1944) "Morrison and Related Deposits in and Adjacent to the Colorado Plateau," *Geological Society of America Bulletin,* v. 55, p. 951-992.

—————————— (1952) "Lower Cretaceous in the Colorado Plateau," *American Association of Petroleum Geologists Bulletin,* v. 36(9), p. 1766-1776.

Stovall, J.W. and W. Langston, Jr. (1950) *"Acrocanthosaurus atokensis,* a New Genus and Species of Lower Cretaceous Theropoda from Oklahoma," *The American Midland Naturalist,* v.43(3), p. 696-728.

Weishampel, D.B. and J.B. Weishampel (1983) "Annotated Localities of Ornithopod Dinosaurs: Implications to Mesozoic Paleobiology: Mosasaur," v.1, p. 43-87.

* * *

ABOUT THE AUTHOR

Frank L. DeCourten is a Professor of Geology and Geophysics at the University of Utah, and is Assistant Director and Adjunct Associate with the Utah Museum of Natural History. During the summer, Frank divides his time between field work at Long Walk Quarry and administrative duties at the Museum.

Frank DeCourten and John Akens preparing plaster to coat a bone block. Photo by Jean Akens

YOU CAN CALL HIM "AL"
Allosaurus and the Cleveland-Lloyd Quarry

by Richard M. Warnick

GENERAL INFORMATION

Emery County, Utah--150 million years ago. It is not hard to imagine him lurking in the shadows at the edge of the forest, perhaps camouflaged with the "tiger stripes" of a modern artist's conception, fixing his fierce eye upon a herd of camarasaurs and thinking, as predators so often do, about the next meal...

Visitors to the Cleveland-Lloyd Dinosaur Quarry, the College of Eastern Utah Prehistoric Museum and other attractions in the "Dinosaur Triangle" often get the short version about *Allosaurus fragilis,* Utah's state fossil. There's plenty more to tell, some of it still a subject of ongoing research.

So little of what we "know" about dinosaurs comes from direct observation that some guesswork is always needed to form an idea of what they may have been like. Allosaurus bone fossils are relatively abundant, especially for a meat-eating theropod. Yet vertebrate paleontologists are still trying to answer some basic questions concerning these late Jurassic Period predators from the Morrison formation.

Probable relatives of Utah's alloaurus have been unearthed on six continents in strata that roughly correspond with the approximately 150 million-year-old Morrison. One of these is the megalosaurus, the first dinosaur identified as such in a scientific publication. Its bones and huge, bladelike teeth came from a slate quarry near Oxford, England in the 1820s.[1]

The first identifiable allosaurus bone was collected by the Hayden Survey in 1869 and brought to Joseph Leidy in Philadelphia. It almost certainly came from the Morrison formation, the source of all other such finds, but the site is unknown. Leidy coined the genus and species *"Antrodemus valens;"* some museums still use this name.

Othneil Charles Marsh, who is responsible for naming most of the Morrison fauna, first used *"Allosaurus fragilis"* to describe some fossils excavated at the Garden Park quarry in Colorado in 1877. A nearly complete skeleton was found six years later at the same site, making a "paratype" better than the first specimen.[2] Allosaurs appeared again at Como Bluff, Wyoming in 1879, where Marsh and his assistants faced competition from rival paleontologist Edward Drinker Cope, who had been part of the Hayden Survey.

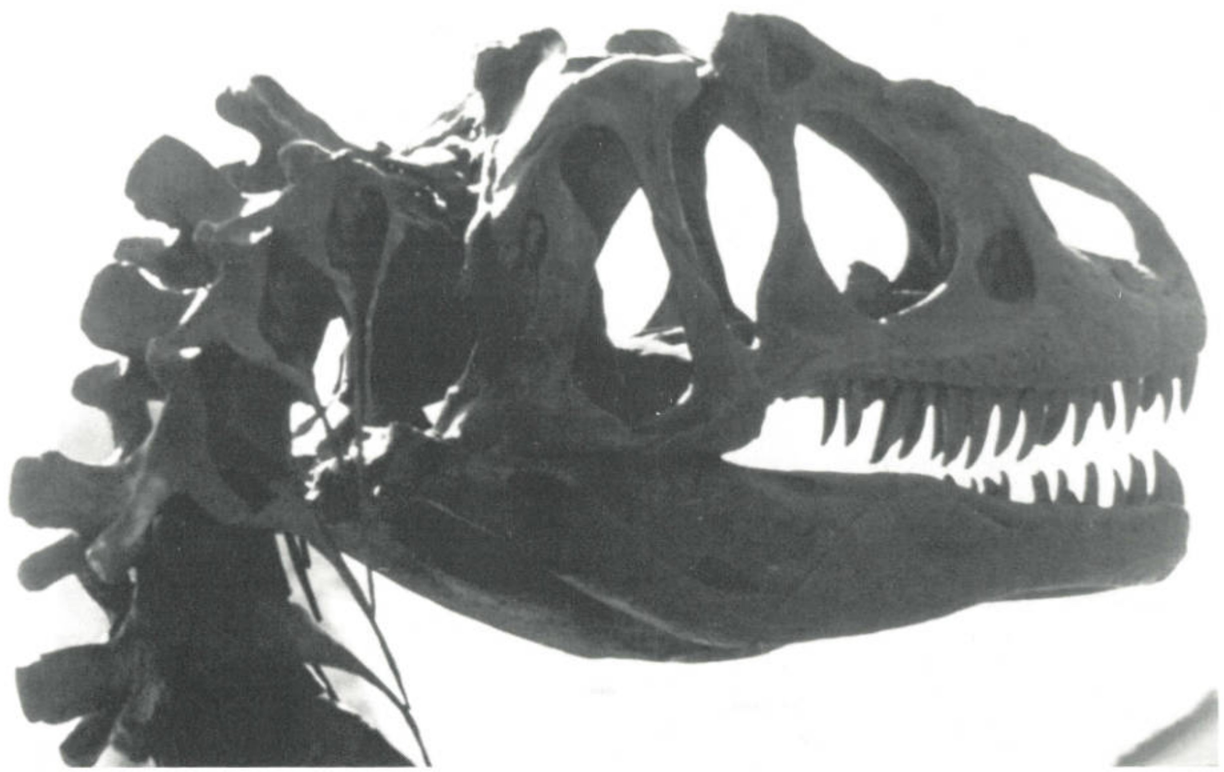
Marsh confused the name issue, as he did with several dinosaurs, by also using *"Allosaurus atrox."* This is how the mounted skeletons at the American Museum of Natural History and at the Smithsonian are identified. Recently Robert Bakker and Gregory Paul have suggested using the "atrox" name for allosaurus skeletons with a somewhat elongated skull, which they believe ought to be set aside as a separate species. If this controversial change were more widely adopted, Utah's state fossil would be *A. atrox,* although Bakker favors *"Creosaurus atrox."*[3]

The only intact allosaurus skull was found at Dinosaur National Monument by the University of Utah in 1924, and today is on display at the monument. This was a unique discovery because allosaurs have an articulated skull that apparently was capable of widening as the jaws opened (snakes can do the same thing) and it consisted of some fifty bones. In most cases these skull pieces came apart and became scattered.[4]

CLEVELAND-LLOYD DINOSAUR QUARRY

The most important allosaurus treasure-trove, and one that is still capable of providing surprising new information, is the Cleveland-Lloyd quarry south of Price in Emery County. The quarry began as a natural outcropping of fossils embedded in mudstone, lost in the rolling Morrison terrain of Cow Flat. No one can agree on exactly who first reported these dinosaur bones, but the first scientific interest came in 1929 in the person of Golden York, working under the direction of Dr. Frederick J. Peck for the University of Utah.

William Lee Stokes, who visited the 1929 dig on horseback from his home in nearby Cleveland, came back during 1940-41 as a geologist to dig about 2500 bones for Princeton University. Philanthropist Malcolm Lloyd, Jr. financed operations those two summers and his name has been attached to the quarry ever since. The culmination



An Allosaurus skull.

of the project came much later when an allosaurus skeleton, nicknamed "Malcolm," was unveiled in the Guyot Hall Museum in 1961.[5]

By this stage it was clear that the vast majority of bones belonged to *Allosaurus fragilis*. Eventually, about 50 different allosaurs were identified, mixed in with at least ten other species. The site had been a late Jurassic bog or intermittent lake that must have acted as a predator trap.

The quarry was reopened in 1960-65 for what became known as the University of Utah Cooperative Dinosaur Project. Stokes (who by this time was the chairman of the Department of Geology at the U. of U, along with James H. Madsen, Jr.), succeeded in making the dig pay for itself by providing dinosaur skeletons (consisting in large part of plaster cast bones) to some 40 museums around the world. As a result, the allosaurus is the world's most widely exhibited dinosaur.

In Utah, "Al" can be seen at Cleveland-Lloyd itself, in Castle Dale, Price, Salt Lake City, Ogden and at Dinosaur National Monument. Grand Junction, Colorado, also part of the "Dinosaur Triangle," has an allosaurus on display at the Dinosaur Valley exhibit.

Some 10,000 bone fossils were excavated at Cleveland-Lloyd in the 1960s and the Princeton collection was returned to Utah (except for "Malcolm"). As a result, there exists a large study collection, some two-thirds of which consists of allosaurus bones. This relative abundance has provided paleontologists with the material to study the growth of allosaurs from juvenile to adult, and even some pathological specimens (examples of fractured and cancerous bones). Some of the stegosaur and camarasaur bones display teeth marks from an allosaurus, showing that "Al" was indeed a meat-eater.

In 1968 Cleveland-Lloyd Dinosaur Quarry became a national landmark administered by the U.S. Department of the Interior, Bureau of Land Management. There is a visitor center open to the public on weekends from Easter to Memorial Day, and Thursday through Monday from Memorial Day until Labor Day. Hours are 10:00 a.m. to 5:00 p.m. Excavation of the bone bed has continued on an occasional basis, in recent years by the Brigham Young University Earth Science Museum.

IN SEARCH OF THE LIVING ALLOSAURUS

One of the most unusual dinosaur fossils ever uncovered in Utah appeared one day in September 1987 as BYU fossil preparator Dee Hall worked at Cleveland-Lloyd. He picked up an oval-shaped lump of gray rock, not too different from hundreds that had been tossed onto the spoil heap in the process of exposing the petrified bones that lie thickly scattered in the quarry. But this one seemed to resemble an egg about four inches long, a dinosaur egg where nothing of the sort had been found in all the years of digging.

Could it be an allosaurus egg? CAT-scans of the interior revealed an embryo in a very early stage of development, not enough evidence to answer the question with more than a "maybe." Study of the microscopic structure of the eggshell has shown it to

be unlike that of the sauropod dinosaurs, but more evidence is being sought.

The muddy environment of the Cleveland-Lloyd predator trap was completely unlike the high and dry nesting sites that appear to be the normal choice for dinosaurs. Karl F. Hirsch of the University of Colorado Museum has theorized that the slightly squashed condition of the fossil egg means it was never laid. There is additional evidence for this view in the fact that the shell acquired several distinct layers, as the retained eggs of present-day reptiles often do.[6]

If we are unsure how allosaurus reproduced, there are even more mysteries surrounding their place in the Morrison fauna. We want to know what they did for a living, ecologically speaking. Here we are helped by the nature of the Morrison formation, whose sediments were laid down over millions of years by rivers and streams. These changed course often, leaving buried sandbars (such as the Dinosaur National Monument quarry) and oxbow lakes (the probable origin of the Cleveland-Lloyd quarry). The sandbar-type sites contain dinosaurs whose remains were swept down the stream during a flood, producing a somewhat random sample from a wide area. The lake or bog sites seem to have preserved a skeletal accumulation from dinosaurs inhabiting that vicinity.

Altogether, the Morrison represents the largest sample of dinosaurs known from a single sedimentary unit. These range from the tiny nanosaurus (weight 1.5 lbs., length 1.5 feet) to the immense ultrasaurus (weight approximately 100 tons, length about 100 feet). The largest plant-eaters appear to have evolved into their most spectacular size by the time the uppermost Morrison beds were deposited.

Using a statistical model based on the fauna of the Amboseli Basin in Kenya, Africa, Dale Russell of the National Museum of Natural Sciences in Ottawa, Canada, has tried to approximate a census of Morrison species. He computed an average density of 33 herbivorous dinosaurs per square mile, along with 5 allosaurs plus a variety of smaller carnivores. Russell's estimate, which excludes the Cleveland-Lloyd quarry as an unusual occurrence, is that 10 percent of all the dinosaurs of the Morrison Basin belonged to the genus Allosaurus.[7] Obviously, this would have indicated a high population of predators compared to the 5 percent or less we see in mammal ecological models. Russell points out that his predator/prey ratio would work, however, if the Morrison dinosaurs possessed a lower-energy, reptilian metabolism.

Robert T. Bakker of the University of Colorado takes the opposite view, that allosaurs had a warm-blooded and very active physiology. He has found ratios in the Morrison fossil evidence to indicate that 10 percent would be the upper limit for allosaurs, with 1.5 percent what he considers to be average.[8]

Others have attempted to resolve the question of "warm-blooded versus cold-blooded" allosaurs by analyzing bone cross-sections. The better-preserved dinosaur bones reveal details of the interior cell structure, so it is possible to trace such features as growth rings, which are more numerous in cold-blooded animals, and Haversian canals, found more often in warm-blooded animals. The "canals" are long cylinders, pointed at both ends, where bone material had been dissolved and then re-deposited in

Camarasaurus pelvis, showing bite marks; Cleveland-Lloyd Dinosaur Quarry. Courtesy of the Bureau of Land Management.

concentric layers, a trait associated with most mammals and certain dinosaurs. Armand de Ricqles and others have used Cleveland-Lloyd specimens to study bone texture, which in general seems consistent with fast-growing, high metabolism dinosaurs.[9]

The hunting strategy of the allosaurus is yet another intriguing aspect of Utah's dinosaur. How could a typical 2-ton allosaurus attack and kill a 20-ton brontosaurus? (Do we know he did? Example needed here.) For a long time, the conventional wisdom said that allosaurs and other large carnivores lived by scavenging carcasses and stealing the prey of smaller predators. More recently, some paleontologists have suggested that pack-hunting would have been a successful strategy, albeit one that presupposes a warm-blooded physiology.

Studies of pack-hunters such as wolves have revealed their ability to kill much larger animals, even the musk-ox that defends itself in herds not unlike those of the Jurassic sauropods. It is not difficult to imagine the terrific concentration of allosaurus remains at Cleveland-Lloyd to be evidence of pack behavior.

What happened when the Morrison's big plant-eaters evolved into the forms of supersaurus, ultrasaurus and seismosaurus, to name a few of the ever-larger sauropods we find near the top of the formation? This comparatively sudden jump in size is an example of what evolutionary theorists call "punctuated equilibrium." After a long settled period of ecological stability, some change in the environment prompts an upheaval resulting in new species that then appear in the fossil record.

The answer was the new, improved allosaurus--A. amplexus, or as Bakker has proposed, Empanterias amplexus. Some 30 million years before the Tyrannosaurus, there evolved an allosaur so big that the first of its bones were mistakenly catalogued as brontosaur remains! A new find in Colorado indicates this monster was 50 feet long and weighed 4 tons, compared to the 30 foot, 2 ton A. fragilis.[10]

Despite the unsolved mysteries of the allosaurus, artists are bringing these dinosaurs to life. New paintings and sculpture are appearing all the time, and even animated scale models. Such details as coloration and skin texture are speculative and derive from the artist's imagination and analogies with better-known animals, but the basic musculature can be recreated with great precision from the skeleton outward. The depiction of such activities as hunting and social behavior of the allosaurus owe a lot to guesswork, but these attempts help our imagination to go beyond the "bare bones" of the quarries. Now we can see "Al" as a living, breathing and majestic creature even as we try to piece together a better understanding.

NOTES

1. Wilford, John Noble, p. 34-35.
2. Paul, Gregory S., p. 309-310.
3. Paul, p. 311.
4. Bakker, Robert T., p. 265-267.
5. Stokes, William Lee, p. 265-267.
6. Hirsch, Karl F., p. 1713.
7. Russell, Dale A., p. 87
8. Bakker, p. 258 and 391.
9. Bakker, p. 350-360.
10. The New York Times, 1-7-90.

FURTHER READING

Bakker, Robert T. *The Dinosaur Heresies.* William Morrow & Company, New York, 1986.

Hirsch, Karl F. et al. "Upper Jurassic Dinosaur Egg from Utah." *Science,* March 31, 1989, vol. 243 pp. 1711-1713.

Lambert, David. *A Field Guide to Dinosaurs.* Avon Books, New York, 1983.

Madsen, James H. *Allosaurus Fragilis: A Revised Osteology.* -------------. "The Dinosaur Department Store" in *Guide to the Dinosaur Triangle.* Grand Junction, 1987.

Paul, Gregory S. *Predatory Dinosaurs of the World.* New York Academy of Sciences, New York, 1989.

Russell, Dale A. *An Odyssey in Time: The Dinosaurs of North America.* University of Toronto Press, Toronto, 1989.

Stokes, William Lee *Window to the Past: The Cleveland-LLoyd Dinosaur Quarry.* U.S. Government Printing Office, 1985.

Wilford, John Noble. *The Riddle of the Dinosaur.* Knopf, New York, 1985.

ABOUT THE AUTHOR

Rick Warnick, originally from New York City, spent three summers as a ranger with the Bureau of Land Management at the Cleveland-Lloyd Quarry south of Price, where he also volunteered many hours of work without pay. Warnick, who attended Georgetown University and Utah State University, has a background in Recreation and Resource Management. He also donated many volunteer hours at the College of Eastern Utah Prehistoric Museum.

Cleveland-Lloyd Quarry south of Price.
Courtesy of Bureau of Land Management.

College of Eastern Utah Prehistoric Museum

The College of Eastern Utah Prehistoric Museum in Price, Utah reopened its doors to the public on April 7, 1990 after closing in November 1989 to move to a new facility. The new "Hall of Dinosaurs" is complete and work continues on additional displays and programs.

Currently being remodeled, the old exhibit hall will house the "Hall of Man" exhibits, as well as a new classroom and curation offices. Expected completion date is in early 1991.

The main exhibit in the Hall of Dinosaurs is a set of four complete skeletons made up of fossil bones excavated at the Cleveland-Lloyd Quarry. A high percentage of bones on display are the original fossils and others are cast replicas.

These dinosaurs lived approximately 150 million years ago in a large river basin whose sediments make up the present-day Morrison formation. The basin was first-class dinosaur habitat, and the "Morrison Fauna" includes many of the best-known species of dinosaurs.

One of the dinosaurs on exhibit is the allosaurus, Utah's state fossil. It was a highly adapted predator, and the relative abundance of its fossil bones suggest that this sauropod may have hunted in packs. Several sets of allosaurus teeth marks have been found on the bones of other dinosaurs, including the museum's own camarasaurus.

The allosaurus on display--the museum mascot, nicknamed "Al"--is 22 feet long and 7 feet tall a the hips. It probably weighed 2 tons.

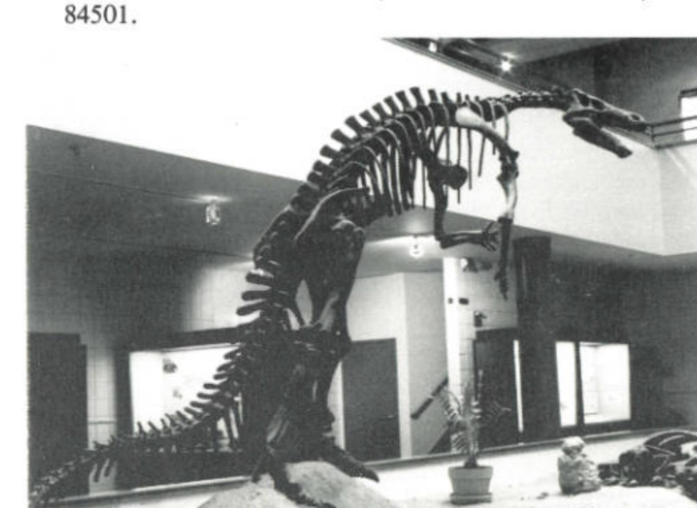
There is also a camptosaurus on exhibit. This species had a small beak and teeth suited for selective browsing in forest foliage. It most likely chewed vegetation well before swallowing. The neck of the camptosaurus is short but highly flexible. In feeding, this dinosaur may have often rested on its solidly constructed forelimbs. The one on display is 18 feet long and 5 feet tall at the hips. It weighed approximately 1 ton when alive.

The stegosaurus is one of the most readily recognizable dinosaurs because of its unique armor plates. These contained blood vessels and may have acted as radiators to control body temperature. The feeding habits of the stegosaurus may have been similar to the camptosaurus. The museum's specimen is 18 feet long and 7 feet tall at the hips. It most likely weighed 2 tons.

Camarasaurus is the most representative of the Morrison sauropod dinosaurs. Its feeding equipment was designed to strip foliage from tree branches. This probably was swallowed without chewing and ground up in a gizzard by stones ingested for this purpose. The camarasaurus skeleton on exhibit is 51 feet long and 9 feet tall at the hips. The living animal may have weighed 20 tons.

The museum has a recent addition to the dinosaur family. Upstairs in the new facility is the skeletal replica of a prosaurolophus, a Cretaceous Period dinosaur. Although this particular specimen comes from Canada, where there are complete skeletons, it represents the hadrosaurs (a family of dinosaurs with the duck-bill feature) that left tracks in local coal mines. A collection of dinosaur tracks, which may be the largest in the world, are displayed along with the prosaurolophus.

The CEU Prehistoric Museum invites everyone to come and see its dinosaurs. During the winter, it is open Monday through Saturday from 10:00 a.m. until 5:00 p.m. Between Memorial Day and Labor Day (approximatley) it is also open on Sundays. The museum is located on the north side of the Price Municipal Building. Highway signs direct visitors to the museum location. For more information or to schedule group tours, call (801) 637-5060 or write the College of Eastern Utah, Prehistoric Museum, 451 E. 400 N. Price, UT 84501.



A camptosaurus skeleton, CEU Prehistoric Museum.

QUATERNARY CORNER

Late Ice Age Extinctions: Whodunit?

by Janet L. McVickar

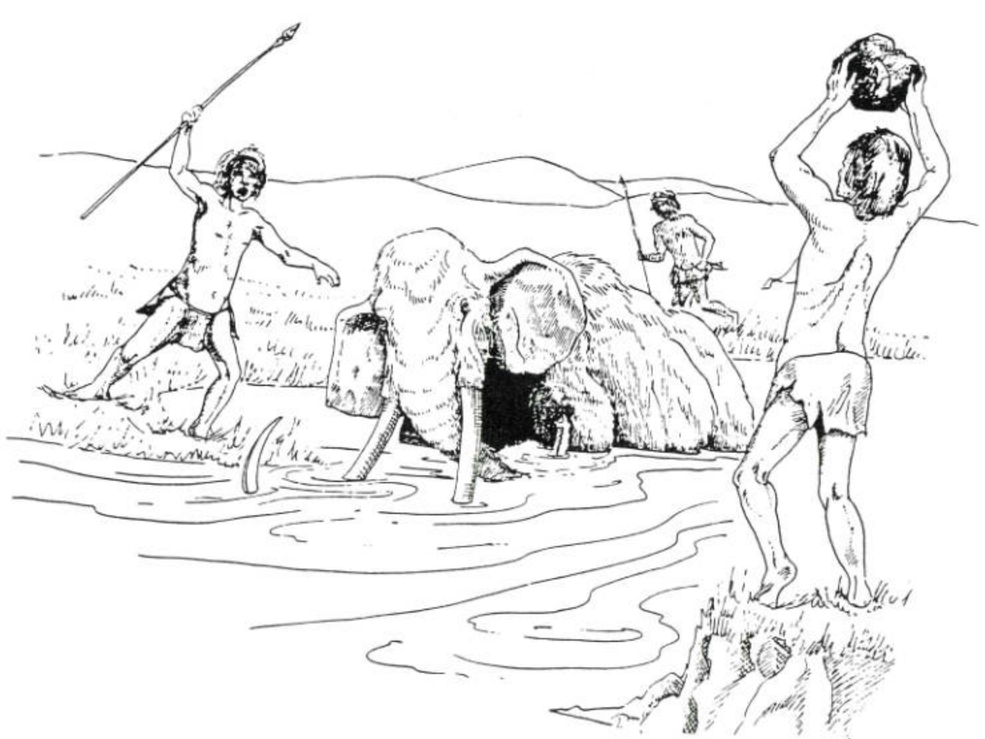
Twenty-three types of large Ice Ace animals, or megafauna, became extinct in North America around 11,000 years ago. These included mastodons, mammoths, cave bears and spectacled bears, sabertooth cats, and long-horned bison. What caused this massive extinction is still not known today. But the beginning of widespread human population in North America appears to have coincided with the extinctions. The simultaneous occurrence of these events led Paul S. Martin, paleontologist and editor of the book *"Quaternary Extinctions,"* to propose his controversial idea, known as the "overkill hypothesis," to explain the extinctions.

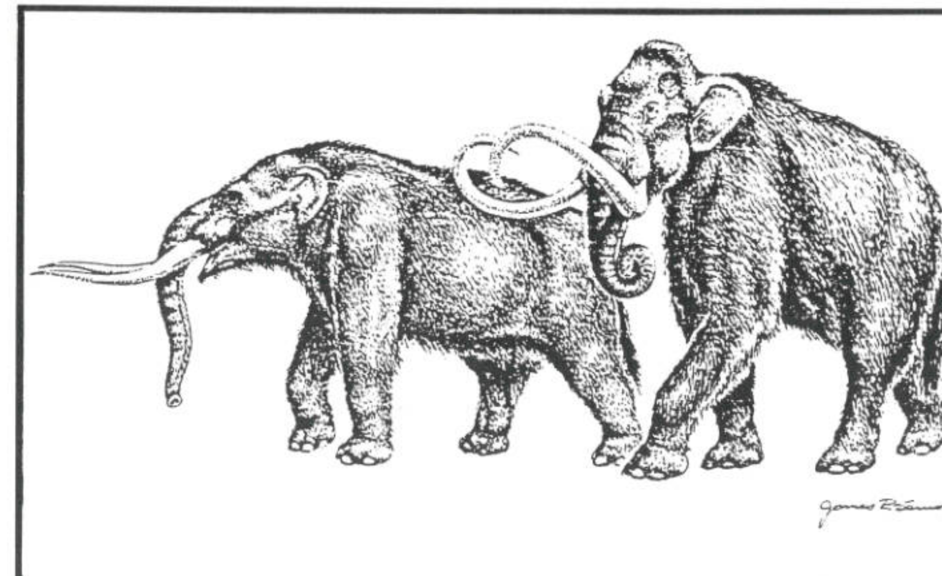
From careful scrutiny of radiocarbon dates and other types of data, Martin observed a widespread pattern of synchrony between the megafaunal extinctions and the influx of humans into North America. The apparent coincidence of these events led Martin to suggest that the extinctions had resulted directly from intensive hunting by humans. These large mammals had developed no defensive adaptation against humans as yet, and were extremely vulnerable to attack. Such intensive hunting of the animals would have caused a rapid and significant decrease in their populations, leading eventually to their demise. Martin's "overkill" idea has weathered the storm of controversy remarkably well over the last 23 years. Though many disagree with it, the concept remains essentially intact.

Paleontologist Larry G. Marshall, in *Quaternary Extinctions,* makes an irresistible comparison of the Ice Age extinctions controversy to an Agatha Christie mystery: what or who caused the sudden disappearance of so many different species of mammals in such a relatively short period of time? Expanding upon Marshall's "whodunit" idea in this paper, I shall take the position of a reporter covering a court case in which two suspects are being tried. The "witnesses" in the case are several authors in the book, *Quaternary Extinctions,* who have researched and written about the question of how this large and sudden extinction of so many megafauna may have happened.

Two individuals have been accused: Man and Climate. Considerable and compelling evidence has been gathered against each of the accused, but not yet enough to make a conviction for either individual.

The scene opens with Man cast as the accused, and Martin as the primary witness. Man has been all but convicted of the crime on the strength of Martin's testimony presented in his "overkill hypothesis." Martin's position is strong and seemingly impervious to attack by the defense. In short, Martin is certain of Man's guilt and wishes to convince the jury of his position. The jury adjourns to consider the case before them. In the interim, however, additional testimony is brought to the attention of the court. The jury reconvenes to hear the new material and, to their surprise, the testimony suggests that the crime may have been committed by Climate. Continued questioning brings serious incriminating evidence to light against the accused Climate. The question of a conspiracy between Climate and Man against megafauna is considered, but conclusive evidence for the existence of such a plot is absent. Though there are no data to suggest that Man and Climate were involved in collusion, enough evidence is presented against Climate to shift much of the burden of guilt from Man to Climate. Furthermore, the evidence suggests that Climate may have been the initiator of the crime. A summary of some of the more salient pieces of evidence against Climate are presented below.





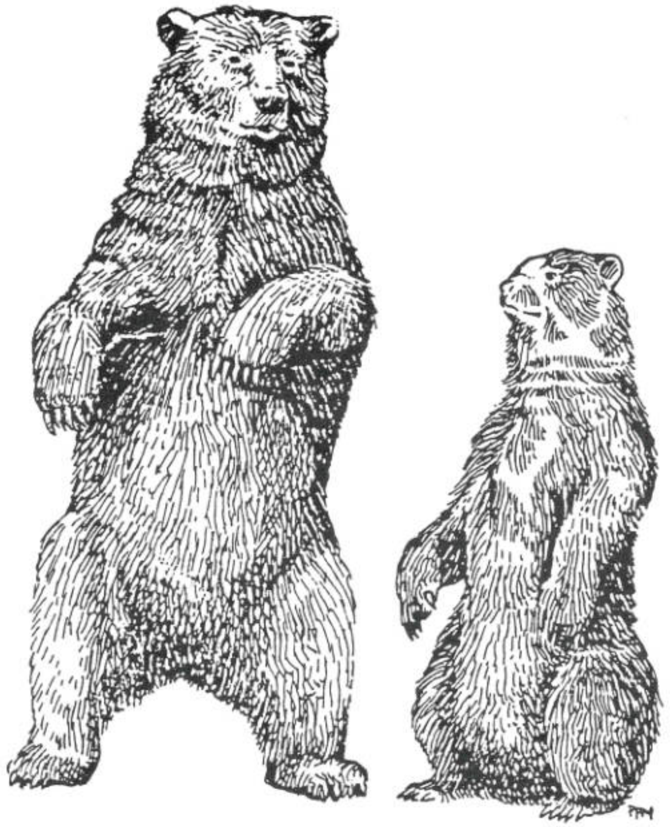
Two species of mammoths, Mammut americanum and Mammuthus columbi. (From Kurten and Anderson, 1987.)

Two witnesses, paleontologists Graham and Lundelius, propose that the onset of climatic instability may have caused a disruption of the established coexistence between plants and animals of the Ice Age. Based upon evidence from various sources, many of the plants and animals that coexisted in the Ice Age would not be expected to live together in the same region in a modern environment. The unusually diverse flora and fauna of the Ice Age suggests that the climate was equable, or even, with little change in seasons. Lack of extremes in temperature and precipitation fostered plant and animal associations not possible today due to such factors as different survival limits and competition (or lack of it) between certain species.

Toward the end of the Ice Age, however, the climate started to lose its equability, and the formation of distinct seasons began to occur. The biological communities, confronted with a more variable climate, responded to the change on an individual species basis. Some species migrated out of their known regions to maintain their ecological niches, some remained where they were, and some became extinct. In this way, climatic change may have proven fatal to many plant and animal species because their conditions for survival were significantly disturbed, as the two paleontologist witnesses had suggested.

As an example, the migration over time of a plant species favored by a particular grazing mammal, or herbivore, might initiate a parallel migratory response in the grazer whose diet was dependent upon this plant. The herbivore, in search of the food it desires, may push the environmental limits of its own survival. At the same time, the plant, while in its migratory pattern, may grow poorly and produce very little seed, and the additional stress of grazing might push it beyond its ability to reproduce and survive. The herbivore population, in the meantime, will become weakened by its successively more futile search for food, lose its capacity to reproduce, and become extinct also.

A change to shorter, more defined seasons can also be accompanied by an "increase in local plant competition and a geographic decline in the range of climatic tolerance for individual plant species" according to Guthrie, another new witness. Competitive succession of plant species, or the replacement of one species with another over time, leads to a decrease in biodiversity, which results in a corresponding decline in the megafaunal populations dependent on the plants being replaced. Guthrie, in his pursuit of evidence against Climate, describes studies showing that grazers, such as cows, tend to select plants by taste rather than by nutritive value. This relates to the case in two ways. First, plant species that accommodate an abbreviated growing season, as with reduced climatic equability, attain maturity at a more rapid rate. As a result, the earlier growth phase of the plant, which tends to be more nutritious, digestible and tasty to the herbivore, is shortened, and the quantity and quality of food is reduced. Second, increased competition and the reduction of diversity tend to enhance the development of defensive toxins or natural poisons in plants. Lack of adaptation to these poisons by the grazers results in further reduction of palatable food for them. Thus, the shortened growing season and increased climatic variability that developed in the late Ice Age may have allowed less time for large grazing animals to obtain a diet sufficient for growth and reproduction. Nutritional deficiency would then follow, leading to a reduction of the mammal population. Once a population is so reduced, a greater potential for eventual extinction can



Ursus spelaeus, the extinct cave bear of Europe (left) and Tremarctos, the spectacled bear, extinct in North America but surviving in South America. (From Martin and Klein, 1989.)

result as reproductive capacity is diminished, testifies Guilday, still another witness.

In the course of the case, other witnesses are brought to the stand who present incriminating evidence against both Man and Climate. For the sake of brevity, I have presented only a few highlights from their testimonies. After hearing the new evidence against Climate, the jury adjourns once again. Intense deliberation ensues, but no consensus is reached and the jury remains hung today.

Bolstered by journalistic license, I report the following conclusions of my own. Neither Man nor Climate is innocent of the crime. Since guilt is not relative, they both are guilty as charged. In looking at the finer points of the case, however, it appears that Climate probably did initiate the crime long before Man arrived on the scene, much like a person slipping a cumulative poison to a victim, knowing that death will occur only after a long period of time. Much later, Man came along and unwittingly applied stress to a now severely weakened megafaunal population by hunting it for his own survival. Unable to withstand this final onslaught, the megafauna succumbed, never to walk the earth again.

SUGGESTED READING

Grayson, Donald K.
1987 *Death by Natural Causes: Did Human Hunters Extinguish The Legendary Ice Age Mammals of North America?* Natural History, 96:8-13.

Kurten, Bjorn, and Elaine Anderson
1987 *Pleistocene Mammals of North America,* Columbia University Press, New York.

Martin, Paul S. and Richard G. Klein, eds.
1989 *Quaternary Extinctions: A Prehistoric Revolution,* University of Arizona Press, Tucson.

Martin, Paul S. and H.E. Wright, eds.
1967 *Pleistocene Extinctions: The Search for a Cause,* Yale University Press, New Haven.

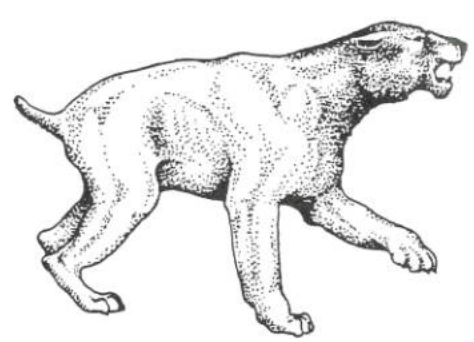
Mosimann, J.E., and Paul S. Martin.
1975 *Simulating Overkill by Paleoindians.* American Scientist, 63:304-313.

Shutler, Richard, Jr., ed.
1983 *Early Man in the New World,* Sage Publication, Beverly Hills.

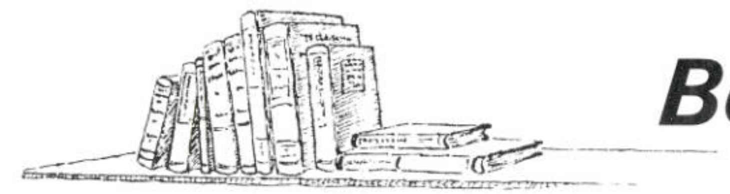
ABOUT THE AUTHOR

Janet L. McVickar is an archaeologist specializing in the prehistory of the Colorado Plateau. She is currently pursuing a Masters of Science degree in the Quaternary Studies Program at Northern Arizona University in Flagstaff. The focus of her present research is the reconstruction of paleoenvironments through the analysis of fossil plant remains from packrat middens associated with archaeological sites.

Bison latifrons, the extinct long-horned bison of the North American late Pleistocene. (From Martin and Klein, 1989.)



Smilodon, the New World sabertooth, and Homotherium, the scimitar cat, both extinct. (From Martin and Klein, 1989.)



Books of Interest

DIGGING DINOSAURS
by John R. Horner and James Gorman
Harper and Row, New York, 1988
210 pgs., Illustrated
$18.95 (hard cover), $8.95 (soft cover)

How can one account for the thrill of finding a fossil? Of the excitement of realizing the object in your hand was alive millions of years before mankind evolved! DIGGING DINOSAURS recreates that experience; it begins with the discovery of clues and ends by using them to solve a remarkable mystery.

Beginning in Montana in 1978, John Horner and his crew excavated colonies of baby dinosaurs, many of which were found in their nests. This story documents the discovery of a new reptilian dinosaur, *Maiasaura peeblesarum,* meaning "Good Mother Lizard," as well as startling data suggesting that these late Cretaceous duckbills were not only making nests but nurturing their young, just as if they were immense, leathery robin redbreasts. This book captures the moment of discovery and presents a well written account of the anatomical, ecological and behavioral aspects of these exceptional creatures.

by Virginia Fossey

THE RIDDLE OF THE DINOSAUR
by John Noble Wilford
Vintage Books-Random House, New York, 1985
325 pgs. Illustrated
$8.95 (soft cover)

Wilford, a pulitzer prize-winning science reporter for the *New York Times*, combines a thorough reporting of dinosaur discoveries with character sketches of the people who found them. He also pursues various theories that have arisen about the "Terrible Lizards" and their disappearance.

In the early days of paleontological discoveries, the main concern was reconciling geologic time with the Bible. The author discusses this, as well as Darwin's "Missing Link" hypothesis, then leads the reader to the recent theories and paleontological inquiries focused on: Were dinosaurs hot or cold blooded? Were they nurturing parents and did they travel in groups? Was extinction gradual or cataclysmic? Were extraterrestrial forces such as meteorites or comets a factor? Wilford throws a parting thought to ponder, mentioning that only humans are capable of bringing about their own extinction, either by nuclear war or by abuse of the planet.

by Jean McDowell

ICE AGE MAMMALS OF THE COLORADO PLATEAU
by Lisa Nelson
Northern Arizona University, Flagstaff, 1990
23 pgs., Illustrated

Hot off the press is a much awaited book about Pleistocene megafauna (large mammals) of the northern Colorado Plateau. This publication was spurred by recent discoveries and research of the Quaternary Studies Department at Northern Arizona University, headed by faculty researchers Jim Mead and Larry Agenbroad.

The introduction expertly outlines the Quaternary Period (the last 1.8 million years of earth history), complete with an easily understood glossary of scientific terms. Highlighted in this book are the dung and fossil evidence of many megafaunal mammals, browsers and carnivores, which lived and perished in the Grand Canyon and Canyonlands National Parks.

by Keith Montgomery

A FIELD GUIDE TO DINOSAUR RIDGE
By Martin Lockley
Friends of Dinosaur Ridge, Denver, 1990
29 pgs., Illustrated
($5.00 soft cover)

The Dinosaur Ridge area near Morrison, Colorado has been one of the world's most famous dinosaur hunting grounds since 1877. Discoveries include *Apatosaurus* (better known as *Brontosaurus*), *Stegosaurus* (the Colorado State fossil), and *Allosaurus.*

Written and illustrated by Dr. Lockley, renowned "Dinosaur Tracker," this trail guide is directed to the paleontological and geological resources of Dinosaur Ridge. Although it is well- supplemented with notes on the ecology and history of the area, it's most interesting focus are the tracks, trails, and traces of extinct dinosaur activities.

by Pat Flanigan

THE GREAT DINOSAUR HUNTERS And Their Discoveries
by Edwin H. Colbert
Dover Publications, Inc., Mineola, NY, 1984
282 pgs., Illustrated
$7.95 (soft cover)

THE GREAT DINOSAUR HUNTERS And Their Discoveries is a history of the pioneers in the science of dinosaur study. Included in this definitive work are in-depth profiles of scientists who devoted their lives to dinosaur research. The fascinating story begins in 19th century England, then takes the reader to the Arctic, the Gobi Desert, Canada, and to numerous sites in Utah, Wyoming, Montana and Colorado. It explores discoveries of bones, the rivalry between bone hunters, and the development of museums and quarry sites, including a comprehensive history of Dinosaur National Monument in Utah.

Colbert, a former Curator of Vertebrate Paleontology at the American Museum of Natural History, explores the origin of the various names of dinosaurs, including the term itself. He tells of the discovery of fossilized dinosaur skin and eggs, the development of excavation techniques, and the transportation and reconstruction of the great reptiles. There are also maps, a bibliography, 47 line drawings and 116 photographs (mostly rare historic plates).

THE GREAT DINOSAUR HUNTERS is written in an informal style that never bogs the reader down in technical data. It is a story of adventure most readers will find not only educational but also captivating and enjoyable.

by Eric Bjørnstad

****

CHILDREN'S CORNER

THE ILLUSTRATED DINOSAUR ENCYCLOPEDIA
by Dougal Dixon
Gallery Books, New York
143 pgs., Illustrated
$9.98 (soft cover)
Ages 11 and up

This is a complete story of the dinosaur family magnificently illustrated with over 250 pictures, maps and photographs. As an added bonus, there is an 84 page field guide examining each of the most popular dinosaurs in detail. It is presented in simple language and designed in clear-coded sections describing evolution, ecology and history.

by Ruth Trimble

Museum News

by Keith Montgomery

The Dan O'Laurie Museum offered the public a wide spectrum of events and shows during the first half of 1990. This resulted in museum visitation more than double that of the previous year.

With the advent of winter, a photographic exhibit of "National Wildlife" magazine's contest winners dispelled any doldrums brought on by the season. The Traveling Exhibit Committee then displayed "Dinosaurs of the Colorado Plateau," which was also well-attended. This was followed by the "first-time" showing of an exhibit from the Museum of Northern Arizona, entitled the "History of Extinction," which runs through July.

The museum was presented with a Utah Endowment for the Humanities (UEH) 1989 merit award for the *Canyon Legacy* lecture series and premiere issue, *Survival Through Time in Canyonlands.* Another UEH grant was then given for the lecture series, *River History of the Colorado Plateau.*

Since one of the museum's goals is to stimulate enthusiasm and raise awareness of the need to protect our cultural and natural heritage, spring saw the implementation of a new program whereby southeastern Utah schools are notified about museum activities and exhibits. Approximately 800 school children, some coming from as far away as Blanding and the Wasatch Front, came to visit. Special recognition is given to Virginia Fossey, Museum Receptionist, who donated many off-hours and assisted teachers in planting the seeds of curiosity by way of the museum experience.

Jean McDowell, Director/Curator, has completed stabilizing a large portion of the collections in storage and devised a method to provide easy access and retrieval for study and research. Recent donations to the museum include an antique player piano. Appreciation is extended to those who have made contributions.

Other museum activities include ongoing art shows on the mezzanine, which feature a different local artist each month. Large attendance at receptions and favorable comments from the public have proven the popularity of these exhibitions.

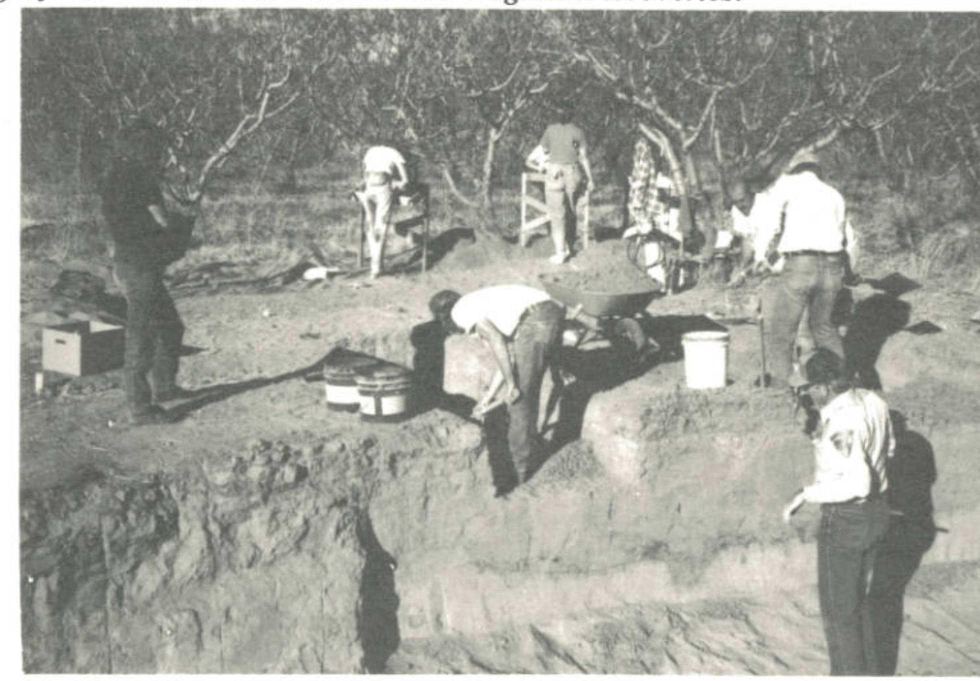
1989 witnessed a marked increase in revenue generated by membership, donations, and museum store profits. Thanks to all involved, for the money goes a long way toward updating and improving the museum.

The Board is now finalizing plans for a very exciting summer season. Watch for details...

NEXT ISSUE...

Man's part in the prehistory of Canyonlands is re-created through excavation and continued research by archaeologists, both professional and avocational. Each year new discoveries are made; a prehistoric road system, an exciting cache of Fremont figurines from Huntington Canyon near Price, Utah, and a one-of- a-kind early Ute Subsistence Bundle, are but a few recent finds that help to piece together the past.

As the heat of summer diminishes and the leaves begin to change colors, the seventh issue of *Canyon Legacy* will focus on ***Recent Archaeological Discoveries.***



Members of the Moab Archaeological Society, under the direction of Bureau of Land Management District Archaeologist Bruce Louthan and other professionals, excavate Orchard Pithouse, *one of the oldest structures of its kind found thus far in Utah.*
Photo by Jack Akens

Back cover: A three-toed allosaurus track. BLM archaeologist Julie Howard places her hand beside the track to show scale.
Photo by Vicki Barker

Canyon Legacy ISSN: 0897-3423
Dan O'Laurie Museum
P.O. Box 624
Moab, UT 84532